CITIZEN'S GUIDE TO

COLORADO WATER CONSERVATION

Prepared by

Colorado Foundation for Water Education

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Citizen's Guide to Colorado Water Conservation

This *Citizen's Guide to Colorado Water Conservation* is part of a series of educational booklets designed to provide Colorado citizens with balanced and accurate information on a variety of subjects related to water resources.
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Mission Statement

The mission of the Colorado Foundation for Water Education is to promote a better understanding of water issues through educational opportunities and resources, so Colorado citizens will understand water as a limited resource and make informed decisions. The Foundation does not take an advocacy position on any water issue.

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Introduction

A pitcher of water sits in the center of a table, sparkling in the sunlight. Seated around the table are eight people, all of whom want a drink. After some negotiating, the eight people agree on how much water each will get, and their glasses are filled accordingly. Sounds reasonable enough, right? But what if every year a larger group gathers around the table? And what if the amount of water in the pitcher varies from year to year?

This scenario, though vastly oversimplified, illustrates a dilemma at the core of all water use in Colorado—multiple water users with diverse needs and goals must share limited, fluctuating supplies.

•••

The Colorado General Assembly defines water conservation as water use efficiency, wise water use, water transmission and distribution efficiency, and efficient management of water supplies.

Strategies that promote water conservation in Colorado and elsewhere are generally intended to reduce demand and stretch existing supplies. More efficient use of water at homes, factories, and farms is driven by regulations and incentives designed to change public attitudes and behaviors, combined with implementation of water-efficient technologies and best management practices.

Water conservation in Colorado is no longer just a response to drought. Watering restrictions, fallowed fields, and surcharges associated with drought may result in short-term reductions in water demand but are not long-term conservation solutions. That's because in the long-term, demand is steadily increasing. Population growth and the need for water for agriculture, homes, industry, recreation, and the environment, place constant upward pressure on the state's limited water supplies.

Long-term conservation strategies will require water providers to invest in structural solutions to improve the efficiency of storage reservoirs, delivery systems, and pipelines. Consumers will be called upon to invest in higher-efficiency plumbing fixtures, appliances, and irrigation systems. Nonstructural solutions such as more flexible water management arrangements, public education, and prices that promote efficient water use will be equally important.

This *Citizen's Guide to Colorado Water Conservation* is designed to provide a balanced overview of the water conservation technologies, incentive programs, regulations and policies promoting efficient water use in Colorado today. For educational purposes only, it is not intended as a substitute for professional legal or engineering advice.

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During the drought of 2002, Denver Water's advertising campaign turned more than a few heads, as did these placards on the 16th Street mall.

Conoco refinery, Commerce City.

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A section of gated pipe makes a nice seat for short legs.

Water Supply, Demand and Consumption

Figure 1 – Water Deliveries in Colorado (2002)

86.5%

Agriculture

Irrigation, livestock watering

6.7%

Municipalities

Indoor plumbing fixtures and appliances
Landscape irrigation
Fire suppression
Flood control
Swimming pools

3%

Recreation, Fisheries and In-stream Flows

In-stream flows
Fish hatcheries
Wildlife refuges
In-channel recreational diversions
Releases from storage for boating and fishing
Augmentation and replacement

1.9%

Commercial, Industrial and Institutional

Manufacturing and processing
Cooling – air conditioning, process and equipment cooling
Plumbing fixtures and appliances
Landscape irrigation
Power generation

1.9%

Augmentation and Replacement of Groundwater in Shallow Aquifers

Water deliveries to fulfill augmentation plans and recharge groundwater

Limited Supplies/ Multiple Demands

Colorado's fluctuating water supplies are limited by natural constraints—rainfall and snow, where precipitation falls, the amount of water available in aquifers, and the amount of surface water stored from previous years. More than 80 percent of the water Coloradans use throughout the year comes from snowpack that melts in the spring and pours into rivers and storage reservoirs in early summer.

Water demands, on the other hand, have the potential to grow exponentially. Homes, businesses, farms, recreational activities, and the environment all compete for a share of the state's finite supplies. As the state's population grows, competition for water resources intensifies, and so does the significance of efficient water use.

How Coloradans Use and Consume Water

How Coloradans use and consume water is a reflection of our climate, landscape, and changing social values. Uses in which water is not returned to the immediate water environment—for example, water lost to evaporation, incorporated into crops or products, or consumed by people or livestock—are called "consumptive uses." The Colorado Water Conservation Board (CWCB) estimates that current total consumptive use in Colorado equals about 6 million acre-feet in an average year.

Figure 1 illustrates how Coloradans use the water diverted or withdrawn from the state's rivers, reservoirs, and groundwater aquifers. The Colorado State Engineer's office provided these statistics for groundwater and surface water deliveries in 2002.

Water use in Colorado's municipalities is increasing faster than in any other water use sector in the state, a trend expected to continue. Urban population growth demands additional water resources to supply homes, as well as businesses and high-water-use facilities such as golf courses and parks.

The map in Figure 2 illustrates the state's eight river basins and shows projected increases in municipal, commercial, and industrial water demand, as well as demand from users of private wells, expected by 2030. The estimated percentage increase for each basin appears above the projected annual

Figure 2 – As part of the Statewide Water Supply Initiative, the Colorado Water Conservation Board projected out to the year 2030 increases in municipal, commercial, and industrial water demand, as well as demand from users of private wells. The percent increase calculated by river basin appears in yellow above the additional quantity required, expressed in acre-feet (af).

water demand expressed in acre-feet (estimates calculated by the Colorado Water Conservation Board).

Efficient Water Use in Homes and Cities

According to 2002 statistics from the Colorado State Engineer, municipal uses account for almost 7 percent of the water delivered annually from Colorado's rivers and shallow groundwater wells. Municipal water suppliers—city and regional utilities or water and sanitation districts—treat this water to make it fit for drinking and deliver it to individual homes and businesses. Treated, potable water is used primarily for drinking, sanitation, and landscape irrigation, as well as to supply public facilities such as swimming pools, golf courses, and parks. Water used for commercial, industrial and institutional purposes, though primarily supplied by municipal providers, is usually classified separately.

The success of water efficiency initiatives for homes and businesses depends largely on people's attitudes toward conservation, their understanding of how to reduce water use, and the availability of appropriate incentives and technologies.

Household Water Use

During Colorado's warm dry summers, lawns, trees, and gardens often consume as much as 70 percent of the water delivered to residences. In contrast, during the winter, 5-6 percent of the water delivered is consumed by indoor water demands such as drinking and cooking, with minimal outdoor use for watering trees.

Comprehensive statistics on per-person, or per-capita, water use in Colorado are not available, but estimates are available for selected cities. According to *Smart Water,* a Western Resource Advocates study of urban water use across the Southwest, average daily per-person indoor and outdoor water use in single-family households in four Colorado cities in 2001 was:

- Boulder: 140 gallons/day
- Denver: 159 gallons/day
- Grand Junction: 182 gallons/day, and
- Highlands Ranch (a Denver suburb): 140 gallons/day.

Nationwide, the U.S. Geological Survey (USGS) estimates that average per-person water use in single-family households is approximately 100 gallons per day. Colorado's higher average use reflects a number of factors, including high evaporation rates associated with the state's semi-arid climate, the need to irrigate gardens and landscapes during the growing season, and the custom of planting landscapes and lawns typical of more water-rich regions of the country.

Indoor Water Use

Generally, in homes where no water-efficient fixtures or appliances have been installed, toilets use most of the water delivered, followed by clothes washers, sink faucets, showers, bathtubs, and dishwashers. Leaks may also increase indoor water use.

Water-efficient plumbing fixtures, appliances, and retrofit devices are the main technologies available to reduce indoor water use in homes (Table 1).

Acre-foot (AF) *– Amount of water required to cover an acre of land at a depth of 1 foot—roughly 326,000 gallons. According to Denver Water, an acre-foot of water can meet the water needs of one to two households per year.*

Recharge *– Addition of water to a groundwater supply either by natural (precipitation) or artificial (infiltration or injection) means.*

Augmentation Plan *– Court-approved plan that allows a junior water user to divert water out of priority, provided the consumed water is replaced with water from another source. To ensure that water rights of senior users are not harmed, replacement water must be of suitable quality, and the required amount must be delivered at the appropriate time and place.*

Table 1 – Potential Water Savings From Conversion to Water-Efficient Fixtures and Appliances

Plumbing Fixtures	Water Use: High-Efficiency Models	Water Use: Pre-1980 Models	Per-Capita Reduction in Daily Water Use by This Fixture or Appliance
Toilets	1.6 gal per flush	5–7 gal per flush	58%
Faucets	0.5–2.5 gal per min	3–7 gal per min	13%*
Showerheads	1.5–2.5 gal per min	5–8 gal per min	4%
Appliances			
Clothes washers (14 lb. capacity)	24–48 gal per wash	56 gal per wash	38%
Dishwashers	7 gal per wash	9.5–14 gal per wash	NSS

*Sources: Amy Vickers. Handbook of Water Use and Conservation. Amherst, Mass.: WaterPlow Press (2001). William DeOreo et al., "Retrofit Realities," Journal AWWA (March 2001) * Estimated based on retrofitting faucets with aerators, not replacing the entire faucet*
NSS = Not statistically significant

Efficient Water Use in Homes and Cities

Substituting new or modernized parts or systems for older fixtures—a process called retrofitting—can significantly reduce in-home water use. For example, installing plastic water-displacement bags, adjustable flapper valves, or flapper connection adapters in toilets can save 0.5 to 1.5 gallons per flush. Gravity-tank toilets, the type most commonly found in residences, can be fitted with dual-flush adapters to provide alternative flush controls.

All landscape watering systems, whether for home gardening or large commercial golf courses, can waste water unless they are properly managed and maintained.

***Evapotranspiration**—Loss of moisture to the atmosphere through plant transpiration and evaporation from soil and plant surfaces.*

Repairing leaks in gravity-tank toilets usually involves replacing aging flapper valves and valve seals and deteriorating mechanical parts such as ballcocks, refill valves, lift chains, and flush levers.

In a study conducted by Aquacraft Inc. and Seattle Public Utilities (SPU), replacing inefficient appliances and plumbing fixtures and retrofitting sink faucets allowed per capita indoor water use in the sample households to drop by 37 percent.

Water Delivery Systems

Municipal water suppliers can contribute to wise water use by delivering water efficiently. Water utilities rely on three major strategies to ensure efficient water distribution—controlling leaks, maintaining the integrity of buried pipelines, and installing customer meters.

Using sophisticated sonic devices that can detect the sound of moving water, utilities can pinpoint the exact location of leaks in buried transmission lines. Leak control programs can reduce systemwide water losses to less than 10 percent, according to *The Evolving Water Utility,* a water utility management text published by the American Water Works Association in 2003.

Municipal water providers may also use statistical models to predict the remaining useful life of buried mains by analyzing data on pipe material, leak history, pipe installation date, and soil composition.

Installing meters at homes and businesses enables water utilities to look for problems by comparing the amount of water delivered with the amount leaving the treatment plant. Metering records also allow utilities to monitor water use over time, to charge customers for the amount of water actually used, and to impose higher rates or surcharges for water use that exceeds specified limits. At least 86 percent of Colorado's municipal water utilities use meters for at least some of their customers, according to the CWCB's *2004 Drought and Water Supply Assessment report.*

A meter replacement program launched in Grand Junction in 1996 reduced losses of unaccounted-for water by eight percent, according to a May 2002 report issued by the city. Between 1996 and 2002, this translated into total water savings of some 615 acre-feet, enough water to serve close to 300 households for a year.

Irrigation Systems

Because landscape irrigation is the largest source of municipal water demand, choosing water-efficient irrigation systems for lawns and gardens can play a major role in potential water savings (Table 2). As with agricultural irrigation, the efficiency of residential irrigation systems is primarily a function of reducing evaporation and runoff, as well as improving the uniform distribution of water where and when it is needed.

Generally, irrigation efficiency in municipalities depends on the irrigation system's overall performance in delivering the amount of water required by the growing plants while minimizing overwatering. For example, if an irrigation system is 75 percent efficient, this means that the desired landscape directly consumes 75 percent of the water applied. The other 25 percent may be lost to evaporation or may return to groundwater aquifers and rivers to be consumed by other water users.

Sometimes the most water-efficient systems involve more than one type of irrigation. Pop-up spray or rotor heads may be best suited for turf, whereas drip irrigation may be more appropriate for areas containing groups of similar plants such as flowers, shrubs, or trees.

Reuse and Recycling

Reuse of potable and nonpotable water is becoming increasingly common in Colorado and the West. Nonpotable reuse involves secondary treatment of return flows, such as effluent from wastewater treatment plants, such that it is made safe for irrigation of golf courses, parks, or commercial/industrial cooling, for example (see Commercial, Industrial, and Institutional Recycling and Reuse, p. 15).

In Colorado, utilities provide nonpotable reuse water only for commercial/industrial customers; it is not currently available for residential customers. However, potable (drinking) water is commonly provided through indirect reuse.

In indirect reuse, highly treated wastewater is mixed with raw (untreated) water from rivers or reservoirs, before it re-enters the municipal system. Indirect reuse is very common in Colorado. Unless a municipality's water supply comes directly from a river's headwaters or from deep

Table 2 – Comparison of Efficiencies for Common Residential Irrigation Systems

Irrigation Technology	Description	Estimated Efficiency (% range)	Best Management Practices
Automatic in-ground sprinkler systems	Retractable pop-up spray or rotary sprinkler heads connected to underground piping spray water across landscaped areas.	40–80%	Adjust sprinkler heads to avoid runoff onto sidewalks, streets, driveways, decks, or patios.
Microirrigation (drip or micro-sprinkler) systems	Drip systems deliver water directly on or below the soil surface through emitters along pipes or hoses. Microsprinklers deliver water from small emitters placed on short risers just above the soil surface.	Up to 95%	Set to irrigate only when soil is somewhat dry. Water deeply, but infrequently.
Soaker hoses	Made of semi-permeable materials, soaker hoses slowly release water along the length of the hose.	Unknown: somewhat less efficient than drip systems	Set to irrigate only when soil is somewhat dry. Water deeply, but infrequently.
Hose end sprinklers and "hose-dragging"	Traditional hoses connected to a moving sprinkler head are dragged manually across the irrigated area. Hose-end sprinklers vary in the amount of water applied. Spot sprinklers irrigate small areas quickly. Oscillating sprinklers cover larger areas and apply water more slowly.	Variable efficiency depending on management	Water only landscaped area. Avoid runoff. Set timers and move sprinklers when needed.
Automatic controllers for sprinkler systems	Standard automatic controllers can be programmed to water different landscape zones for specific times.	May or may not improve efficiency depending on management	Watering lawns before 10 a.m. or after 6 p.m. minimizes ET water losses. Automatic rain sensor devices override programmed watering schedules and shut off the system during or after significant rainfall.
	Traditional ET controllers are pre-programmed on the basis of historical ET records--daily, weekly, monthly, or annual records--over a period of several years. Some systems may also have their own sensor that transmits information to the controller.	Can improve efficiency 20–50%	
	Real-time weather-based controllers collect and disseminate data from weather stations across the country.	Can improve efficiency 10–95%	

Sources: Tom Ash. "ET Controllers, Weather-Based Controllers, Smart Controllers: What Do You Need to Know to Achieve Long-term Water Use Efficiency?" White Paper written for the California Bay–Delta Authority (CALFED). Richard A Diamond. "Project Review of the Irvine ET Controller Residential Runoff Reduction Study." Irvine, Calif.: Irvine Ranch Water District (2003). See www.greenco.org for more BMPs.

groundwater aquifers, at least some of the surface water that enters the city's treatment facilities has already passed through someone else's upstream wastewater treatment plant. Although many people do not like the idea of drinking treated wastewater, many cities in Colorado rely on this recycled water.

At home, when people consider reusing and recycling water, they often think of reusing graywater. Although using graywater for irrigation may seem like a simple way for homeowners to reuse water drained from clothes washers, bathroom sinks, and showers, graywater reuse is actually a public health issue. In Colorado, discharging household graywater requires a permit from the county health department, and it must first be disinfected. A monitoring program is also required. However, these public health rules do not apply to warm-up water, which is presumed to contain no harmful substances. Homeowners can collect warm-up water in buckets and use it to water plants.

Graywater—*Untreated wash or rinse water drained from clothes washers and bathroom sinks, showers, and tubs. Graywater does not include water from toilets (which contains human waste) or water from dishwashers and kitchen sinks (which contains organic waste, bacteria, and possibly other pathogens).*

Warm-up water—*Unused household water allowed to drain until it reaches a desired temperature.*

Best Management Practices

Best management practices (BMPs) are recommended voluntary technologies or practices developed in this case, to improve water use efficiency in and outside the home.

In many cases, efficient water use depends less on the type of technology employed, and more on the way it is managed. For example, all landscape-watering systems—even hand-held hoses—can waste water unless they are properly operated and maintained.

American Water Works Association studies across the country found that homes with automatic irrigation controllers use 47 percent more water than homes without automatic controllers. Data from Denver Water show that in its service area, single-family homes with automatic controllers use 50 percent more water than landscapes need. The problem is that people with automatic systems often set their timers at the beginning of the year for watering rates more appropriate for the peak irrigation season in July. Then they never adjust them to variable conditions. Hose-draggers are likely to irrigate smaller areas, and be much more sensitive to changing factors such as wind, rainfall, or temperature.

Landscape Selection

Used in conjunction with water-efficient irrigation systems and scheduling, one of the most effective strategies for improving outdoor water use efficiency is installing low-water-use landscapes—landscaped areas that require minimal water to supplement natural precipitation. Although rare in urban areas, the ultimate water-wise landscape relies almost completely on natural precipitation, preserving and reintroducing indigenous plants in order to minimize the need for supplementary watering. Another popular approach to water-wise landscapes is called Xeriscape™.

In a 1992 study of single-family residences served by the East Bay Municipal Utility District in Northern California, water-conserving landscapes achieved average water savings of 42 percent compared with traditional landscapes. A similar study conducted in Las Vegas during 1996–2000 found that homes where at least 500 square feet of the landscaping was converted to Xeriscape achieved water savings of 40 percent. Preliminary results of a five-year study of Xeriscape conversions at single-family homes in seven metropolitan areas along Colorado's Front Range indicate that water savings during the April–October growing season ranged from 18 to 63 percent.

Incentives for Efficient Water Use in Homes and Cities

Incentives to use water more efficiently in urban residential settings often take two forms: 1) financial incentives such as conservation water rate structures or rebate and retrofit programs, or 2) education and technical assistance designed to inform water users and help change attitudes and behaviors. State, federal, and local regulations and policies may also serve to encourage wise water use (see Regulations and Policies Promoting Efficient Water Use, p. 27).

Municipal water providers design and implement most water efficiency incentive programs in urban settings. However, watershed groups, universities, state agencies, and local public interest organizations may also provide educational programs and information.

Using water wisely takes on magnified importance in times of water shortage. During periods of drought, water providers generally strengthen their incentive programs, informing customers about

Overwatering Can Damage Residential Foundations

During 2003, several insurance companies hired a Colorado engineering firm to investigate claims related to foundation problems and inadequate surface drainage in three residential developments—two in Colorado Springs and one in Arvada, northwest of Denver. As part of its investigations, the engineering firm compared actual water use records with estimated annual irrigation requirements at the three sites. Rather than finding inadequacies in drainage engineering or construction as the primary culprit, the firm discovered that a key source of the problems was excessive landscape irrigation on the part of the homeowners' associations.

The data show that irrigation applications at the three sites averaged 252 percent of the amount of water required. In the Arvada development, where the estimated irrigation requirement was 29 inches per year, documented annual irrigation during 2000–2001 averaged 80 inches per year, 276 percent of the amount required. In addition to damaging foundations, the overwatering wasted an average of 51 inches of water each year.

new watering restrictions or surcharges and striving to heighten awareness about the need to reduce water use both indoors and outdoors.

Although drought-related surcharges and restrictions can significantly lower demand on a temporary basis, the continued success of efforts to reduce urban water use largely depends on long-term incentive programs designed to change public values and behaviors, coupled with the installation of more water-efficient technologies.

Conservation Water Rates

Rates are an important component of any municipal water conservation program because they send customers a message about the value of the water they use. Still, most water-efficiency experts agree that to achieve long-term reductions in demand, conservation water rates must be combined with educational and regulatory incentives. More than half of Colorado's municipal water utilities (54 percent) use some form of water conservation pricing, according to the 2004 Drought and Water Supply Assessment.

At least five common rate structures can be viewed as supporting efficient water use: uniform rates, seasonal rates, increasing block rates, excess-use rates, and water budget rates.

Uniform rates. All metered water use is priced at the same unit rate, regardless of customer classification, amount of water used, or when the water is used. Although uniform rates do not actually promote efficient water use, it is more efficiency-oriented than some older rates structures that charge lower unit prices for larger volumes of water. In Colorado, uniform rates are used in Alamosa, Buena Vista, Golden, Greeley, and Pueblo.

Seasonal rates. Unit rates vary from season to season. The higher rates charged during peak-demand periods reflect the increased cost of providing service at that time of year. Water rates for some customer classes in Denver, Colorado Springs, Durango, and Fort Collins take seasonal use into account.

Increasing block rates. Increasing block rates (also known as inclining block or inverted block rates) use a series of blocks or tiers to charge higher unit prices for higher quantities of water. Increasing block rates reward customers who use minimal amounts of water. Equitably designed increasing block rates can recover costs from each customer class in such a way that no one group is rewarded more or less than another for reducing demand.

Many Colorado municipalities—including Colorado Springs, Denver, Durango, Fort Collins, Grand Junction, Steamboat Springs, Vail, Walsenburg, and Westminster—use some type of inclining block rate structure. Longmont uses increasing block rates for residential customers but charges uniform rates to irrigation customers and commercial customers that use large volumes of water.

Published reports indicate that water savings attributable to inclining block rates vary significantly (from 5 to 33 percent), depending on geography, the severity of the price increases in each tier, and the degree of public outreach on the part of the utility (including how well the water bill conveys the rate structure).

Excess-use rates. A form of increasing-block rates, excess-use rates involve calculating a rate for a base level of water use depending on the customer's average use during a nonpeak period (usually winter). During peak periods, water use some percentage above this base level is priced at the base rate plus an excess-use rate. Boulder uses excess-use rates for residential and commercial customers; for all other customers it uses an increasing block rate. Delta's water rate structure includes a flat rate plus excess-use charges.

This beautiful Xeriscape garden created by Marcia Tatroe of Centennial, illustrates how low-water-use plants can provide a colorful and pleasing landscape.

Wise Water Use Through Xeriscape™

The Xeriscape concept was born in Colorado in 1981, the brainchild of a water conservation task force formed by Denver Water. The trademarked term combines the Greek word "xeros" (dry) with the word "landscape," but the moniker is not intended to imply desert gardens consisting solely of cactus and rock. Carefully chosen low-water-use plants of assorted heights, colors, textures, and fragrances can make xeriscapes as pleasing and distinctive as thirstier landscapes.

Xeriscaping entails seven principles that promote attractive landscapes and efficient water use. These principles—proper planning and design, soil analysis and improvement, efficient irrigation, appropriate selection and grouping of plants, mulching, limited turf areas, and proper maintenance—are described in detail on Xeriscape Colorado's website (www.xeriscape.org).

Water budget rates. Utilities that use water budgets assign each residential customer a monthly allotment of water based on three types of information: size of the landscaped lot, number of household residents, and average evapotranspiration rate for the area. Dwelling and household size determine the allotment for indoor water use; the irrigated area and weather data determine the allotment for outdoor use.

Utilities that adopt water budgets typically use an increasing block rate structure. The first block, for example, provides at least enough to cover indoor use; the second block covers outdoor use. Total water use exceeding 100 percent of these two blocks would go into an additional block incurring significantly higher charges.

Drought Restrictions

In 2002, when many Colorado communities faced reduced water supplies, a number of utilities imposed watering restrictions. Sample restrictions included permitting twice weekly irrigations for households with automatic sprinkler systems, limiting average watering times to 15 minutes per zone, prohibiting watering between 10 a.m. and 6 p.m., and requiring permits for installing new sod.

A study conducted by the Center for Science and Technology Policy Research at the University of Colorado found that in 2002 mandatory water use restrictions in selected Colorado cities had variable results, reducing demand systemwide by 18–56 percent. Other cities in the study showed initial reductions in use followed by small increases.

Confronting another consecutive summer of drought, 10 of the largest water utilities along Colorado's Front Range—from Pueblo to Fort Collins—planned to spend an average of $2.50 per customer on water use efficiency programs in 2004, according to a *Rocky Mountain News* survey. These utilities budgeted funds to educate consumers about water use restrictions, to heighten customer awareness about the need to use water as efficiently as possible throughout the summer, and to underwrite the cost of financial incentives, such as rebate programs, and enforcing customer compliance with restrictions.

Water Budgets Reduce Demand at Highlands Ranch

Highlands Ranch, a rapidly growing planned community developed in the 1980s, is now home to almost 75,000 residents. The Centennial Water and Sanitation District, which serves the community, adopted a water budget rate structure in the spring of 2003.

In customizing water budgets for its residential customers, the utility used three assumptions: an average household has three residents, landscaped areas comprise 42 percent of household lots, and evapotranspiration rates are for cool season turf grasses (for example, bluegrass) in the area.

Centennial's water rate structure is based on various percentages by which a household might exceed its budget. For example, water use that exceeds a household's water budget by more than 140 percent will cost more per gallon than water use exceeding the budget by less than 120 percent.

After one year with water budgets in effect, the community had reduced overall water demand by 20 percent, according to Rick McLoud, Centennial's water resources manager. McLoud says the water budgets are not merely a response to drought; they are an ongoing reminder to customers to use water efficiently.

Surcharges

A surcharge is a temporary additional fee added to customer water bills in times of peak demand or water shortage such as drought. Results of a 2003 customer survey conducted by Denver Water indicated that surcharges combined with other water-efficiency measures—including water use restrictions and enforcement—can be an effective tool for encouraging more efficient water use.

Like ongoing water rate structures, surcharges vary according to customer class and can include varying numbers of tiers, each representing a larger quantity of water and a higher unit cost.

Rebate and Retrofit Programs

Several Colorado utilities offer rebate programs that reimburse residential water customers for expenses related to installing water-efficient appliances or irrigation equipment. The most common rebates are offered for ultra-low-volume toilets, high-efficiency clothes washers, and lawn irrigation equipment.

Utility retrofit programs usually provide basic water-efficiency devices to customers free of charge or at greatly reduced prices. Retrofit equipment may include high-efficiency showerheads, swivel kitchen faucet aerators, and flip on–flip off aerators for bathroom sinks. A recent retrofit program

in a Colorado Springs apartment complex reduced water use by 38 percent.

Since 2001, Denver Water has distributed more than 5,000 retrofit kits to students in grades 4–8, mostly in middle schools serving low-income neighborhoods. Each of these "Learning to be WaterWise®" kits contained three retrofit devices that students could install at home—plus lessons (disguised as games) to educate students about efficient water use. Literature included in the kit explains that a household that installed all three devices could save up to $125 a year on water and energy bills, and could reduce water use by as much as 75 gallons per day per household.

Education and Technical Assistance

Virtually every municipal water utility in Colorado invests in some form of community outreach or public education. Traditional methods focus on bill inserts and direct-mail materials, and these are still the only methods guaranteed to reach every customer. More recently, now that many households have personal computers and Internet service, utility websites have become standard fare, and many of them highlight information on efficient water use.

Large water utilities hire staff members with expertise in public relations and contract professional public relations and marketing firms to design and implement extensive public awareness campaigns.

Typical public education programs include water use audits for commercial and industrial customers, displays at public events such as home and garden shows, public advisory committees, demonstration gardens illustrating water-wise landscaping, and workshops and training programs on specialized topics such as irrigation scheduling. For children, many utilities fund water-related educational materials and water festivals for schools.

Rebate Programs Pay for Change

During 2002–2003, Colorado Springs Utilities paid residential customers roughly $193,000 for installing 2,573 dual-flush toilets and almost $332,000 for installing 2,655 high-efficiency clothes washers. In 2003, the utility issued rebates of $30,850 for residential irrigation equipment such as rain shutoff devices, irrigation controllers, drip irrigation systems, and spray heads with check valves. The utility's rebates for residential landscape consultations, water-wise lawn installations, and mulches and soil amendments totaled almost $58,000 in 2003.

The City of Boulder, which reimburses customers for most of these same water-saving expenditures, also offers rebates of up to $250 for turf-type buffalo grass (at a rate of $.25 per square foot).

In its 2002–2003 rebate programs, Denver Water reimbursed single-family residential customers for 12,500 low-water-use toilets, at a cost of $1.36 million, and 5,600 clothes washers, at a cost of $700,000. Together, these programs reduced annual indoor residential water demand in Denver Water's service area by more than 500 acre-feet. Rebate programs aimed at reducing Denver's outdoor residential demand reimbursed customers for some $368,000 worth of lawn irrigation equipment and soil amendment materials, including more than 2,100 low-water-use trees and shrubs and almost 1,000 automated irrigation system controllers.

Challenges to Water Conservation in Homes and Cities

Achieving efficient water use in Colorado's municipalities depends on overcoming a number of challenges. Some key stumbling blocks include low water rates, a pervasive public perception that water conservation is not important, and insufficient understanding of the options available to increase water use efficiency.

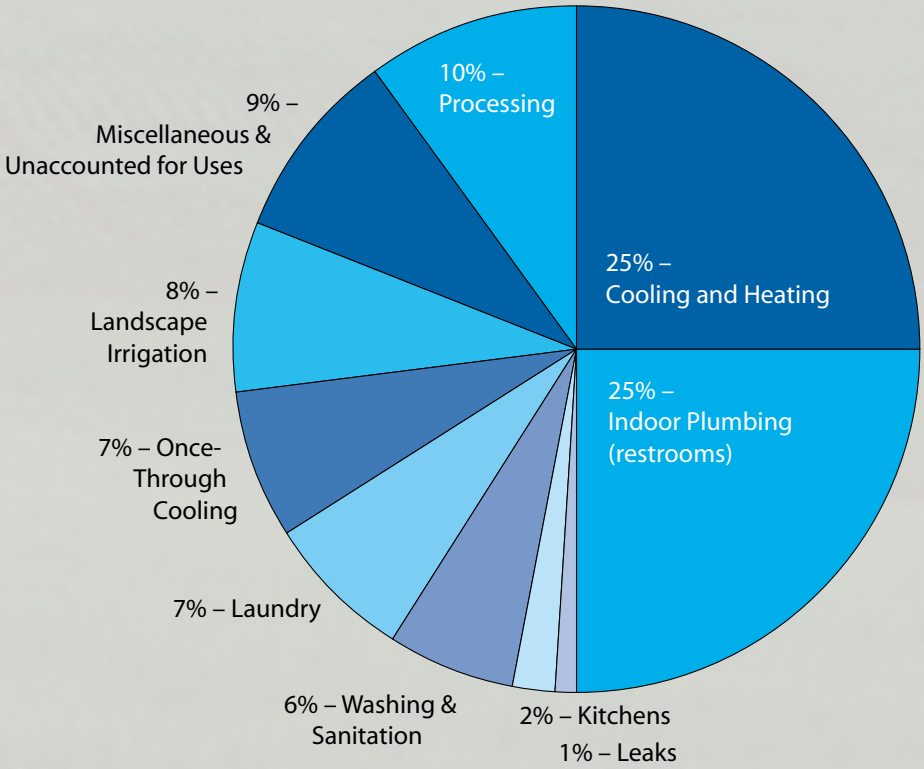
Income, personal choice, and access to information are some of the factors that typically influence the public's sensitivity to the price of water. Studies have shown that customers are often relatively unresponsive to small increases in price. In addition, some researchers claim that because water has historically been underpriced, consumers have become accustomed to low prices that do not adequately account for the full costs of water supply, treatment, and distribution. So long as water is relatively inexpensive, they argue, and there is no perceived reason to conserve, the application of more water-efficient technologies and management practices will be limited.

Increasing public understanding is vital. Informing consumers about such topics as low-water-use landscaping, efficient plumbing fixtures and appliances, or how to avoid overwatering is an ongoing challenge to widespread implementation of conservation practices.

Most water providers have created a variety of bill inserts and brochures designed to educate their customers about reducing water use.

Efficient Water Use in Commerce and Industry

Figure 3 – Business and Institutional Water Use in Denver Water's Service Area



Heating and cooling systems are the largest sources of water consumption in many commercial/industrial facilities such as this refinery in Commerce City (center right) and power plant near Craig (top). Other forms of processing, such as the washing and rinsing of produce (above), can also require large quantities of water.

Efficient Water Use in Commerce and Industry

Although water deliveries to businesses, industries, and institutions tap less than 2 percent of Colorado's available water resources, they claim a substantial portion of municipal supplies (for example, 18–36 percent of municipal water deliveries in Denver, Boulder, and Colorado Springs). Therefore, using water more wisely in commerce and industry can contribute significantly to stretching municipal water supplies.

Denver Water has compiled statistics on how businesses, factories, and institutions in its service area use water (Figure 3). In the Denver metro area, roughly half of commercial and industrial water deliveries are used for cooling and heating, and indoor plumbing. Landscape irrigation, processing (manufacturing), and miscellaneous uses make up the other half.

Heating and Cooling

Cooling and heating systems are the largest water users in typical commercial, industrial, and institutional facilities. Cooling towers use large volumes of water because they remove heat by evaporation. Single-pass, or once-through, cooling systems are the most water-intensive of all cooling methods. In these systems, water is directed through a piece of equipment once and then drained into the wastewater system.

Water can be lost from cooling towers in three ways: evaporation, bleed-off, and drift. The largest volume of water is lost through evaporation. Bleed-off involves discharging a portion of the circulating water to remove suspended and dissolved solids. Drift refers to water droplets and mist carried out of the cooling tower by airflows.

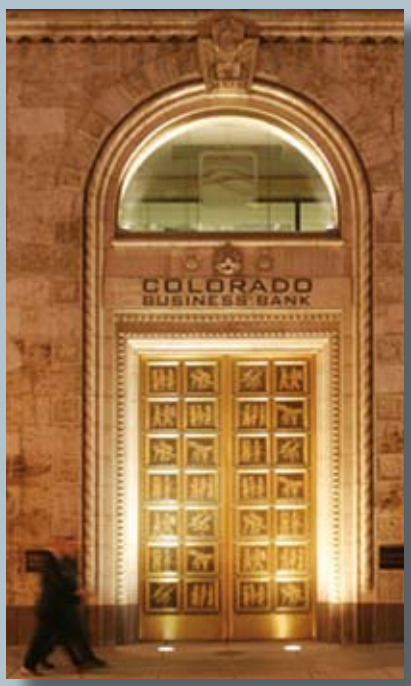
Because evaporation rates are primarily controlled by how much cooling is needed, evaporative losses offer limited opportunities for conserving water. Instead, facilities that want to improve the efficiency of cooling towers can use some of the following strategies:

- Minimize bleed-off. Postpone the frequency of bleed-off by improving the quality of cooling tower water—either through chemical adjustments or filtration.
- Recycle and reuse. Recycle bleed-off water for landscape irrigation, for example, or reuse a certain quantity of water discharged from the system.
- Install closed-loop cooling systems. Closed-loop systems recirculate the cooling water instead of disposing of it. After recirculation, the water may be appropriate for irrigation or cooling tower make-up water, or vehicle washing.
- Replace water-cooled with air-cooled equipment.

Boilers and steam generators are often used to heat large buildings or complexes. Older boiler systems can cause water losses resulting from corroded steam traps and other deteriorated components. Technologies that can improve water use efficiency in heating systems include steam trap replacement kits (which prevent water losses from escaping steam), condensate return systems (which reduce the amount of make-up water needed by returning steam condensate to the boiler system for reuse), and automatic blowdown controls (which time bleed-off discharges to release only the amount of water necessary to maintain desired water quality).

Keeping Coors Field green doesn't necessarily mean wasting water. During construction, special attention was paid to soil preparation and drainage to minimize irrigation requirements. After games, players shower under low-flow showerheads, and high-efficiency sprayers wash down the stadium seats. Instead of hosing down sidewalks, workers employ scrubbers with recirculating tanks.

Closed-Loop Cooling System Saves Water at Historic Office Building



Recent installation of a water wise cooling system in the historic Colorado Bank Building cut the building's water use in half, lowering both water and energy costs.

The nine-story Colorado Business Bank Building in downtown Denver was built in 1908. The first multistory reinforced concrete building constructed west of the Mississippi River, it is listed in the Register of National Historic Places. Today, its office space accommodates some 300 workers, and its tenants include a bank, advertising and law firms, and a restaurant.

When a new owner took possession of the building in 1997, its water use was 8 million gallons a year, despite the fact that it was only 40 percent occupied. Between 1999 and 2002, the new owner removed two aging cooling towers, connected a line of chilled city water to the building's cooling system, and installed a closed-loop cooling system for the refrigeration equipment in the restaurant. These projects reduced the building's water use by 4 million gallons, or 50 percent, lowering both water and energy costs for tenants. Now the building's office space is fully occupied. With total annual savings of $77,000 and total project costs of $246,000, payback for the projects was achieved in just over three years.

Homebuilders know that consumers want low-maintenance, attractive water-thrifty landscapes. This garden at a McStain Neighborhoods development near Denver showcases one of their xeric designs.

Homebuilders Offer Water-Efficient Landscapes

Recognizing that the construction industry can provide significant opportunities to share information and implement water-efficient practices, the Homebuilders Association (HBA) of Metro Denver recently initiated the Built Green® Colorado program and the Quality Construction Certification Program.

Built Green Colorado, introduced in 1995, encourages homebuilders to use technologies, products, and practices that preserve natural resources, reduce water use, and provide greater energy efficiency. Efficient water use practices identified in the program include amending soils before installing landscaping, selecting drought-tolerant plants, installing efficiency-oriented irrigation systems, and implementing additional Xeriscape practices.

The Quality Construction Certification Program offers construction site supervisors a manual and training course on a variety of topics, including landscaping and water use. Emphasizing the importance of builders working closely with landscape contractors, the manual gives builders a landscaping checklist covering topics such as alternative turf grasses, efficient irrigation, soil improvements, and grouping plants in zones according to their water needs.

In 2004, HBA also began a cooperative project with GreenCO and the Colorado Governor's Office of Energy Management and Conservation to collect and share information from builders who have implemented innovative water-efficiency practices. Two case studies—Engle Homes and McStain Neighborhoods—are representative.

Engle Homes gives its homebuyers a Water Wise booklet that provides information on water-wise landscaping and irrigation, plus five alternative Xeriscape designs from which buyers can choose. Buyers can have Engle's subcontractors install the landscape, hire their own subcontractor, or install the lawn themselves. As part of its standard front-yard landscaping package, Engle limits turf to 50–60 percent of the total landscaped area, provides drought-tolerant bedding areas and mulches in the rest of the yard, installs drip irrigation in shrub beds, and provides rain sensors for the irrigation system.

As part of designing its residential developments, McStain Neighborhoods developed a guidance document called "McStain Neighborhoods Water Conservation Standards for Common Area and Open Space Landscapes." The standards include water budgets (maximum water allowances for landscaping) incorporated into homeowners' association fees, irrigation design criteria, and landscape maintenance criteria (which include comparing actual water use with the water budget to guard against overwatering).

Indoor Plumbing (Restrooms)

To improve water use efficiency, restrooms used by employees or the public can be equipped with low-volume plumbing fixtures and retrofit devices. High-traffic facilities such as passenger terminals, entertainment venues, and office buildings can install sensor-activated control devices that automatically flush toilets and urinals or release water from lavatory spigots for preset times. These devices improve efficiency by preventing water from running in fixtures that are not in use. As in residential settings, sink faucets and toilets may also be retrofitted with more water-efficient parts to help reduce water demand.

Landscape Irrigation

Golf courses and other large landscaped areas surrounding suburban office parks or residential communities can be responsible for considerable water demand. Large landscapes are prime candidates for conversion to water-wise designs and water-efficient irrigation systems and management.

In addition, landscape contractors and homebuilders can play a significant role in improving water use efficiency. An understanding of water-wise landscaping alternatives and the latest advances in water-efficient irrigation systems, as well as regular implementation of accepted best management practices, can significantly decrease water demand at new developments and existing residential and commercial properties.

Process Water

Businesses and industries use process water to clean products; to transport or remove ingredients, products, or contaminants; and to control pollution or dispose of waste. Process washing and rinsing are integral components of many manufacturing operations, including metal plating and finishing, paper production, and semiconductor chip fabrication. Process water is also used to develop x-ray and photographic film. Because the amount of water required for processing varies according to its use, both demand and potential reductions in demand are fairly site-specific.

Among the technologies that can improve the efficiency of process water use are smaller tanks or sinks for washing and rinsing, intermittent-flow rather than continuous-flow systems, and batch processing equipment. In-flow meters, control valves, or sensors allow flow rates to be adjusted to the minimum amount required and to be stopped as soon as rinsing or washing is completed.

Recycling and Reuse

Nonpotable water is becoming increasingly common for use by commercial, industrial, and institutional consumers. In a nonpotable reuse system, municipal water providers treat return flows, such as effluent from a wastewater treatment plant, to make it safe for irrigation of golf courses, cemeteries, parks, or commercial/industrial cooling, for example. Colorado Springs has had a nonpotable reuse system in place for many years. Aurora also has a reuse system. Denver Water's reuse project came online in 2004.

Factories or businesses may also engineer systems to reuse process water on-site, including techniques such as sequential rinsing or reusing wash and rinse water. In sequential rinsing, spent water from one process is reused as rinse water for lower-grade process steps or other applications such as cooling tower make-up water. Wash or rinse water from certain manufacturing operations (metal finishing or pulp and paper operations, for example) can be treated and returned to the rinse system for reuse.

Denver Zoo Reduces Water Consumption by More Than Half

The Denver Zoo opened in 1896 with one black bear. During its first 50 years, the zoo added other animals native to the western United States and in the 1950s expanded to encompass species from across the globe. Today, the 80-acre facility houses nearly 4,000 animals representing 750 species and hosts an average of 1.5 million visitors each year.

In the late 1990s, the zoo embarked on a program of facility upgrades and water use reduction measures that included modernizing restrooms and eating facilities as well as replacing or repairing the aging pipelines that distribute water throughout the facility. In addition, the zoo upgraded the filtration and pumping systems at several animal exhibits, including those for polar bears and sea lions, providing better water quality for the animals and allowing these exhibits to be drained and refilled twice a year instead of monthly.

Sea lion exhibit, Denver Zoo

As a result of these improvements, the zoo's water consumption in 2002 amounted to 175 million gallons less than in 1997—a reduction of more than 50 percent of total water demand. This decrease in demand cut the zoo's annual water costs by $194,000. The improved water treatment systems saved another $19,000 a year in lowered costs for treatment chemicals, bringing total annual savings to $213,000.

In the summer of 2004, the zoo connected to Denver Water's recycled water system and began using reclaimed water for landscape irrigation and cage cleaning. The lower cost of the recycled water should further reduce the zoo's water costs.

Green Industry Promotes Water Quality and Efficiency

Green Industries of Colorado (GreenCO) is an alliance of nine landscape-related trade associations representing sod growers, landscape architects, greenhouse growers, nurseries, retailers, landscape contractors, lawn care professionals, arborists, and florists. Realizing that the economic health of the green industry is inextricably linked with the condition of the state's water resources, GreenCO has developed a manual of 29 best management practices (BMPs) that support water quality protection and water-efficient landscaping practices. Entitled *Best Management Practices for the Conservation and Protection of Water Resources in Colorado,* the manual is available at www.greenco.org. Though the manual is targeted toward green industry professionals, it can also serve as a resource for homeowners and for owners and managers of commercial, industrial and institutional facilities.

Topics covered by the BMPs and explained in accompanying fact sheets include landscape design, installation, and maintenance; design and management of large landscapes such as parks and golf courses; irrigation efficiency; irrigation system design, installation, and maintenance; water budgeting; plant selection and placement; production practices for nurseries, greenhouses, and growers; tree care; turf management; and compliance with federal, state, and local regulations affecting nursery and landscaping operations.

GreenCO's efforts to promote water use efficiency also include a public awareness campaign called "It's Easy Being Green." A joint project with the Colorado State University Cooperative Extension, this program focuses on efficient water use for lawns and gardens, tree care during drought, and other water-wise landscaping practices.

Efficient Water Use in Commerce and Industry

Reuse of nonpotable water for commercial and industrial uses, such as irrigation of golf courses or industrial cooling, is becoming increasingly common in Colorado and the West. Pipes and machinery used for nonpotable water are colored purple to distinguish them from drinking water and sewer lines.

Best Management Practices

Best management practices (BMPs) for efficient water use in business and industry are similar to some residential and agricultural practices, specifically regarding efficient irrigation, leak repair, and replacing worn-out plumbing fixtures and equipment with low-water-use models. Other BMPs are unique to commercial and industrial applications, including:

- Conduct water use audits,
- Read water meters regularly and install submeters in large complex facilities,
- Inspect and repair boiler systems,
- Recycle water that flows through cooling towers or replace cooling towers with air-cooled equipment,
- Reuse process water, and
- Replace or retrofit all systems through which water passes only once.

Some common BMPs and retrofitting strategies used to improve water use efficiency in commercial and institutional settings include:

- Commercial laundries: Replacing conventional washers with high-efficiency washers and installing water reclamation systems can reduce water use by as much as 70 percent.
- Car washes: Installing water reclamation systems can reduce water use by 50 percent. These systems separate oil, grease, and grit from wash and rinse water, then treat and filter it for reuse.
- Commercial kitchens: Low-water-use dishwashers, pedal-activated faucets, and point-of-use hot water dispensers can increase water use efficiency.
- Swimming pools: Covering pools that are not in use, backwashing filters only when necessary, and limiting the frequency of refilling are some BMPs recommended to minimize the amount of water evaporated or discharged from pools.

Incentives for Efficient Water Use in Commerce and Industry

Because most commercial, industrial, and institutional customers receive some or all of their water supplies from municipal providers, they have access to many of the same incentives as residential customers. Additional incentives tailored specifically for commercial customers may include financial incentives such as repurchasing programs, through which the utility buys back saved water, and free technical assistance in the form of water use audits, for example.

Repurchasing Programs

In a repurchasing program, the utility subsidizes a facility's investment in water-efficient equipment or processes by repurchasing the water saved during a specified period of time.

Denver Water has offered its commercial, industrial, and institutional customers a performance contracting program since 1997. Under this program, Denver Water pays $4,500 for every acre-foot of water saved during a one-year period, up to a limit of $40,000 per project. Payments apply only to nondomestic indoor water efficiency improvements, typically those requiring changes to equipment or processes such as once-through cooling, cooling tower modifications, cleaning process changes, installation of water-efficient equipment, and reuse applications.

As of early 2004, more than 60 facilities had participated in the program, including 13 hospitals, 12 cooling tower projects, 10 manufacturers, 10 car washes, 7 food processors, 3 restaurants, 2 schools, a beverage bottler, a hotel, and the Denver Zoo. Most of the reductions in demand resulted from recycling process water or cooling water. A recycling system at one of the

food processing companies achieved the largest reduction in demand—an annual savings of 90 acre-feet. Runners-up are a fiberglass roofing-shingle manufacturing plant (39 acre-feet per year) and a bottling company (28 acre-feet per year).

Water Rates

Utilities often use increasing block rates (see Increasing Block Rates, p. 9) for commercial customers. Even so, block rates for commercial, industrial, and institutional customers are usually different (different sets of quantities and unit prices) from block rates for residential customers. In addition, if commercial customers have access to and can use reclaimed water for some purposes, prices for this type of water are usually lower than those for potable water.

Education and Technical Assistance

Several municipal water utilities in Colorado offer commercial customers on-site facility audits. In an audit, a utility staff person visits the facility to assess water use and recommend measures for streamlining it. Auditors remind facility owners that reducing water use saves more than the cost of water—it can also reduce wastewater, energy, and chemical costs. In addition, water audits can include bill analysis and cooling tower audits.

Challenges to Conservation in Industry and Commerce

As in agricultural or residential situations, widespread implementation of water efficient technologies and practices in commerce and industry faces numerous challenges. Some key stumbling blocks are economics, minimal understanding of the importance of conservation or the available options to help conserve, and indifference to water pricing.

Economics are a major consideration in any business decision to implement water-saving technologies or management strategies. Generally, only the most cost-effective measures can be adopted.

Through focus groups, Denver Water learned that most commercial, industrial, and institutional customers want water-efficiency measures to pay for themselves within a year. Facility owners are less inclined to invest in measures involving longer payback periods without incentives such as programs to repurchase saved water or the threat of surcharges related to water shortages.

Though professional water use audits can identify opportunities to improve water use efficiency, businesses must also be willing to devote staff time and resources to evaluating options and implementing changes.

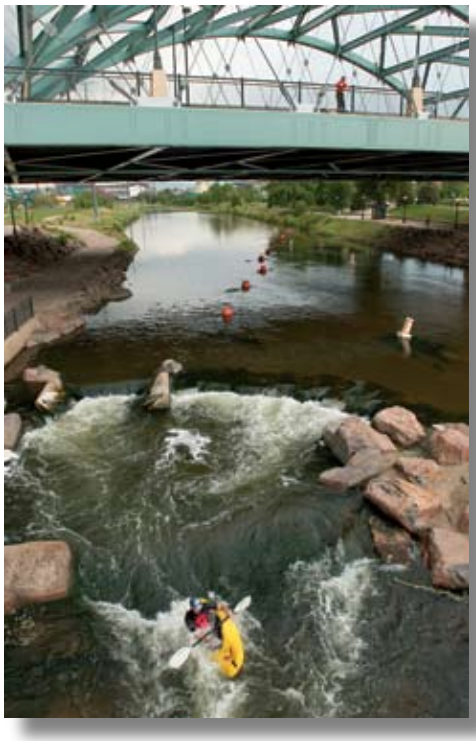
In some businesses, particularly large industrial operations, water accounts for such a small portion of expenses that owners may have little motivation to look for ways to reduce demand. Particularly if a water provider charges uniform rates—in which all metered water is priced at the same unit cost, regardless of the amount used (see Uniform Rates, p. 9)—large commercial and industrial water users may have few financial incentives to improve water use efficiency.

Audits Provide Incentives for Conservation

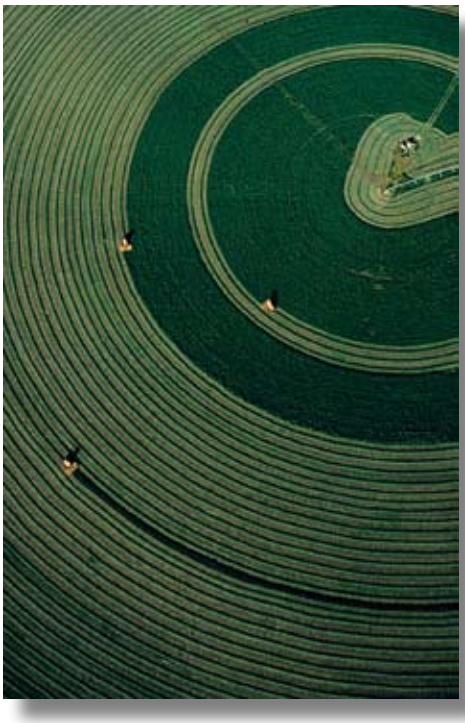
Sometimes, it pays to know. Professional water audits can be an effective way to target opportunities for businesses and manufacturers to use water more efficiently.

Initiated by Denver Water in 1990, audits of 36 facilities in the metro area projected the following potential water savings in various types of facilities: commercial office buildings (45 percent), hospitals (42 percent), hotels (30 percent), food-processing operations (30 percent), schools (21 percent), commercial laundries (14 percent), and beverage processors (10 percent).

When Denver Water followed up with the 36 facilities a year later, only five had implemented formal water-efficiency programs incorporating some of the recommended measures and had reduced their water consumption by 3–29 percent. Still, overall water use at the 36 original facilities decreased by 16 percent, or 284 million gallons, over the course of a year. This represents a water use reduction of almost 871 acre-feet.



All rivers in Colorado, such as the South Platte (above), are diverted from their channels for industrial, residential, agricultural and recreational uses. In the case of whitewater courses, water is diverted in the channel through special structures designed to create waves and drops.



Varying terrain requires different irrigation practices. Seen from above, the circles created by center pivot irrigation systems create a unique patchwork quilt on the landscape

Efficient Water Use in Agriculture

The Colorado State Engineer estimates that agriculture receives approximately 87 percent of the groundwater and surface water delivered annually in the state. Some 75 to 80 percent of this water comes from diversions out of rivers, lakes, and reservoirs; the other 20 to 25 percent is pumped from groundwater aquifers.

Water use efficiency on irrigated farms and ranches is often viewed as a function of the quantity of water consumed by growing crops versus the amount of water delivered. Efficiency may also be evaluated by looking at the yields and value of the crops produced per unit of water consumed.

Water use efficiency in agriculture can vary by field, farm, or river basin. As with water-efficiency measures for homes and businesses, farmers and irrigation water providers can reduce the water demands of growing crops and improve the efficiency of irrigation delivery and application systems.

Several concepts are key to understanding agricultural water use and conservation—specifically, return flows, salvaged water, and saved water.

Return Flows/Recycling

From a basinwide perspective, water recycling and reuse has long been practiced in agriculture. Basinwide efficiency reflects a continuous cycle of withdrawing water from rivers or aquifers, applying the water to use, and returning what is not used back to the system.

A return flow is surface water or groundwater that returns to rivers and shallow aquifers after being put to beneficial use. Return flows are not wasted water. In river basins all around Colorado, the same water is diverted and returned to the river and shallow aquifers three to seven times or more before it leaves the state. Water users downstream depend on surface water and tributary groundwater return flows to fulfill their water rights. Return flows are considered part of the public's water resource and are not part of an individual user's water right. Treated effluent from a wastewater treatment plant is another typical example of a return flow.

Although return flows allow for repeat uses of the same water, they can also create water quality problems. Multiple irrigation applications potentially pick up salts, fertilizers, pesticides, or metals, and carry these constituents into the rivers and shallow groundwater.

Return flows are not the same as tailwater (see Tailwater Recovery, p. 20), which a farmer can legally continue to control, recirculate, and re-apply to the field.

Salvaged and Saved Water

The possibilities for salvaged water from agriculture are often misunderstood, particularly in the context of agricultural irrigation. Discussion of salvaged water often comes about when an irrigator replaces an earthen ditch with a pipeline. The pipeline will largely eliminate water lost to evaporation or consumed by water-loving plants or trees growing along the ditch.

The question then arises: can an irrigator take this "salvaged" water (which before the pipeline would have evaporated or transpired and not returned to the river or aquifer) and sell it or use it to irrigate more acres? According to the Colorado courts, the answer is no.

Under the *Southeastern Water Conservation District v. Shelton Farms* deci-

sion of the Colorado Supreme Court in 1975, a person cannot "salvage" water and count that water as part of a water right. If this approach were taken, according to the court's opinion, "the use of a power saw or a bulldozer would generate a better water right than the earliest ditch on the river." The court ruled that any salvaged water belongs to the watershed, not the individual who reduces evaporation or removes water-thirsty plants.

"Saved" water, as opposed to return flows or salvaged water, is not expressly defined in Colorado water law and, therefore, is also much debated. Using the same scenario, an irrigator who replaces a previously unlined ditch with pipe "saves" water by reducing seepage. However, unlike water lost to evaporation, this seepage would have returned to nearby rivers or aquifers and been used by other water users to fulfill their water rights.

So can the irrigator sell "saved" water or use it to irrigate more acres? Again the answer is no. Because downstream users depend on these return flows to fulfill their water rights, saved water cannot be tacked onto an individual's existing water right decree or made into a new water decree. Saved water would reduce future return flows of surface runoff and shallow groundwater back to nearby rivers. Timing of the return flows might also be altered, and other water rights could be injured as a result.

Nevertheless, saving water in this manner can be a valuable contribution to water efficiency, especially during drought. Water not lost to seepage can be held in a reservoir for later use. By minimizing water lost to seepage, cities or farmers can more efficiently direct water deliveries to the desired homes or fields. Also, water no longer diverted at the headgate to compensate for seepage and evaporation can be left in that part of the stream to potentially improve aquatic habitat or become readily available to other downstream users.

Water Delivery Systems

Improving irrigation water delivery systems is an important strategy for increasing agricultural water use efficiency. To reduce seepage and evaporation, ditch or irrigation companies can increase the efficiency of their water delivery systems by lining open earthen ditches or converting them to pipelines.

Results of a 10-year study conducted by the U.S. Bureau of Reclamation indicate that lining ditches or replacing them with buried pipelines can reduce seepage by 70 to 90 percent. Effective linings include paving materials such as concrete; exposed and buried membranes made of plastic, synthetic rubber, or bentonite clay; and polymers such as polyacrylamides.

However, lining of water delivery systems can dramatically reduce and alter historic return flow patterns in shallow

Many Colorado farmers have started using flexible plastic irrigation tubing to deliver water to furrow irrigation systems. The plastic tubing is similar to gated pipe but much less expensive.

Uncompahgre Valley Begins Replacing Ditches With Pipeline

The Uncompahgre Valley Water Users Association in southwest Colorado began converting some of its open-ditch delivery system to pipelines in 1999, when it installed its first 7.5 miles of pipe. The association now boasts a 25-mile network of delivery pipe and continues to add a few miles each year, according to manager Marc Catlin. However, converting the entire delivery system will take years—it still includes more than 500 miles of earthen ditches. In the meantime, Catlin says, the association lines ditch sections that have pronounced seepage leaks with a polymer called polyacrylamide or a new synthetic rubber material that is resistant to ultraviolet light and maintains flexibility in temperatures as low as 25 degrees below zero.

Asked why the association began replacing its unlined ditches with pipeline, Catlin cites three reasons: a desire to improve the quality of water delivered to farmers, the availability of federal funds for salinity control and selenium reduction projects, and water conservation.

groundwater-dependent systems such those found along the South Platte and Arkansas River Basins. During certain months, base flows in these rivers are provided almost entirely by seepage from irrigation canals. Lining of ditches could greatly reduce surface water flows during specific times of the year, and potentially injure other water right holders.

The delivery systems of 48 percent of Colorado's agricultural water providers include some pipelines or lined ditches or canals, according to the *2004 Drought and Water Supply Assessment*.

Irrigation Systems

Finding the most efficient irrigation system for a given field involves consideration of many factors such as topography and soil properties, capital costs versus the value of the crop grown, operation and maintenance costs, energy requirements, and the system's effects on crop yields and quality. For these reasons, no single irrigation method can be considered superior in all situations.

Three types of irrigation are used for crops in Colorado—surface (gravity-flow) systems, sprinklers, and microirrigation (drip) systems. Surface systems irrigate almost two-thirds of Colorado's irrigated land, according to statistics gathered in a 2000 USGS water use survey. Furrow irrigation is the most common type of surface irrigation in Colorado. Sprinkler systems are used for most of the remaining third of the state's irrigated ground. Less than 1 percent of Colorado's farms and ranches use microirrigation systems.

Surface irrigation systems, such as furrow or flood methods, are the oldest and least expensive means of irrigation, but they are also the least efficient. In order for water to reach the end of the furrow or field, irrigators must apply extra water to the upper end of the field, causing runoff, or tailwater, at the lower end. Irrigation systems that minimize runoff by distributing water more evenly and precisely across the field—for example, sprinkler or drip systems—are considered more efficient.

Generally, irrigation efficiency describes the overall performance of the irrigation system in delivering water to the root zone of plants on an individual farm or field. For example, if an irrigation system is 75 percent efficient, this means that 75 percent of the water diverted from its source and applied to the field is stored in the root zone and consumed by the growing crop. The other 25 percent may be lost to evaporation or may return to the river or groundwater aquifers to be withdrawn by another user.

Tailwater Recovery

When soil in irrigated fields becomes saturated, runoff collects at the lower end of the field. Some irrigators capture this tailwater and reuse it on their own fields. However, according to Dick Wolfe, chief of water supply in the State Engineer's office, they cannot capture runoff that originated from someone else's property. Runoff from another irrigator's fields must be allowed to return to the stream for appropriation by downstream water users.

Although Wolfe says minimizing runoff is probably a more cost-effective way to boost on-farm water efficiency, tailwater recovery and reuse can contribute to water savings. According to the Colorado State University (CSU) Cooperative Extension, reusing tailwater can increase on-farm water use efficiency by 25–30 percent.

Best Management Practices

Recommended irrigation management practices can increase water use efficiency, as well as improve water quality by reducing erosion and nonpoint source pollution from fertilizers, pesticides and herbicides. Best management practices (BMPs) for managing agricultural irrigation are described in numerous documents. Common BMPs include irrigation scheduling, land leveling, and conservation tillage. Irrigation BMPs specific to Colorado agriculture are detailed in CSU Cooperative Extension's Bulletin XCM-173, available at http://www.colostate.edu/Depts/SoilCrop/extension/WQ/WQPubs.html

Irrigation Scheduling

Irrigators can enhance on-farm water efficiency by scheduling irrigations based on soil moisture and plant evapotranspiration (ET) rates. Ideally, irrigators should

Coalition Fights Tamarisk Invasion

Tamarisk removal may involve cutting down the plants and spraying the stumps with herbicide. Monitoring and maintenance may also be required to ensure removal.

Invasive plants are gulping millions of gallons of Colorado's water each year, stealing supplies that could be put to beneficial use and exacerbating the droughts and wildfires afflicting the West. An Asian shrub called tamarisk (Tamaricaceae: *Tamarix ramosissima Deneb*) is a particularly notorious thief. Invading low-elevation riverbanks throughout the West, including those of the Colorado River and its tributaries, tamarisks guzzle up to 200 gallons of water per plant every day. In Colorado, tamarisks may consume 250,000 acre-feet per year more than native vegetation, according to research cited in a 2003 joint resolution passed by Colorado's General Assembly in support of national legislation to authorize studies of tamarisk and other non-native plants.

Tamarisk root systems can reach depths of 50 to 100 feet, tapping into both surface water and shallow groundwater supplies. The resulting tamarisk thickets quickly crowd out native trees and grasses and displace wildlife. In addition, tamarisk—also known as salt cedar—leaves salt residues that can damage productive agricultural land.

The Tamarisk Coalition, a nonprofit organization headquartered in Grand Junction, is dedicated to controlling tamarisk and other invasive plants. To learn more about the Tamarisk Coalition's mission and activities, visit its website at www.tamariskcoalition.org.

Table 3 – Comparison of Efficiencies for Common Agricultural Irrigation Systems

Irrigation Systems	Technology	Description	Irrigation Efficiency (% range)	Best Management Practices
Surface (gravity-flow)	Flood	Water is diverted from ditches with little or no controls (other than gravity) to direct the spread of water across the field or pasture.	40–50%	Lining delivery ditches or replacing them with pipe Gated pipe Land leveling Surge irrigation Tailwater recovery
	Furrow	Most common type of surface irrigation in Colorado. Water is channeled down furrows and applied to only a portion of the field at one time.	40–60%	
	Border	Water is applied to sloping rectangular strips of land bordered by ridges.	50–80%	
	Surge	Valves on gated-pipe systems send water down furrows in intermittent surges. The first surge wets the surface of the furrow, causing soil particles to consolidate and form a seal; this allows subsequent applications of water to flow more uniformly down the furrow.	Additional 5–30% compared with continuous-flow irrigation	
Sprinklers	High-, medium-, and low-pressure systems	Lateral pipelines deliver water across a field using big sprinkler guns (high-pressure systems) or nozzles suspended at varying heights from hoses (medium- and low-pressure precision application systems). Sprinkler systems can also be differentiated by the mechanisms used to move the pipelines across the field. Common systems include center pivots, side rolls, and lateral move systems.	High-pressure 50–65% Medium-pressure 60–85% Low energy precision application 80–95%	Use sprinkler irrigation on fields with coarse-textured soils. Change nozzle configuration, height, or droplet size to minimize runoff and increase the uniformity of water distribution. Use lower water pressures to apply water within or below the crop canopy rather than spraying water high into the air.
Microirrigation	Surface drip	Emitters along pipes or hoses deliver water directly to the soil surface.	70–95%	To minimize clogging, water for micro-irrigation systems must be filtered through screens or sand filters.
	Subsurface drip	Emitters along pipes or hoses deliver water below the soil surface.	70–95%	
	Micro-sprinkler	Small emitters placed on short risers deliver water just above the soil surface.	70–95%	

Sources: Colorado High Plains Irrigation Practices Guide, Special Report 14. Colorado Water Resources Research Institute, Colorado State University (2003). Reagan M. Waskom. *Best Management Practices for Irrigation Management.* Colorado State University Bulletin XCM-173 (August 1994).

apply the proper amount of water needed, at the right time, to replenish soil moisture and maintain optimal plant growth.

Determining soil moisture can be as simple as feeling the soil or as sophisticated as using computers to download data remotely from on-farm moisture sensors. Other methods include soil sampling and weight analysis or monitoring devices such as gypsum blocks and tensiometers.

This information can then be combined with data from gauges that estimate ET in the field, allowing irrigators to see how crop water use varies with changing weather conditions. In some cases, computerized irrigation-scheduling programs can be linked directly to pipeline flow meters in the field, allowing water applications to be continually adjusted for soil and weather conditions.

In some areas of Colorado, irrigators can obtain local ET values and weather data from the Internet. For example, the Colorado Agricultural Meteorological Network (CoAgMet) collects local climatologic data through a system of weather stations located throughout the state. These data, along with real-time ET estimates, are available online at http://ccc.atmos.colostate.edu/~coagmet/.

Proper irrigation scheduling can achieve water savings of at least 20 percent, according to research conducted by CSU. However, a 2001 Nebraska study found up to 35 percent savings in both water and energy use.

Land Leveling

Land-grading equipment minimizes variations in field contours and facilitates more uniform distribution of flood or furrow irrigation water. Laser leveling, the most precise land-leveling technology, uses laser-controlled grading equipment.

Conservation Tillage

Conservation tillage refers to any cultivation method that leaves at least 30 percent of the soil surface covered by crop residue or stubble. By maintaining more ground cover and disturbing less soil than traditional cultivation methods, conservation tillage techniques impede soil erosion, reduce runoff by holding snow and rainfall on the field, decrease surface evaporation, and promote the storage of moisture in the soil.

Polyacrylamides

In recent years, use of polyacrylamides (PAM) has become increasingly popular to facilitate more efficient movement of water across a field and to reduce seepage in earthen canals. When added to irrigation water as it is applied to a field or flows through leaking canals, this long-chain, high-molecular-weight polymer adheres to soil particles suspended in the water, making them heavier and precipitating them to the bottom of the furrow or canal. The soil particles then work to "seal" the soil, reducing vertical infiltration of the water.

In large irrigation canals, PAM has been shown to significantly reduce leakage if the canal water carries enough silt. In the field, PAM can increase the efficiency and speed with which the water moves down the furrow and can reduce erosion by 30–90 percent, according to current research.

Crop Selection

Finding ways to reduce the water demands of growing crops is a significant challenge to reducing agricultural water use. Under specific soil, rainfall, and other conditions, a given crop requires a known quantity of water to grow and produce the desired yield. For example, alfalfa gener-

Conservation tillage refers to any cultivation practice that leaves at least 30 percent of the soil surface covered by crop residue. Maintaining more groundcover helps to reduce runoff and increase soil moisture. Traditional cultivation practices can be seen below in this historical photo from Haxtun (misspelled on postcard).

Drop nozzles on sprinkler systems can be set at various heights. Applying water within or below the crop canopy, as opposed to spraying water high in the air, can significantly reduce water lost to evaporation.

ally consumes up to 36 inches of water per growing season to reach optimal yields. A healthy bluegrass lawn might require some 29 inches of water.

Therefore, aside from planting low-water-use crops or accepting smaller yields, the only other way a farmer can reduce a crop's basic water demand is by reducing evaporation. Medium- and low-pressure sprinkler systems, as well as drip irrigation systems, are particularly efficient at reducing evaporation because they apply water beneath the plant canopy or close to plant roots. Other management practices that help the soil retain moisture, such as conservation tillage (see Conservation Tillage, p. 22), can also reduce the amount of irrigation water that needs to be delivered to a field.

Farm and Ranch Management

When water is in particularly short supply—for example, as a result of drought or limited groundwater resources—agricultural producers may have to change their water management strategies to strive for the best possible returns. Some common demand reduction strategies include:

- Reduce the total acreage of irrigated crops,
- Plant several crops with different peak water requirements in order to distribute irrigation over a longer time span,
- Reduce the amount of irrigation water applied on a given field (by accepting lower quality crops or lower yields),
- Delay irrigation until crops reach critical water requirement stages, and
- Switch from irrigated to dryland crop production.

Incentives for Efficient Water Use in Agriculture

Farmers and ranchers have a variety of incentives to pursue more water-efficient irrigation equipment and management techniques. Some incentives are economic, including potential increases in crop yields, reduced energy and pumping costs, and time savings associated with less labor-intensive systems. Other incentives include improved water quality, storage of water in reservoirs for release when it is most needed, or preservation of water in deep aquifers for future generations.

Financial Assistance/ Cost-Share Programs

Agricultural producers who want to enhance the efficiency of their irrigation or livestock watering systems can obtain technical and financial assistance from a variety of resources, including local, state, and federal agencies, universities, and private companies.

For Colorado farmers and ranchers, the most extensive federal source of technical and financial assistance is the Natural Resources Conservation Service (NRCS), a branch of the U.S. Department of Agriculture. Multiple programs offer assistance to address a variety of natural resource concerns, including water quality, water use efficiency, soil quality, and soil erosion.

One of the most recent and best-known

NRCS programs is the Environmental Quality Incentives Program (EQIP). This program offers both technical and financial help to farmers and ranchers who want to implement more water-efficient irrigation systems or practices. EQIP shares up to 75 percent of the cost of installing more water-efficient technologies including ditch lining, gated pipe, or sprinkler systems.

Another NRCS initiative, the Ground and Surface Water Conservation (GSWC) program, is a cost-sharing program for landowners who adopt conservation measures to reduce consumptive water use. In 2002 and 2003, the GSWC program paid farmers a total of more than $7 million to reduce water use by rotating crops or retiring marginally productive irrigated land. In 2004 GSWC funds were available to landowners in three watersheds that depend on groundwater from the Ogallala Aquifer, as well as in the Rio Grande watershed in the San Luis Valley.

Through the Upper Colorado River Salinity Control Program, the U.S. Bureau of Reclamation also provides funds through the Colorado State Conservation Board and local NRCS offices to support salinity control projects in three river basins—the Gunnison–Dolores, Colorado, and San Juan. As part of the program, landowners receive technical and financial assistance to improve the efficiency of their irrigation systems. Efficiency improvements, though initiated for the primary purpose of reducing the amount of salts entering the Colorado River, have the secondary benefit of promoting more efficient application and delivery of irrigation water.

The Colorado State Conservation Board facilitates another incentive program for agricultural producers who rely primarily on groundwater. Known as the Irrigation Water Management Program, it is designed to help eastern Colorado farmers who pump groundwater from the Ogallala Aquifer. This area consists of some 700,000 acres of irrigated land and contains about 5,600 irrigation wells. Services such as well testing and irrigation scheduling help landowners reduce water and energy use associated with well pumping. To date, savings associated with the program have been substantial, allowing some 135,000 acre-feet of water to stay in the aquifer and reducing energy use by an estimated 66,613,000 kilowatts.

Acre-inch – Amount of water that would cover one acre of land one inch deep.

Subsurface drip irrigation systems target water directly at plant roots. Here, circles of wetted soil indicate the location of seeds ready to sprout.

Drip Systems Decrease Water Deliveries and Increase Yields in the Arkansas Valley

Farmers in Otero County are using drip systems to irrigate more than 1,000 acres of vegetables and fruits, according to Mike Bartolo, vegetable crop specialist with Colorado State University (CSU) Cooperative Extension. Bartolo estimates that almost 90 percent of these farmers are also using a practice known as "plasticulture," in which subsurface drip emitters irrigate roots belowground, while aboveground, four-foot-wide black plastic sheets are tucked into the soil around the plants. The plastic sheeting increases water use efficiency by slowing losses of soil moisture and also has been shown to improve yields and fruit quality. In fact, many farmers have seen yields almost double compared to crops irrigated with traditional furrow systems.

Additional studies at onion fields at the CSU Arkansas Valley Research Center in Rocky Ford found significant water savings with drip systems. In a two-year study, researchers found that conventional furrow irrigation of onions required the application of more than 72 acre-inches of water (much of which ran off as tailwater or leached through the soil). In contrast, drip irrigated plots required only 15 acre-inches of water to produce comparable yields.

Water Rate Structures

As in other water use sectors, conservation-oriented rates send agricultural customers a message about the value of the water they purchase. Tiered rate structures, in which the price of water rises with incremental increases in demand, can encourage irrigators to apply water more efficiently in order to reduce costs.

Nine percent of agricultural water providers in Colorado currently use some form of conservation pricing structure, according to the 2004 CWCB report *Drought and Water Supply Assessment*.

Response to these rate structures depends on how the new prices compare with previous ones, as well as on the overall additional cost to the farmer. In some instances, agricultural water districts can use the extra money raised

through conservation rates to improve the efficiency of the district's conveyance systems or to help fund more efficient on-farm irrigation systems.

Other Economic Incentives

When deciding whether to make the often-substantial investment in an improved irrigation system, farmers and ranchers must ask themselves if the investment can pay for itself within a reasonable period of time and if it makes good financial sense.

Irrigators whose primary source of water is groundwater can sometimes see significant reductions in energy costs, as well as increased crop yields and reduced evaporation and runoff, after converting from high- to low-pressure sprinkler systems. The Colorado State Conservation Board has documented numerous case studies from the state's Eastern Plains where irrigators who replaced high-pressure systems with low-pressure ones cut their energy bills by as much as $500 per month while increasing yields.

Growers using surface supplies as their primary source of irrigation water have also seen yield increases after installing more efficient irrigation systems. For example, irrigators in the Arkansas Valley who switched to drip irrigation methods for melon and vegetable crops have noted marked increases in fruit quality and yields.

Education and Technical Assistance

Universities, water conservancy districts, irrigation and ditch companies, and other local agencies offer Colorado's agricultural producers a variety of educational materials, training workshops, and field demonstration projects to help improve water use efficiency. Some agencies also offer incentives such as free installation of soil moisture monitoring devices or on-site technical consultations.

At the state level, Colorado's conservation districts (formerly known as soil conservation districts) provide input and direction to local NRCS offices, supporting statewide and regional programs to help farmers improve irrigation systems and the environment. Conservation districts cover large geographic areas and may contain numerous local water management agencies, including conservancy districts, groundwater management districts, and municipal water providers.

Demonstration Farm Explores Real-World Water Use Efficiency

The Yuma Irrigation Research Foundation demonstration farm is testing the effects of a variety of water use efficiency practices in real-world situations. Located in northeastern Colorado where groundwater is the primary source of irrigation supplies, the farm is exploring how to produce acceptable crop yields with the smallest possible amount of pumped groundwater.

Researchers are focusing on tillage and cropping techniques that reduce evaporation from soil surfaces and encourage crops to maximize root depth. They are also evaluating the ability of crops to withstand stress during noncritical water use periods. The project, launched in 1994, is a partnership effort of landowners, local organizations, private industry, state and federal agencies, and universities. Details about the farm's crops and irrigation systems are available on its website at www.irf-info.com.

The Yuma Irrigation Research Foundation farm provides a testing ground for new irrigation technologies and practices.

Challenges for Water Conservation in Agriculture

Some of the most important stumbling blocks to agricultural water conservation in Colorado are related to economics, over-appropriation of the state's surface water supplies, and common misconceptions regarding the "use it or lose it" provisions of the state's water rights system.

Economic disincentives pose a considerable challenge to agricultural water conservation. Facing strong international competition, rising input costs, and commodity prices that have not increased in real terms in 30 years, farmers in many areas can ill afford the significant expenses often associated with efficiency improvements. If water prices are relatively inexpensive, this creates additional disincentives to conserve.

In addition, almost all of Colorado's river systems are over-appropriated—meaning the courts have approved more

rights to divert water out of the stream than the amount of water flowing in the stream can satisfy during an average year. This means that when senior water right holders free up or "save" water (see Salvaged and Saved Water, p. 18), many junior users are automatically waiting in line to use it. So the question arises: why install an expensive irrigation system to save surface water or groundwater, just to have it flow downstream for another user, or just so your neighbor can pump more groundwater?

Water rights are extremely valuable property rights. However, under Colorado law, if a water right has not been put to beneficial use for a period of 10 years or more, another party may petition the water court to declare that water right abandoned. Although a water right cannot be legally considered abandoned unless the owner shows intent to abandon, non-use of the right for 10 years does make it vulnerable to this sort of proceeding. Many water right holders are concerned that if efficiency measures no longer require them to divert as much water at their headgate, they could lose some portion of their water right permanently.

This common concern misinterprets what constitutes the measure and limit of a water right in Colorado. Say, for example, that a farmer wants to sell his or her water right to a city. As part of the required "change of use" proceeding, the water right will be quantified based on its historic consumptive use—the amount of water a given crop on a given number of acres has consumed over time. A crop's consumptive use will not change substantially with the use of more water-efficient irrigation techniques (see Crop Selection, p. 22), and therefore the quantity of an individual's water right will also not change. Still, some water right holders incorrectly perceive that if they ever want to sell their water right or change its use, more efficient practices diverting less water may diminish the amount (and value) of their water right.

Research into the efficiency of agricultural irrigation systems is ongoing throughout the many areas of the world that rely on irrigated agriculture, including California, Israel and large portions of India and China.

Regulations and Policies Promoting Efficient Water Use

Numerous public policies—federal, state, and local—mandate, promote, or otherwise affect behaviors and attitudes toward using water wisely in Colorado. These policies include legislation passed by the U.S. Congress or the Colorado General Assembly, guidelines issued by the U.S. Environmental Protection Agency (USEPA), regulations issued by the Colorado Department of Natural Resources, legal decisions handed down by Colorado's water courts, and local ordinances and covenants.

Federal Legislation and Guidelines

Plumbing fixtures. Passed by Congress in 1992, the U.S. Energy Policy Act established for the first time national maximum allowable flow rates for plumbing fixtures. The legislation specifies maximum flow rates for toilets (1.6 gallons per flush), urinals (1.0 gallon per flush), showerheads (2.5 gallons per minute), and faucets (2.5 gallons per minute). These national water-efficiency standards apply to plumbing fixtures installed in all newly constructed or renovated residential and nonresidential facilities.

Conservation planning. As mandated by federal legislation (1996 amendments to the Safe Drinking Water Act), in 1998 the USEPA issued guidelines for municipal water utilities to follow in developing local water conservation plans. The guidelines are designed to help utilities integrate water use efficiency into planning for new facilities. Three sets of guidelines are presented: basic guidelines for water systems serving 10,000 people or fewer, intermediate guidelines for systems serving 10,000 to 100,000 people, and advanced guidelines for systems serving more than 100,000 people. Components of the intermediate and advanced guidelines include forecasting water demand and evaluating water use efficiency measures on the basis of cost–benefit analyses.

Siphon tubes pull water from a concrete-lined ditch in the Arkansas River Valley.

State Legislation and Guidelines

Conservation Planning. In 1991, Colorado became one of the first states to pass statewide water conservation legislation. Originally designed to improve urban water use efficiency, the Colorado Water Conservation Act created the Office of Water Conservation within the Colorado Water Conservation Board (CWCB) and required water providers with annual deliveries of more than 2,000 acre-feet (also known as "covered entities") to develop water conservation plans by 1996. In their plans, providers were instructed to consider, at a minimum, water rate structures, regulatory measures, incentives, water reuse systems, and education, among other measures.

Amendments to this legislation in 2004 continued to enhance water conservation-related financial and technical incentives for Colorado communities. Amendments included provisions specifying that after July 2006, covered entities seeking financial assistance from the CWCB or Colorado Water Resources and Power Development Authority must submit a new or revised conservation plan for the board's approval before funds can be released. Other provisions increased the scope of work for the

In1992, the federal government established maximum flow rates for plumbing fixtures nationwide. Faucets may provide no more than 2.5 gallons per minute.

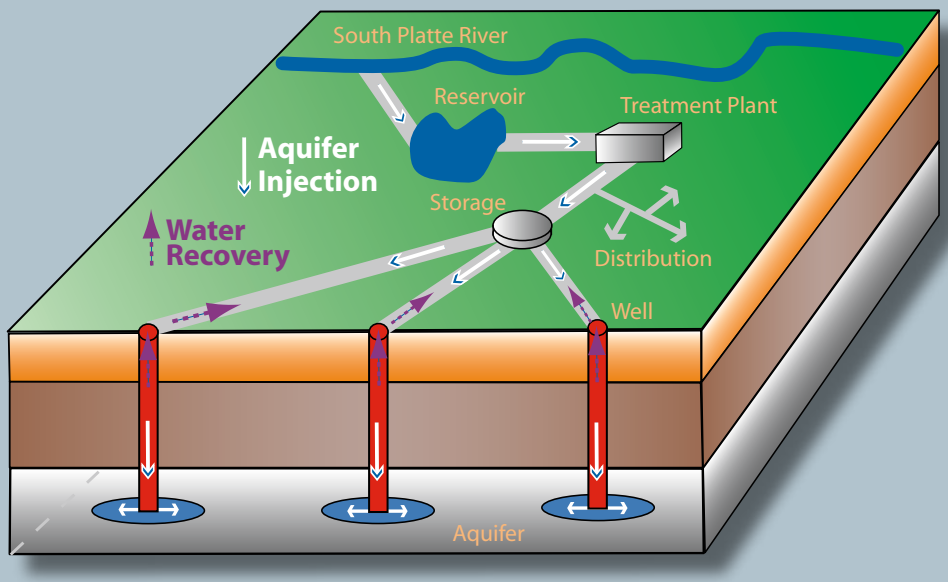
Conjunctive Use Helps Highlands Ranch Weather Dry Years

Among the rapidly growing suburban communities in Arapahoe and Douglas counties south of Denver, Highlands Ranch is in the unique position of having developed two distinct water supply systems—a surface supply from the South Platte River and a groundwater supply from the deep confined aquifers of the Denver Basin. Surface water accounts for about three quarters of the district's total supply, and nonrenewable groundwater sources make up the rest, according to Rick McLoud, water resources manager at the Centennial Water and Sanitation District, which serves Highlands Ranch.

In 1992 the district embarked on Colorado's first conjunctive use project involving deep-well injection. Adapting some of its wells with injection equipment, the district began replenishing its groundwater supplies with potable surface water in wet years.

"In years with average stream flows, we rely on surface water," McLoud said, explaining how conjunctive use works. "In wet years, we use surface water and inject any excess into the groundwater wells. Then in dry years, we can fall back on the groundwater source. This way we can avoid continuously depleting our groundwater supply, because it's our savings account."

By 2004, the district had equipped 21 wells for injection and had added almost 7,000 acre-feet of treated water to its groundwater stores, McLoud reported. So far withdrawals, made only during the dry summer of 2002, have amounted to 570 acre-feet. Injected water comes from the same potable supply distributed to customers.



Conjunctive use systems take water from rivers in wet years, and inject that water into underground aquifers. During dry years, that water can be recovered from the aquifer and distributed to homes and cities. Conjunctive use allows cities to more sustainably manage their water supply system—replenishing groundwater supplies in wet years, and providing more reliable water supplies in dry years.

Office of Conservation to include technical assistance to agricultural and industrial water providers and state agencies, as well as assigning it the new title of "Office of Conservation and Drought Mitigation."

In 2003, the state also weighed in on water-efficient landscaping, passing a law prohibiting the adoption of any new covenants that restrict low-water-use landscaping.

That same year the state legislature also adopted a joint resolution (House Bill 1091) containing a set of 10 principles designed to guide future water policy for the state. The ninth principle asserts that "water conservation measures that do not injure other water rights should be aggressively pursued."

Efficient Management of Water Supplies

How water supplies are managed at regional, local, and statewide levels can have a significant impact on how efficiently that water can be put to use. In recent years, the state legislature and local water providers have been developing mechanisms to increase the flexibility with which water can be transferred, stored, and moved around the state in order to meet demands effectively as they arise.

These strategies include innovative water management technologies (such as conjunctive use) and procedures (such as interruptible water supply agreements) to facilitate more flexible and responsive water management on a local and regional level. The following discussion is not meant to be a comprehensive list but provides an overview of currently available options.

Conjunctive use. Conjunctive use is a management approach in which surface water and groundwater supplies are managed jointly to produce a larger, more reliable supply than either source could generate alone. During wet years with above-average precipitation and runoff, surface water is stored for later use by injecting it into groundwater aquifers. In this scenario, a deep confined aquifer is used for storage in much the same way as a surface reservoir. A water management district might also direct water from streams, lakes, or reservoirs to permeable areas of a groundwater basin where the water can

infiltrate the soil through recharge ponds. In either case, the stored water can be withdrawn at some future point when surface sources are in short supply.

The goal is to allow water providers to extend the life of their aquifers while fully using their surface water rights, managing short-term shortages, and minimizing the need for new, above ground storage reservoirs.

Dam and reservoir repair and rehabilitation. Maximum beneficial use of Colorado's surface water supplies depends in part on the state's ability to fully utilize the storage capacity of its reservoirs. The Colorado Division of Water Resources (CDWR), which administers the state's Dam Safety Program, determines safe storage levels in order to protect water supplies—as well as people, property, wildlife, and crops—from dam failures. Reservoir storage capacity may be reduced as a result of restrictions imposed for safety reasons.

In 2002, CDWR estimated that reduced reservoir capacity in Colorado amounted to more than 140,000 acre-feet of storage. Restoring lost capacity by repairing and rehabilitating dams and reservoirs can be much less expensive than constructing new storage facilities. In fact, CDWR has estimated that 25,000 acre-feet of lost storage in Colorado could be recovered at an approximate cost of $10 million, the equivalent of about $400 per acre-foot—far lower than costs for new storage projects, which can run thousands of dollars per acre-foot.

Substitute water supply plans. Substitute supply plans allow temporary out-of-priority diversions if sufficient replacement water can be provided to cover stream depletions. (An out-of-priority diversion allows the water right of a junior appropriator to take priority over a water right with a more senior priority date.) Always temporary, these plans must be approved by the State Engineer. Substitute supply plans may be approved when augmentation plans—long-term plans to replace out-of-priority stream depletions—are still pending in water court.

The substitute or replacement water may be owned or leased, but it must be available in the proper quantity, quality, place, and time necessary to prevent harm to other water right holders. Potential sources of replacement water include flows from surface streams or storage reservoirs, nontributary groundwater, and groundwater from recharge wells or basins.

Interruptible water supply agreements. In years when stream flows are particularly scarce, agricultural producers may consider irrigating their fields a fruitless endeavor. Leasing their water to a municipality may reap more revenue than growing crops that fail to meet normal yields or quality standards. To facilitate temporary water reallocations without the need for court approval, the state legislature in 2003 authorized the use of interruptible

Aurora Leases Water to Help Fill Its Reservoirs

In March 2004, as Colorado faced its sixth consecutive year of drought, the city of Aurora agreed to lease 4.1 billion gallons of water from 152 farmers in the Arkansas River basin. The $5.5 million deal, expected to boost Aurora's supplies by almost 25 percent, is the largest temporary water agreement in Colorado history. The lease price was based on market prices for crops, mostly hay and corn, averaged over the past few years. The farmers, who hold shares in the High Line Ditch Company in Pueblo and Otero counties, received $5,280 per share under the terms of the lease. Though most of them leased only a portion of their historic consumptive use, the city expects to serve about 25,000 households with the additional supply.

Dan Henrichs, superintendent of the High Line Canal, adjusts one of the gates that helps meter the canal's flow to farm fields and ranch pastures throughout the Lower Arkansas River Valley.

water supply agreements. Interruptible water supply agreements—sometimes known as dry-year leases—are arrangements between two or more water right holders, usually an agricultural water user or users and a municipality.

Under an interruptible water supply agreement, the lending water right owner agrees to lease water to another water user, although the lease can operate only three out of ten years. Temporary changes in the point of diversion, location of use, and type of use are also allowed without court approval, although the agreement is subject to the state's water right priority system and approval by the State Engineer.

Water banking. Designed to help farmers and municipalities survive water shortages, banking of stored water facilitates speedy, low-cost, temporary water transfers—leases, loans, or exchanges, including interruptible water supply agreements—by allowing participants to legally bypass the procedures required for permanent water transfers. Essentially, water banking allows farmers to obtain compensation for their storage water rights without being forced to sell them. Through a water bank, farmers can store water they do not plan to use until another user leases it. Under legislation passed in 2003, water banks are allowed throughout the state, although no transactions had yet been recorded as of early 2004.

Water conservation incentives encourage people to adopt more water-efficient behaviors or technologies. But sometimes enforcement is necessary. Especially during dry years when mandatory watering restrictions are in effect, many cities employ "water cops" to monitor compliance and help educate neighborhoods.

Local Ordinances and Covenants

Many Colorado utilities and municipalities have adopted local ordinances that encourage wise water use. Some of these mandates include:

- Prohibitions on irrigation of driveways, sidewalks, and streets;
- Limitations on the percentage of a landscaped area that can be planted with thirsty species of turf grass (such as bluegrass);
- Requirements for soil amendments before landscape installation; and
- Prohibitions on the installation of new single-pass cooling systems, except in rare cases for backup systems in hospitals.

Some cities have also adopted ordinances or proclamations against wasting treated water. For example, Broomfield has a Misuse of Treated Water ordinance, declaring it unlawful for "any person to flagrantly or wantonly misuse or waste… treated water supplied by the city."

In another example, in 2003 the Pagosa Springs Area Water and Sanitation District, representatives from the town and county, and the local property owners association convened the Archuleta County Water Wise Policy Task Force to develop a set of over-arching principles to guide future conservation planning. The result was a *Joint Water Waste Proclamation* defining "water waste practices" and encouraging local citizens "in the spirit of community cooperation" to use water efficiently.

In contrast, many covenant-controlled residential communities throughout Colorado place restrictions on the amount or character of low-water-use landscaping their residents may install. For example, the planned community of Highlands Ranch requires committee approval of any landscape that is more than 50 percent "xeric." Its covenants also prohibit front lawns from being planted in buffalo grass, a water-thrifty grass that is native to the U.S. central plains and that consumes 90 percent less water than conventional turf grasses such as bluegrass. A 2003 state law, however, prohibits the adoption of any new covenants that restrict drought-resistant landscaping.

If efficient water use is to become a way of life in Colorado, the state's citizens must believe that water conservation is important and that it can make a difference on an individual level.

In order for this to happen, the costs of water conservation must be equitably distributed (so that no one group or location bears the lion's share), existing water rights must be protected, and the water-efficient technologies and management practices offered must be affordable, socially acceptable, environmentally beneficial, and effective.

In addition, citizens must receive consistent messages—in years of drought and flood alike—about where their water comes from, why Colorado's supplies are limited, what water-efficient options are available, and the costs and benefits of their actions.

Addressing the challenges and barriers to conservation will not be easy. Water conservation works on multiple levels—from individual households to entire river basins. Expanding population, variable weather patterns, and changing land uses confound one-dimensional and simplistic approaches.

As Colorado addresses the challenges of the twenty-first century, individuals and communities throughout the state will be called on to make informed decisions about the role of water conservation in stretching limited supplies to meet multiple demands. Recent drought has emphasized the importance of wise water use. Widespread adoption of water conservation technologies and practices will be a continuing challenge.

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Xeriscape gardens can be both water efficient and colorful.

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Water Saver Home (the top five actions for saving water at home and a virtual house tour noting potential water savings for each room), http://www.h2ouse.org

Watersaver.org (an information warehouse with links to the websites of several Front Range municipalities and the RunTime Calculator), http://www.watersaver.org

Xeriscape Colorado, Inc. (photos, links to demonstration gardens, bibliography, and contact information), http://www.xeriscape.org

Cooling towers, such as these owned by Xcel Energy, consume large quantities of water through evaporation.

Day Lily
Hemerocallis fulva

Photograph by William Castner

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