

CITIZEN'S GUIDE TO
WHERE YOUR WATER
COMES FROM

Prepared by
Colorado Foundation for Water Education



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Citizen's Guide to Where Your Water Comes From

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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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For most people,

the question, “Where does your water come from?” has a simple answer: “From the tap.” It seems hard to believe the water for your morning shower may have traveled more than 200 miles, from a melting snow-bank to a high mountain reservoir, through tunnels, treatment plants and pipes. Or it may have been pumped from 2,500 feet below the earth’s surface, tapping ancient water molecules that made their way into these aquifers during the Stone Age.

This citizen’s guide attempts to help explain how weather patterns and aquifers supply much of the water we use, as well as the intricate systems Coloradans have developed over the last 150 years to deliver this water to household taps, businesses, yards, parks and farm fields.

Natural Sources and Constructed Infrastructure

Of course, water comes to us initially from the atmosphere as rain or snow. Two natural sources collect it: rivers (surface water) and underground aquifers (groundwater). Rain and snow recharge both rivers and shallow groundwater aquifers with an annual supply of water. Deeper aquifers are also recharged, but through different flow paths and at much slower rates.

Without human intervention, a large percentage of water would remain underground or flow downstream in rivers toward the ocean. To meet human needs, a great deal of infrastructure has been constructed to divert, collect, convey, treat and distribute water.

Water Providers

Supplying water to homes, farms and businesses requires more than construction of reservoirs, pipes and treatment systems. It also involves working together to manage our water resources and infrastructure. Communities have created utilities, water districts, and other organizations to handle the myriad of tasks necessary to store, treat, deliver and reclaim water.

*Where Does Your
Water Come From?*

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Colorado's Climate & Hydrology

Rain and Snow

In Colorado, average annual statewide precipitation is only 16 inches, with most regions getting from 12 to 16 inches. The driest part of the state is the San Luis Valley, with only 7 inches of precipitation annually. The mountain areas are the wettest, with some regions receiving more than 50 inches annually. Most zones above 10,000 feet elevation enjoy 25 or more inches annually—mostly from snow.

Colorado's location near the center of North America gives it a high elevation and mid-continental climate, with distinct seasonal fluctuations in temperature and precipitation. This location and the state's diverse mountains, plains and mesas combine with dynamic weather patterns to determine how, where and when each region will receive the precipitation that its people and environment depend on.

Annual precipitation averaged 1961-1990. Station observations collected from the NOAA Cooperative and USDA-NRCS SnoTel networks, plus other state and local networks.

*Map provided by Oregon Climate Service,
www.ocs.orst.edu*



Colorado's Climate and Hydrology

Winter brings snow—a natural form of water storage. Heavy snowpack in Colorado's mountains generally builds up during the early spring as a result of storms originating in the Pacific Ocean and moving from west to east. In the mountains, snowfall may reach more than 300 inches. At lower elevations annual snowfall is less, ranging from 20 inches at Las Animas to about 60 inches at Denver.

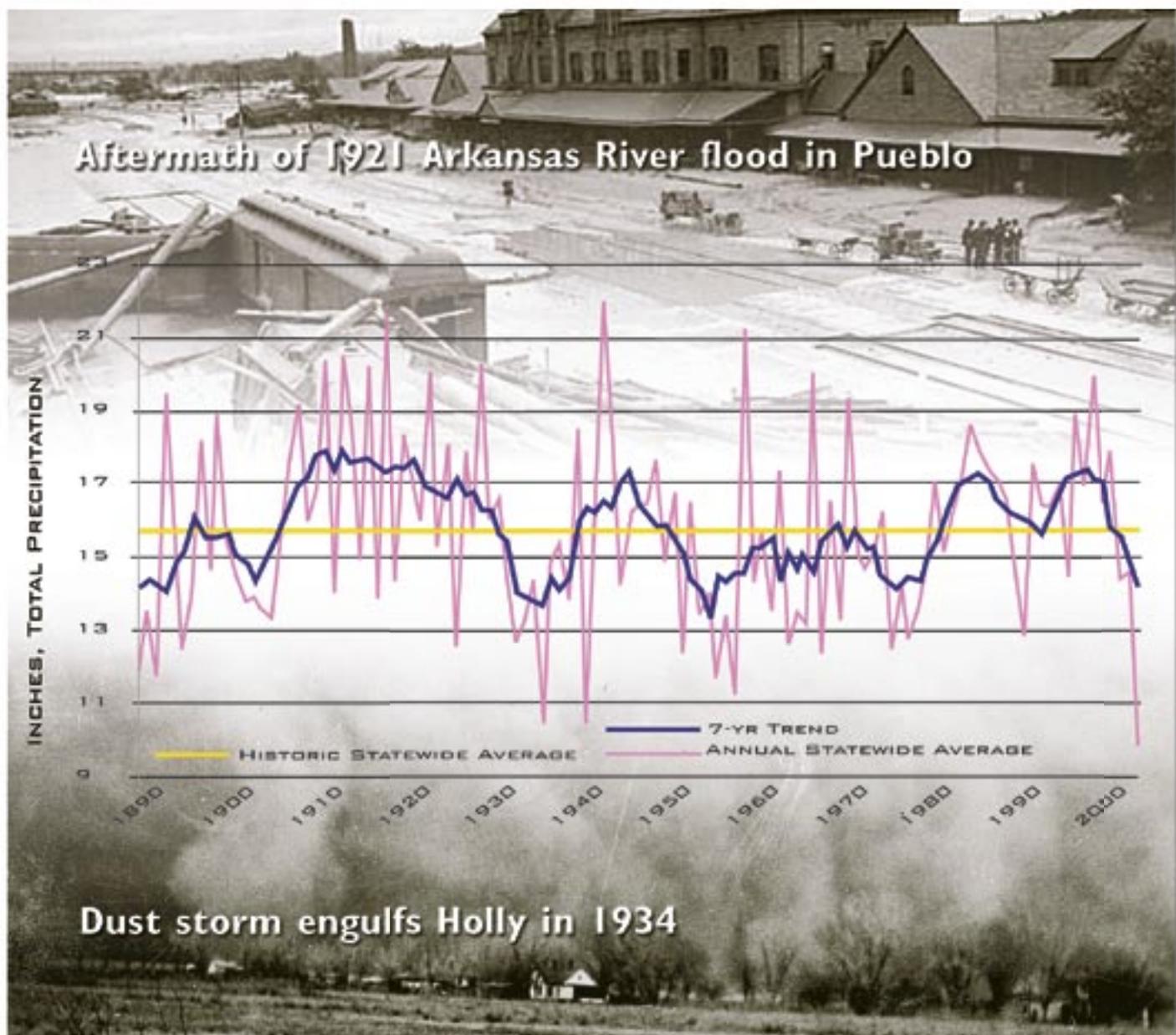
Snowpack — Accumulation of snow on the ground that persists through winter and melts in the spring and summer.

Snow in cold, high-elevation landscapes holds moisture longer, waiting until April, May or June to release its stored water. At

lower elevations, snow melts more quickly, recharging shallow aquifers, replenishing local creeks or just evaporating into the air.

According to the Natural Resources Conservation Service (NRCS)—the federal agency that measures snowpack (among other responsibilities)—approximately 80 percent of river runoff comes from snowmelt. The remainder comes from rainfall and infiltration into rivers from groundwater.

Year-to-year, precipitation levels in Colorado vary markedly, from long drought to sudden floods.





SNOTEL

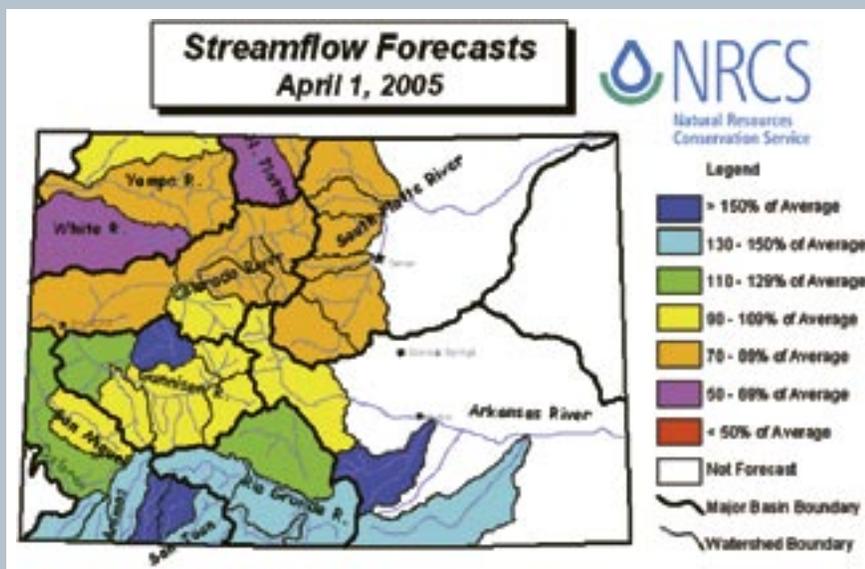
Understanding the amount of water generated by melting of Colorado’s annual snowpack is vital to water managers as they predict yearly water supplies for homes, businesses and farms.

Throughout the West snowpack is measured by the Natural Resource Conservation Service (NRCS) through the National Water and Climate Center and a network of Snowpack Telemetry (SNOTEL) stations. The center provides real-time snow and climate data using automated remote sensing equipment from numerous sites throughout Colorado’s mountains. The information is available in hourly, daily, monthly and yearly increments.

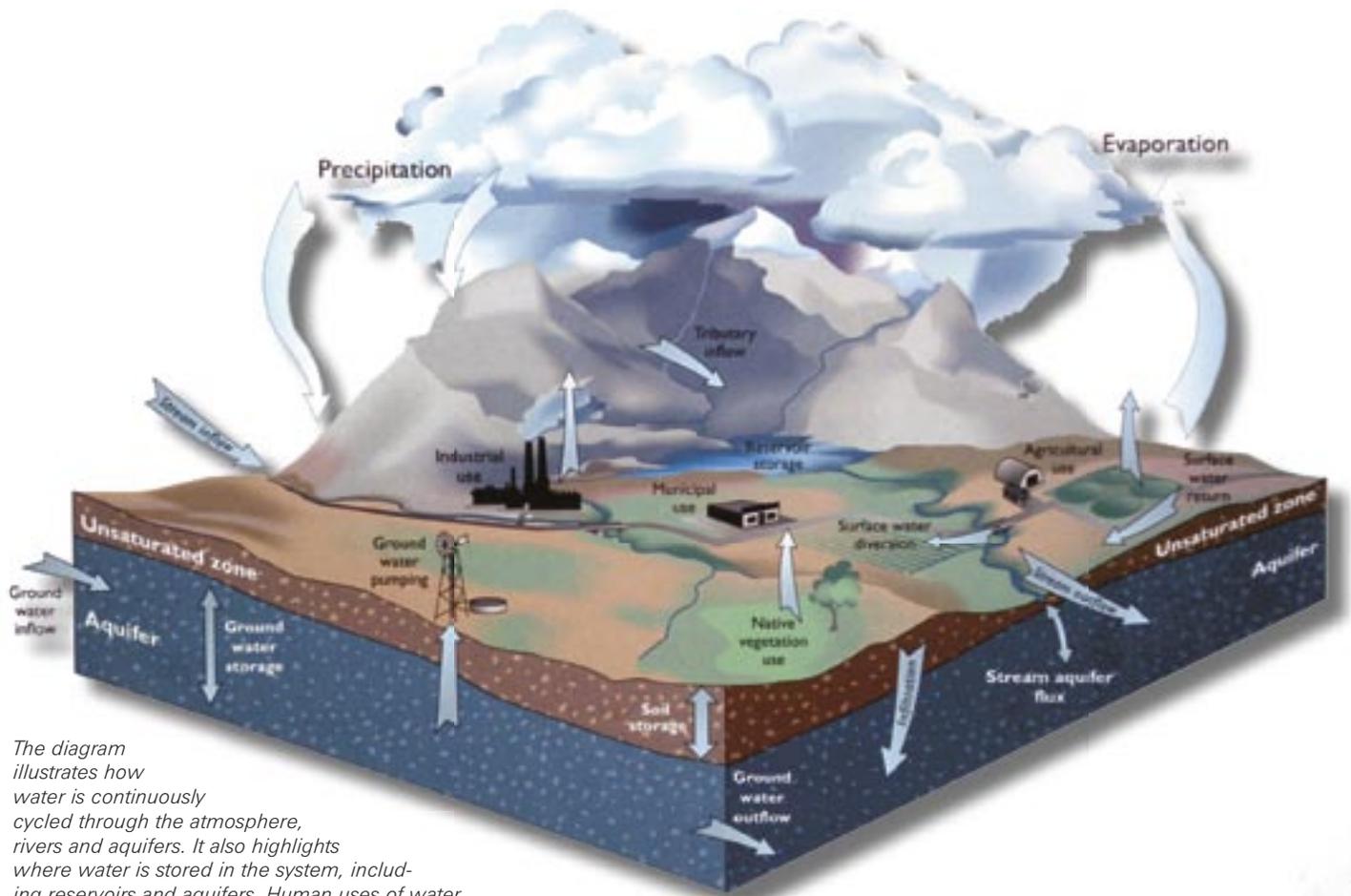
From this data, the NRCS compiles monthly Colorado Water Supply Outlook Reports from January through June. It also develops stream flow forecast maps, such as this one for April 2005.

Generally, water managers look forward to the NRCS’s April 1 snowpack information as the most critical report to shape their water supply management strategies for the coming year. Individual water utilities and districts may also generate their own forecasts.

***Snow-Water Equivalent** — Amount of water contained in a volume of snow (in other words, the amount of liquid water produced by melted snow). The water content of snow varies from less than 10 percent for light powder to 30 percent or more for compact, dense snow.*



Colorado's Climate and Hydrology



The diagram illustrates how water is continuously cycled through the atmosphere, rivers and aquifers. It also highlights where water is stored in the system, including reservoirs and aquifers. Human uses of water can remove water from the environment by consumption of drinking water, irrigation of growing plants or incorporation of water into industrial products, for example.

Hydrologic Cycle

Colorado's water arrives in an annual cycle that starts with snow buildup in the winter and early spring, followed by spring runoff, then rainstorm activity in the late summer. Variations occur from year-to-year and in different regions of the state.

Hydrology—the science of water—explains how the sun evaporates water from its sources, cleans it, and transports it as rain, snow, or hail. It also describes how water moves from its point of origin to its destination, whether in a groundwater aquifer, cloud, or the water we drink.

Wind brings Colorado's moisture from the gulfs of Mexico and California, Pacific Ocean, Mississippi Valley, and local sources.

As the air masses rise over the mountains, if they contain enough water vapor, it will condense and fall as precipitation.

Rainfall or snowmelt infiltrate into the soil and rock layers, increasing soil moisture and filling aquifers. On the surface, runoff and shallow groundwater fills streams, lakes and reservoirs. Surface water and groundwater may be used multiple times for homes, agriculture, recreation, environment and industry. Water not consumed by each use is returned to the aquifers and streams for other uses as it makes its way toward the ocean. Along the way some of the water is evaporating back into the atmosphere, where the cycle begins anew.

Climate Change

Climate change predictions are hotly debated. Much of the controversy centers on differing opinions about future levels of greenhouse gases, as well as differing climate-prediction models.

Natural fluctuations in climate—such as the ice age—are well-documented by ice cores and other sources, making us aware of past cooling and warming cycles. However, in the 21st century climatologists have become increasingly concerned that current warming trends are the result not only of natural variation, but also involve human-induced acceleration of a phenomenon known as the “greenhouse effect.” The greenhouse effect occurs when the earth’s atmosphere traps heat radiating from surface. But increased levels of carbon dioxide, water vapor, methane and other compounds can amplify this process, causing weather patterns and the climate to change.

In the Rocky Mountain region, some researchers theorize that increasing tem-

peratures could mean less snow, less water and more drought, along with other impacts. Some researchers predict that higher temperatures will increase evaporation, removing moisture from the soil faster than it can be added, resulting in net water losses (*Climate Change Impacts in the United States, 2000*).

One of the most significant climate changes that could potentially impact Coloradans’ water supply is less snow in the mountains. Some 30 million Westerners, from Denver to Albuquerque and from Las Vegas to Los Angeles, depend on water from the Colorado River, some 85 percent of which originates as snowfall in the Rocky Mountains.

The U.S. Global Change Research Program (2000) reported with “very high confidence” that climate change would greatly reduce snowpack in the Rocky Mountains. Not only is the climate expected to be warmer overall, but temperatures

are expected to increase more in winter than in summer, more at night than in the day, and more in the mountains than at lower elevations—all leading to less snow.

Researchers at the National Center for Atmospheric Research recently developed a climate model demonstrating how climate change could impact runoff, snowpack and other variables in the Colorado River Basin.

These results predict a 14 to 17 percent reduction in runoff in the Colorado River. Since the four Upper Colorado River states—Wyoming, Colorado, Utah and New Mexico—are required to deliver a set amount of water (a 10-year rolling average of 75 million acre-feet) to downstream states such as California—regardless of drought conditions—this could curtail the amount of water available to Colorado citizens.

**Table 1, Predicted Climate Change Impacts in the Colorado River Basin
Based on Historical Averages**

Period	Average Temperature	Total Precipitation	Snowpack	Runoff	Water Storage
2010-2039	+ 1.8°F	-3%	-24%	-14%	-36%
2040-2069	+3.6°F	-6%	-30%	-17%	-40%

Source: Christensen et al., “The Effects of Climate Change on the Hydrology and Water Resources in the Colorado River Basin,” *Climatic Change* (2004). Projected changes are comparisons to actual observations from the period 1950-1999.



Water Demand & Use

How Coloradans use and consume water is a reflection of our climate, landscape and changing social values.

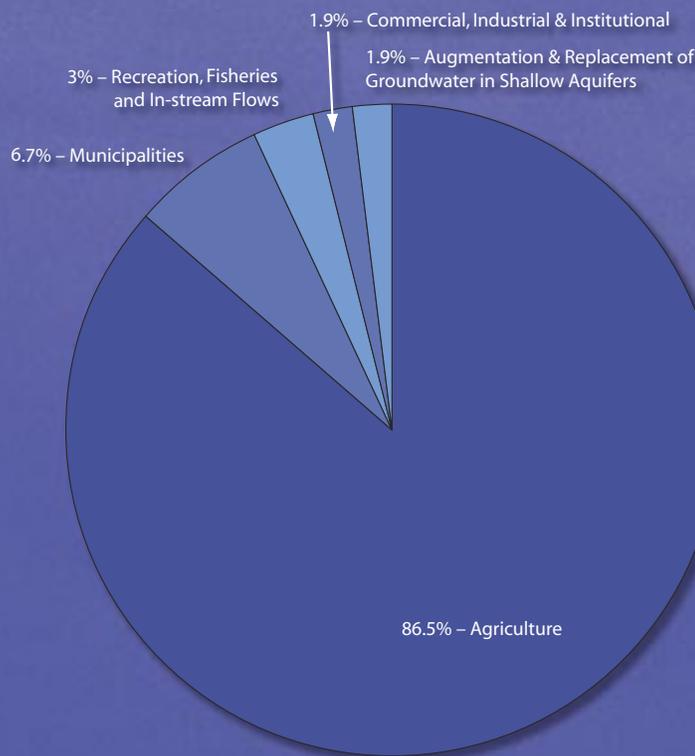


Figure 1 illustrates how Coloradans use the water diverted or withdrawn from the state's rivers, reservoirs and groundwater aquifers. The Colorado State Engineer's office provided these statistics for groundwater and surface water deliveries in 2002.

Agricultural Water Use

In Colorado, agricultural production of food and fiber diverts close to 86 percent of the state's deliverable resources. With the exception of dryland wheat, most of Colorado's agriculture and green industry (nursery and greenhouse) production requires irrigation to generate the desired yields and products.

While agriculture no longer dominates the economy of the western United States, Colorado's agricultural production generates about \$5 billion in direct revenues per year, with the major share coming from livestock production (about \$3.7 billion). Of the some \$1.3 billion in crops grown in Colorado, about \$0.65 billion are food grains or feed crops, the majority of which must be irrigated. Another \$0.35 billion is generated by sales of fruits or vegetables—also irrigated. Of the remaining \$0.3 billion, the majority of the revenue comes from greenhouse and nursery businesses.



Water Demand and Use

Municipal Water Use

The USGS estimates that in 2000, 87 percent of Colorado’s population was served predominately by municipal utilities, water and sanitation districts and rural water districts. These providers supplied an average 899 million gallons of water per day to Coloradans all over the state.

Private wells (which the USGS calls “self-served domestic uses”) withdrew some 67 million gallons each day from local Colorado aquifers for indoor and outdoor needs.

During Colorado’s warm dry summers, lawns, gardens and trees consume as much as 70 percent of the water delivered to residences. For additional information on water use in homes and cities, see the *Citizen’s Guide to Colorado Water Conservation* (CFWE, 2004).

Industrial Water Use

Although water deliveries to businesses, industries and institutions directly 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 are used for commercial/industrial purposes.

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

Return flow – Surface water or groundwater that returns to rivers and/or shallow aquifers after being withdrawn for use.

Water Deliveries v. Consumptive Use

The quantity of water Coloradans consume—or do not return to the immediate water environment because of evaporation, incorporation into crops or products, or consumption by people or livestock—is called “consumptive use.”

This table, compiled from U.S. Geological Survey (USGS) data, shows that a total of approximately 13 million acre–feet of water each year is diverted from rivers or pumped from wells in Colorado for agricultural purposes.

Much of this water is reused multiple times via irrigation return flows. The USGS estimates only an average of 37 percent of the water diverted statewide for agriculture is actually consumed. The following table shows consumptive use as compared to total agricultural withdrawals from streams and aquifers, for each major river basin in the state. According to the USGS data, the highest level of consumptive use occurs in the South Platte River Basin.

Table 2, Agricultural Water Use in 1985

River Basin	Total Agricultural Withdrawals	Agricultural Consumptive Use	Percent Consumptive Use
South Platte	3,404,000	1,930,700	57
Arkansas	1,939,800	822,400	42
Rio Grande	1,797,000	781,700	43
Gunnison	1,933,400	415,900	22
Upper Colorado	2,335,800	443,800	19
Yampa–White–N. Platte	859,000	212,100	25
San Juan–Dolores	731,100	225,000	31
Totals	13,000,100	4,831,600	37

Ref: Montgomery Watson. 1997. Colorado Water Development Study. A Report for the Colorado Farm Bureau. Section 5-3.

Environmental Water Use

In assessing water use, we most often consider agricultural, municipal, and industrial groups. But the environment is also a major water user that shouldn't be overlooked. Colorado's diverse ecosystems include some 22 million acres of forest and more than 30 million acres of rangeland, not to mention the fish and wildlife throughout the state that need water to thrive.

Calculations developed by researchers at Colorado State University attempted to quantify how much water the environment consumes. In their analysis, they factored that Colorado receives approximately 95.5 million acre-feet of precipitation annually. Some 15.6 million acre-feet of this 95.5 million acre-feet flows in our rivers each year, while another 2 million acre-feet is extracted from groundwater. Combined, this approximately equals the amount of water available for use by Colorado and other downstream states.

Using the total amount of precipitation that falls on the state and subtracting all other uses and evaporation, the remaining amount of water, they argue, benefits the natural environment. Using this calculation, an alternative view of where our water goes takes shape.

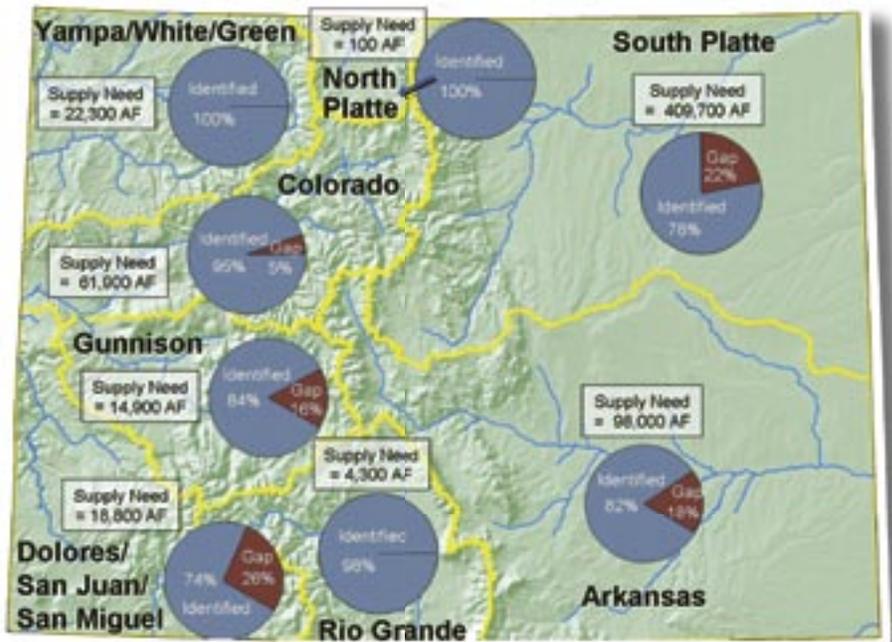
Environment	78%
Agriculture	20%
Reservoir Evaporation	1%
Municipal and Industrial	1%

Source: R. Waskom, *Colorado Water*, December 2003. p.5-6.

Water Demand

Planning for Colorado's growing populations requires that we understand how much water the state will need in the future. To probe this question, in 2003 and 2004 Colorado undertook a landmark study to evaluate its future water needs through 2030. Called the Statewide Water Supply Initiative, this study came up with 10 major findings about Colorado's water future.

1. Significant increases in competition for water will result from population growth, agricultural use, and increases in environmental and recreational demands.
2. Projects and management improvements already scheduled by water providers could meet 80 percent of projected municipal and industrial needs through 2030.
3. If these project and management improvements are not successful, more water will be taken from agriculture to meet all needs.
4. Supplies are not always available where demand occurs, but there may be surpluses elsewhere.
5. Non-renewable ground water may not be reliable for meeting some needs, particularly along the Front Range.
6. If only in-basin solutions are used to meet the remaining 20 percent of needs, there will be impacts on agriculture and the environment.
7. Water conservation is a significant tool to meet demands, but is not sufficient by itself.
8. Environmental and recreational uses are important, but they require planning and implementation.
9. Smaller, rural water providers face financial constraints in meeting their needs.
10. Demands past 2030 have not been evaluated, but they may require more aggressive solutions.



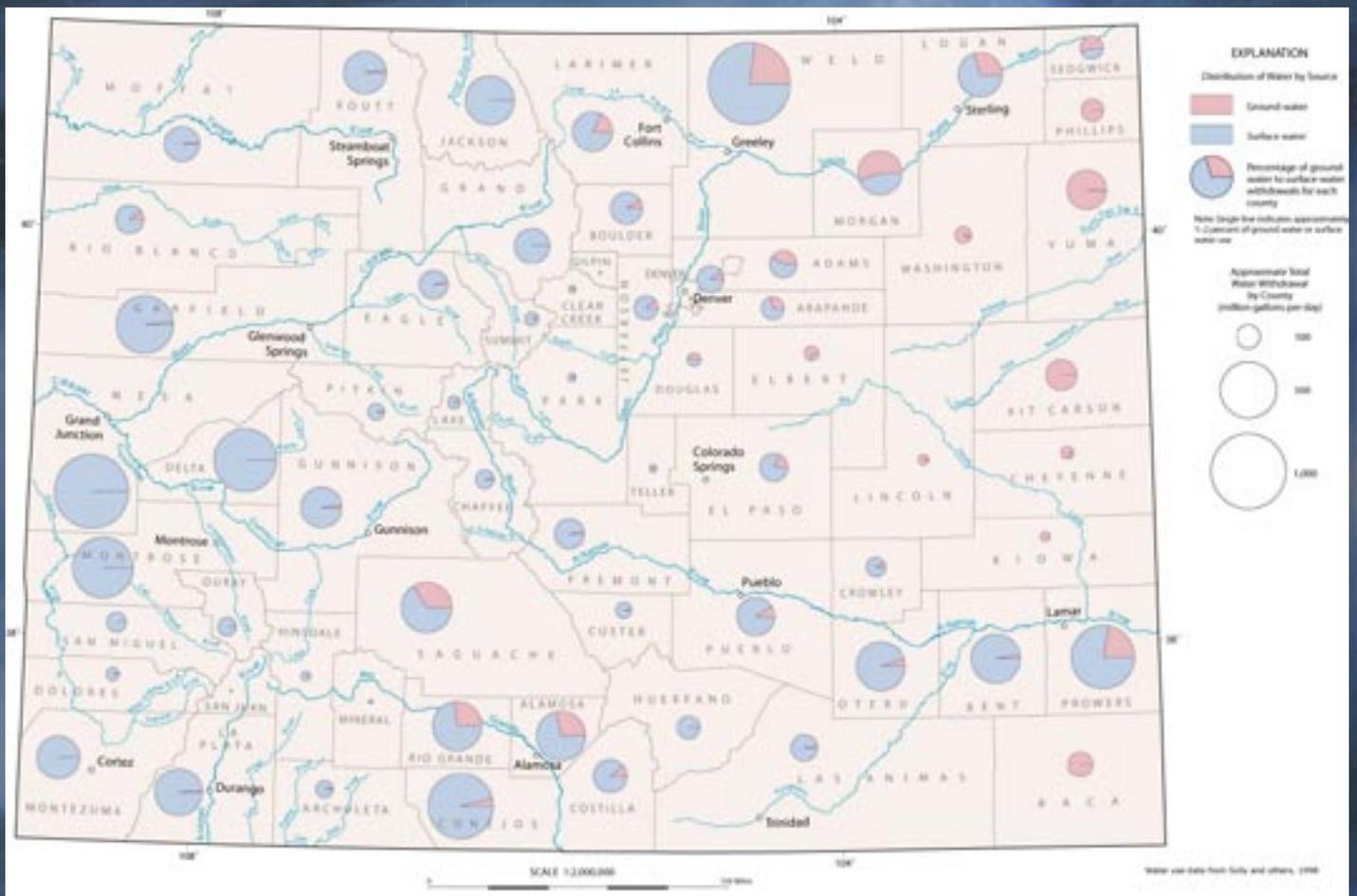
The Statewide Water Supply Initiative was a government-led project to evaluate whether Colorado's water supplies will be sufficient to meet population demands in coming decades. Some of the results of the study are presented in this graphic which shows the shortfall in different basins' abilities to meet water supply needs by 2030, based on current water development predictions. The largest gap is predicted to occur in the South Platte River Basin with a shortfall of some 22 percent or 409,700 acre-feet.

Aquifers and Rivers

No matter where you live, the water you drink or use to irrigate the yard, park, farm or local golf course comes from one of two sources: surface water or groundwater.

Colorado's watersheds and aquifers are the first receiving and storage units for atmospheric moisture. Above ground, watersheds and streams comprise Colorado's surface water network. Lakes and reservoirs are also part of this network.

Beneath the surface, groundwater often exists in shallow aquifers that flow into streams on monthly or yearly time scales. Some groundwater may filter into deeper aquifers and remain in storage for thousands of years. Groundwater aquifers provide a much-needed source of water supply, particularly if managed sustainably.



This map compares what percentage of total water supply comes from surface or groundwater in each county in Colorado, indicating the approximate amount withdrawn in millions of gallons per day. Some counties rely almost exclusively on surface water, such as Montrose, Mesa and Delta counties. By contrast, Yuma and Kit Carson counties get only a very small percentage of their water supply from surface water.



Aquifers

Aquifers are geological formations that yield usable quantities of water to a well or spring. Some people may imagine aquifers as giant underground rivers, but that is far from accurate. Most underground water is held in tiny pore spaces and cracks in or between rocks, some as small as a human hair.

Aquifers are everywhere—under the plains, mesas, and mountains, even under your own backyard. But aquifers vary significantly in the amount of water they hold, their depth underground, and their availability for use by humans.

Alluvial Aquifers

Alluvial aquifers are generally shallow sand and gravel deposits laid down over time in a river channel or floodplain. Geologists often talk about this material as alluvium, meaning unconsolidated—loose and unlayered—silt, clay, sand and gravel deposited by running water in and around rivers.

These aquifers may also receive inflows from streams swollen by high runoff or flood events. Underground, the top of the alluvial aquifer is known as the water table. Groundwater is recharged by the infiltration of rain or snowmelt into the soil and moving down to the water

Alluvial aquifers are often referred to as “tributary aquifers,” meaning that they exchange water back and forth with surface streams. However, for legal and regulatory purposes the term tributary refers only to those aquifers the pumping of which will impact flows to surface streams. Colorado has a number of important alluvial aquifer systems. There are major alluvial aquifers surrounding every large river in the state, and smaller alluvial aquifers around all the creeks and streams.

Colorado’s alluvial aquifers can supply water to cities and farms, but unless they are managed carefully, they can be over-pumped and/or polluted. If wells pump more water than is returned to an alluvial aquifer, this may mean less water is available in nearby rivers and lakes. Current use data shows that alluvial aquifers in the South Platte and Arkansas river valleys have the highest demands placed on them.

Use and management of water in the alluvium requires a closely-scrutinized water balance that accounts for inputs such as recharge from precipitation, seepage from irrigation canals and reservoirs, and inflows from other nearby aquifers. Aquifer losses include discharge to local rivers, water pumped by wells, evapotranspiration by plants, and outflow to other aquifers.

Aquifers

South Platte Alluvial Aquifer

One of the largest and most utilized alluvial aquifers in Colorado is in the lower South Platte River Basin. Wells pumping from the South Platte alluvium can yield 3,000 gallons per minute or more. The South Platte alluvium is situated about 20 feet under Denver and reaches depths of up to 200 feet some 160 miles further downstream. The USGS estimates this aquifer stores approximately 8.3 million acre-feet of water.

In 1930, only about 200 wells extracted water from this alluvium. By 1970, the number had increased to more than 3,200 wells. These are mostly used for irrigation, but a small number also provide water for local communities. Since the late 1960s,

Watershed — Surface area between high points in elevation that catches and directs runoff to the lowest point of elevation. Everyone lives in a watershed. Even if you don't live near flowing water, you still live in a watershed.

Recharge — Replenishment of groundwater in an aquifer either by natural means, such as precipitation, or artificially through specially designed recharge ponds or injection wells.

drilling of new wells in the South Platte Basin has been restricted—particularly for high-volume irrigation wells. This was due to the effects of well pumping on surface water rights. Small wells for domestic and household use, while they require a permit and review by the State Engineer's office, are easier to obtain because they are exempt by state law from the system of water rights governing use of the rivers.

Water quality in the South Platte alluvium is strongly influenced by return flows. For example, dissolved solids and nutrients concentrations increase as the water is used and reused for irrigation. Municipal wastewater discharges into the river also affect water quality.

San Luis Valley Aquifers

Bounded by major mountain ranges to the east and west, the San Luis Valley has accumulated tens of thousands of feet of basin-fill deposits. The basin-fill deposits that form the aquifer system in the San Luis Valley are hydraulically interconnected with the alluvium of the Rio Grande and its tributaries within the valley. The

major aquifers consist of a shallow unconfined alluvial aquifer and a deeper confined aquifer within the Alamosa Formation. A series of clay layers in the upper Alamosa Formation forms the confining layer between the two aquifers. The depth to this confining layer varies from about 100 feet in the norther portion of the valley to about 40 feet in the southern portion.

Farms, rural landowners and towns in the San Luis Valley use a mixture of surface water and groundwater to supply both drinking and irrigation needs, with approximately 20 percent of their water supply coming from groundwater. The primary use of groundwater is agriculture. In fact, the USGS reported in 1995 that some 98 percent of all water use in the basin's five-county area was for agricultural purposes.

Since 1996, and especially after the drought year of 2002, the unconfined aquifer in the San Luis Valley has been steadily dropping. In 2002, the aquifer lost some 439,000 acre-feet of storage, and continued drought and pumping—primarily for agricultural irrigation—has further taxed the system.

Many wells tap the alluvial aquifer surrounding the South Platte River. Well depths in the Upper South Platte basin average 36 feet deep, according to Colorado Division of Water Resources well permit records. In the Lower South Platte basin, they average some 75 feet deep. According to the 2000 Census, approximately 3 million people, or 70 percent of the state's population, live in the South Platte Basin.



Sedimentary Bedrock Aquifers

Sedimentary aquifers exist deep under ground primarily in sandstones and limestones. Multiple geological layers and aquifers exist at different depths. Examples of sedimentary aquifers in Colorado include the Denver Basin, High Plains, and Piceance Basin in northwestern Colorado, as well as others throughout the state.

These deep aquifers are often confined by low permeability rock layers and are not hydraulically connected to nearby rivers, as alluvial aquifers are. Deep aquifers still have recharge areas, but these may be many miles from the aquifer itself. Due to lower porosity and long flow paths, recharge to deep aquifers requires very long time periods—potentially thousands of years.

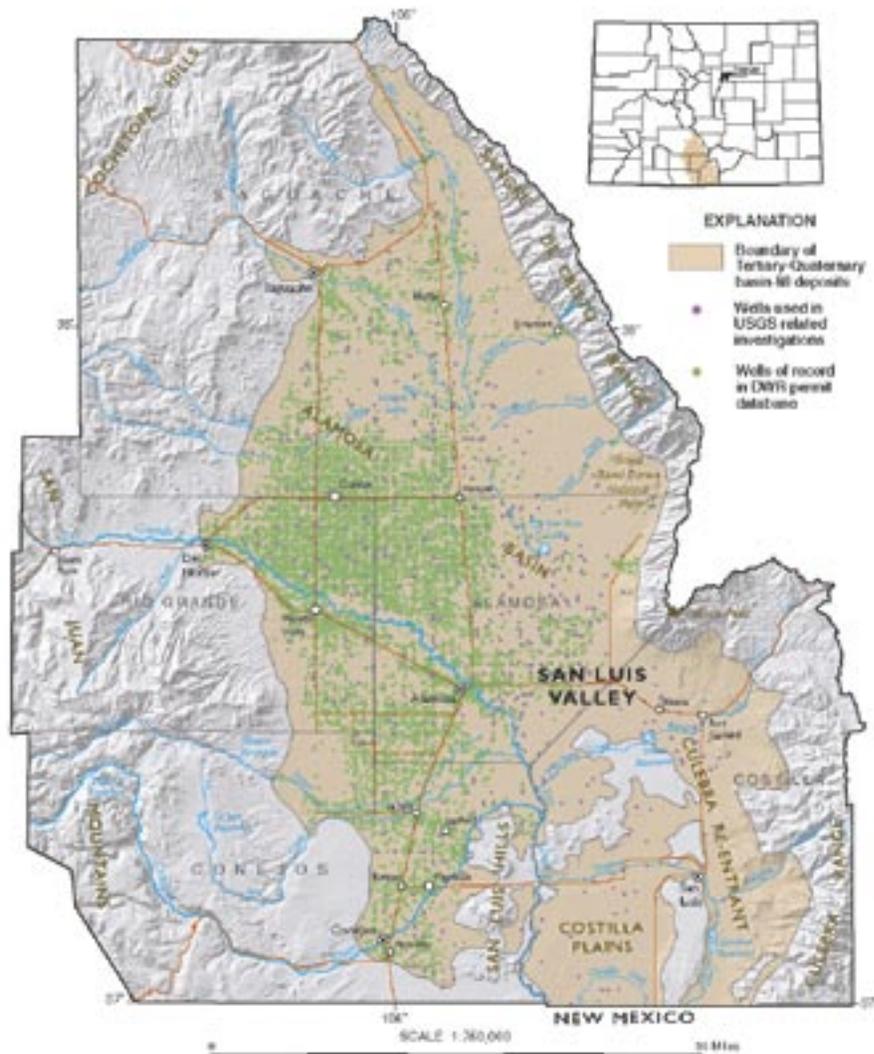
Denver Basin Aquifers

In the Front Range metro area—from Greeley almost to Colorado Springs—bedrock aquifers of the Denver Basin represent a significant groundwater resource. Many homeowners and businesses in that area are served by municipal or regional utilities that access surface water, but others such as the towns of Parker and Castle Rock, rely primarily on deep groundwater. Many individual rural/suburban landowners, particularly in Douglas County, also rely exclusively on this deep groundwater.

The Denver Basin aquifer system includes four aquifers underlying a 6,500 square mile area: the Dawson, Denver, Arapahoe and Laramie-Fox Hills. Each aquifer has different water quality, depths and water availability. Water is found in sandstone beds, often as much as a half mile below the surface, that contain ancient groundwater accumulated over thousands of years.

Currently, all new wells that pump from any Denver Basin aquifer are limited to an annual pumping rate of 1/100th of the amount of Denver Basin groundwater existing under the landowner's property.

Over the last decade, extensive development along the I-25 corridor from the Denver Tech Center in south Denver to the town of Castle Rock, has resulted in 100 to 300 feet declines in the Arapahoe aquifer, the equivalent of some 30 feet per year in localized areas. The Arapahoe aquifer is the principal water supply aquifer because of its favorable hydraulic characteristics for the



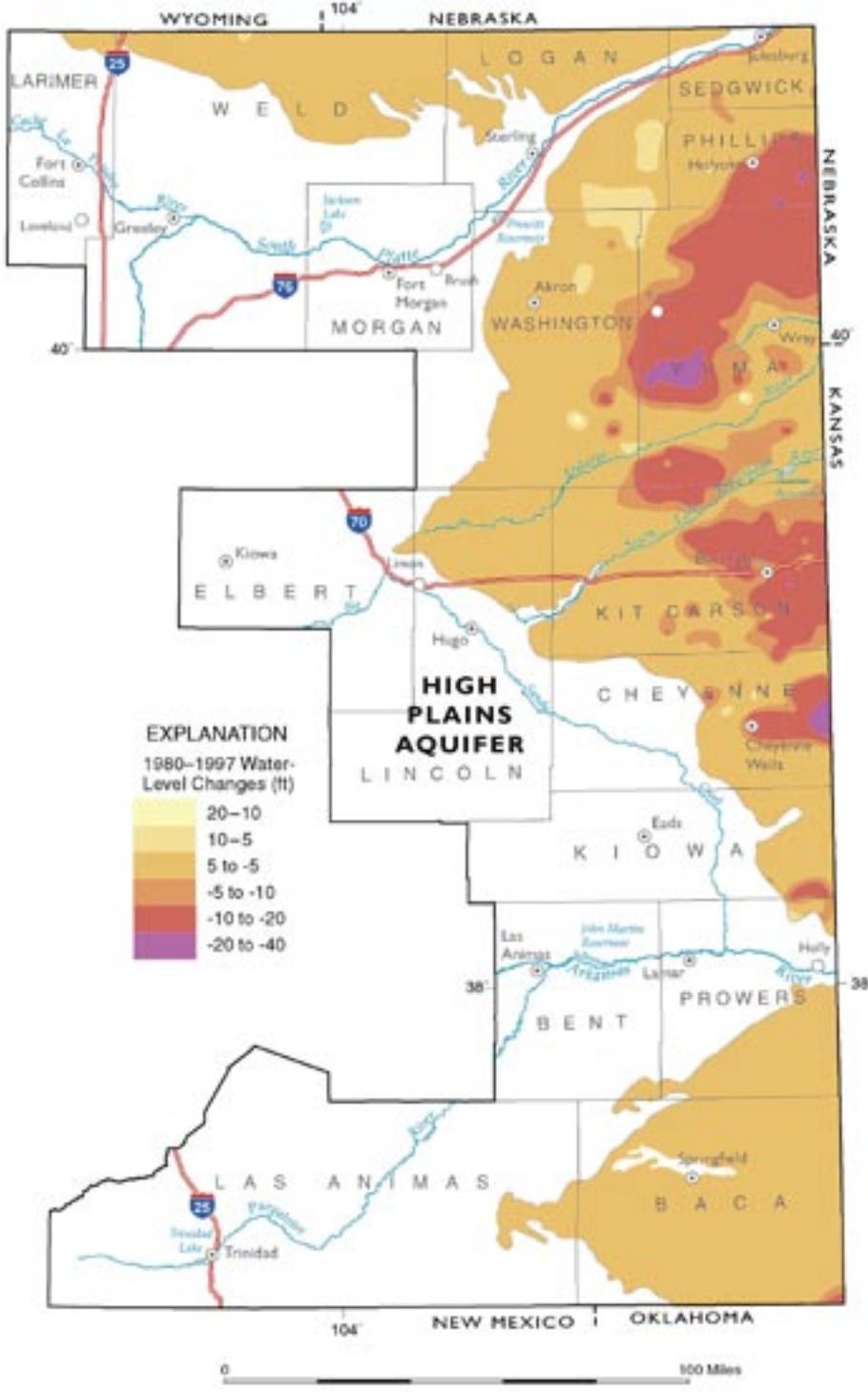
Like a great bowl, over geologic time the San Luis Valley accumulated thousands of feet of what are called basin-fill deposits. These deposits also make good aquifers. However, in recent years unsustainable pumping of groundwater—primarily for agricultural irrigation—has severely depleted these water reserves. Recent drought further exacerbated the problem. Local water managers are working to restore the aquifer by voluntary fallowing of land, and the formation of groundwater management subdistricts, among other options.

Well Pumping Can Take Water From the River

In the Arkansas and South Platte river valleys, pumping of alluvial groundwater for urban and agricultural development can take water away from the river and leave senior surface water users with less water than they had previously enjoyed. In these areas, court-approved engineering plans called “augmentation plans” are required to ensure that water extracted from groundwater wells does not unfairly take water from surface water users and senior well users. Permits for new wells are often denied unless accompanied by an augmentation plan.

In the Arkansas River Valley, a lawsuit was filed against Colorado by the State of Kansas, alleging that Colorado farmers pumped too much groundwater, depriving Kansas of its fair share of water from the Arkansas River based on the 1948 compact between Colorado and Kansas. In 1995, the U.S. Supreme Court’s Special Master ruled in favor of Kansas, and in recent years Colorado has had to curtail well pumping in the Arkansas Valley and develop augmentation plans to comply with its interstate water delivery requirements.

Aquifers



Water levels steadily decreased in the High Plains Aquifer from 1980-1997. The greatest declines were been observed in the Yuma, Cheyenne Wells and Burlington areas with declines of up to 40 feet. Generally, the High Plains aquifer is an unconfined system with recharge primarily from precipitation. Other lesser sources of recharge include infiltration from streams and irrigation water.

storage and transmission of water.

Scientists have differing estimates as to how much water the Denver Basin aquifers contain, ranging from 206 to 295 million acre-feet of recoverable reserves (Topper et al., 2003). Legislation adopted in 1985 (Senate Bill 5) allows landowners and municipalities to pump 1/100th of the underlying Denver Basin groundwater per year until exhausted, assumes Denver Basin groundwater reserves of 295 million acre-feet.

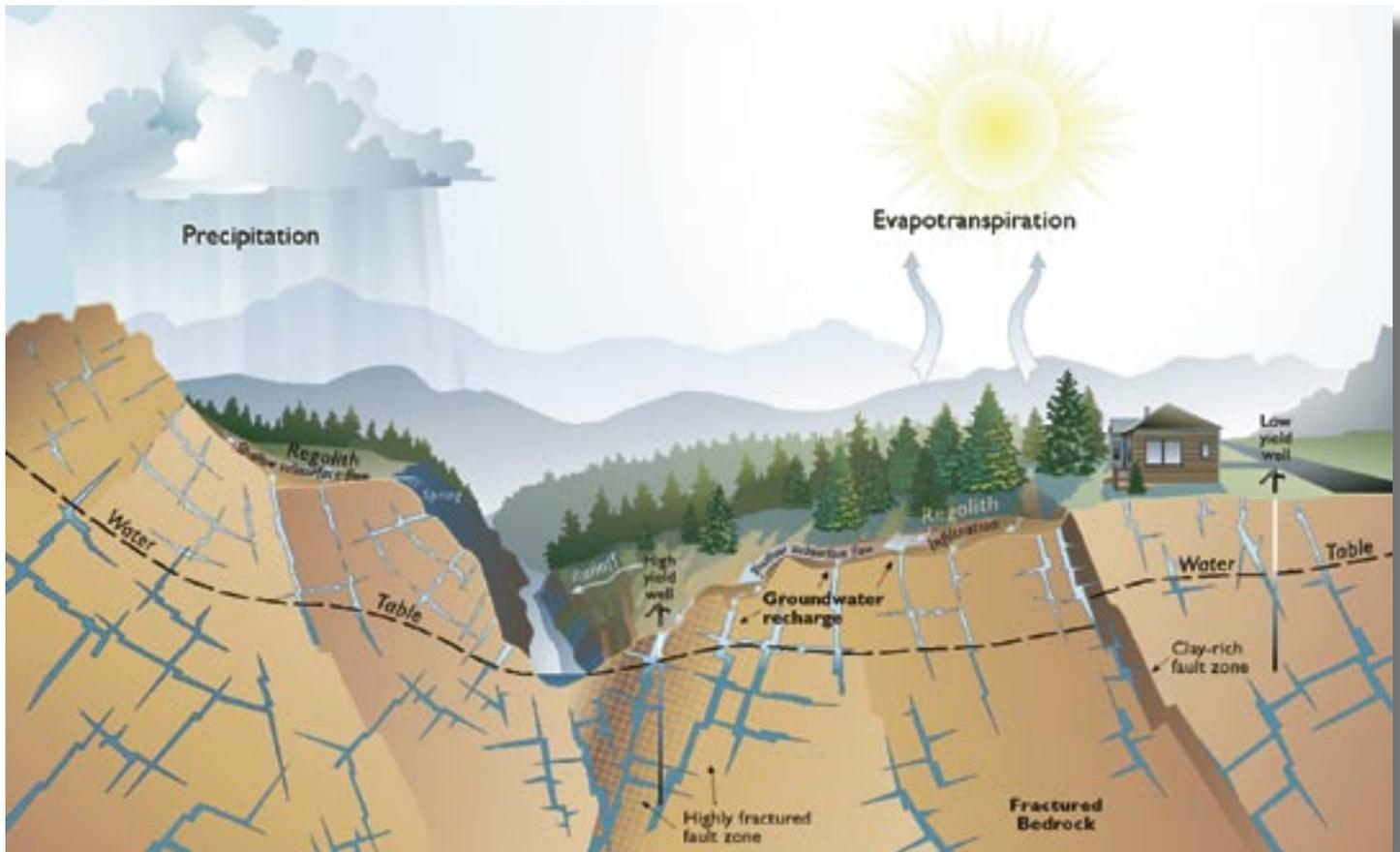
If recent studies describing reserves of only 206 million acre-feet are correct, then current and future homes and businesses could be unsustainably pumping Denver Basin aquifers. Deep wells in some areas along the western edge of the Denver Basin are already going dry, and a larger number of expensive deeper wells will have to be drilled to meet demand. To prolong the life of the non-renewable Denver aquifers, conjunctive use of surface water and collaboration among multiple water providers is needed.

High Plains Aquifer

The High Plains aquifer underlies about 174,000 square miles from South Dakota, to Texas and New Mexico. In eastern Colorado and eastern New Mexico, this is called the Ogallala formation. The Ogallala consists of unconsolidated sequences of sand, gravel, silt and clay.

The High Plains aquifer has national economic and environmental importance as it currently supplies water to about 20 percent of the nation's irrigated farm ground (Gutentag et al., 1984). Domestic use is relatively minor. However, with few streams and rivers in the region, groundwater from the High Plains aquifer is typically the only source of water for homes, farms, and businesses in this area. Looking at the map on page 14, some of the highest rates of groundwater use in Colorado come from pumping the High Plains aquifer in Yuma County, extracting some 300,000 acre-feet per year.

Aquifer recharge comes mostly from local precipitation, but this is limited due to low rates of precipitation and high rates of evaporation in the region. Generally, since the 1960s, people have been extracting more water from this aquifer than has been returned. Recently however, water districts and farmers throughout the region have been working on numerous conservation



Fractured rock aquifers, common in mountainous areas such as Jefferson County, are recharged primarily by snowmelt.

strategies to reduce the amount of water pumped, and as a result rates of water withdrawal from the Ogallala appear to have stabilized. Still, on a regional basis, the system requires careful management to avoid unsustainable use and potential water quality degradation with fertilizers, herbicides and pesticides.

Fractured Rock Aquifers

Fractured rock aquifers are common in mountainous environments. Underneath a layer of soil and loose rocky material, aquifers exist in bedrock full of cracks and fractures created by the natural folding and faulting of the rock over millions of years. These cracks—which may be as small as a human hair—can fill with water supplied by infiltrating snow and rain. But not all fractures contain water. Many may be dry or only periodically contain water; most are only sufficient to supply in-household needs. Springs arise where fractures intersect the land’s surface.

Colorado’s Legal Classifications for Deep Groundwater

For purposes of allocating groundwater to well permittees, Colorado’s deep aquifers are divided into three categories: 1) designated 2) nontributary and 3) not nontributary and nontributary Denver Basin groundwater. For an explanation of these often-confusing legal categories, see the *Citizen’s Guide to Colorado Water Law* (CFWE 2004).

Administered by the Colorado Groundwater Commission, eight “designated basins” have been mapped on Colorado’s eastern plains. These groundwater basins are the primary water supply for all uses in these areas. “Nontributary” water is the term for deep underground water. Pumping of this water is assumed not to impact rivers or creeks within 100 years.



Colorado Designated Groundwater Basins

“Not nontributary” and “nontributary” Denver Basin aquifers refer to the four major Denver Basin aquifers. A portion of the Denver bedrock aquifers are contained within the eight designated groundwater basins mentioned above.

Currently, all new wells that pump from any Denver Basin aquifer are limited to an annual pumping rate of 1/100th of the amount of Denver Basin groundwater existing under the landowner’s property.

Rivers

Colorado is the headwaters state—the majority of its rivers begin in the Rocky Mountains and flow out of the state. Only the Green River and the Little Snake River flow into the state, and then for only short stretches. Rivers are the predominant water source for Coloradans. This water is highly prized because it starts as pristine high-quality snowmelt, not yet used and reused by others. Other states are not so fortunate.

Colorado has eight major river basins: the Green River, North Platte, South Platte, Republican, Arkansas, Rio Grande, San Juan/Dolores and Colorado/Gunnison. Each basin relies on a mixture of precipitation and inflows from groundwater to fill its rivers and creeks.

Arkansas River Basin

The Arkansas River originates near Leadville and flows some 1,450 miles southeast to the Mississippi River in Arkansas. The river takes on three distinct characters during its long path through central North America. At its headwaters, the Arkansas is a steep cold mountain torrent, dropping about 4,600 feet in 120 miles. At Cañon City, it leaves the mountains and enters the

steep rock walls of Royal Gorge. Just west of the City of Pueblo, it is impounded in Pueblo Reservoir. For most of its length through the rest of Colorado and Kansas, it is a typical prairie river with wide shallow banks subject to some flooding.

Rio Grande Basin

At over 12,000 feet above sea level on the eastern slope of the San Juan Mountains, the headwaters of the Rio Grande begin to flow into the broad San Luis Valley. The Rio Grande is the third longest river in the United States and the fifth longest in North America, traveling some 1,900 miles through Colorado, New Mexico, Texas and Mexico before reaching the Gulf of Mexico.

San Juan/Dolores Basin

The San Juan River originates in the southwest part of the state, coalescing in the forested slopes and narrow valleys near Wolf Creek Pass as it starts its descent southward into New Mexico. By the time it crosses the state line, San Juan waters are already impounded by the large Navajo Reservoir. On its journey, the San Juan gains water from its major tributaries, the

Piedra, Rio Blanco and Navajo rivers.

The Dolores River gathers runoff from the snow-laden mountainsides of the Lizard Head Wilderness Area south of Telluride. Not far away, the San Miguel River collects and flows northwest, forming the northernmost watershed in the basin. The San Miguel flows all the way down to the state border before joining up with the Dolores River as it makes a giant “U” around the mountains and flows north and west into Utah.

In the southwestern corner of Colorado, the Mancos, La Plata and Animas rivers also drain out of the mountains and eventually join up with the San Juan River.

On a larger scale, the San Juan and Dolores are part of the Upper Colorado River Basin. The Dolores meets up with the Colorado River just north of Moab, and the San Juan River mixes with the Colorado River at Lake Powell in southern Utah.

South Platte Basin

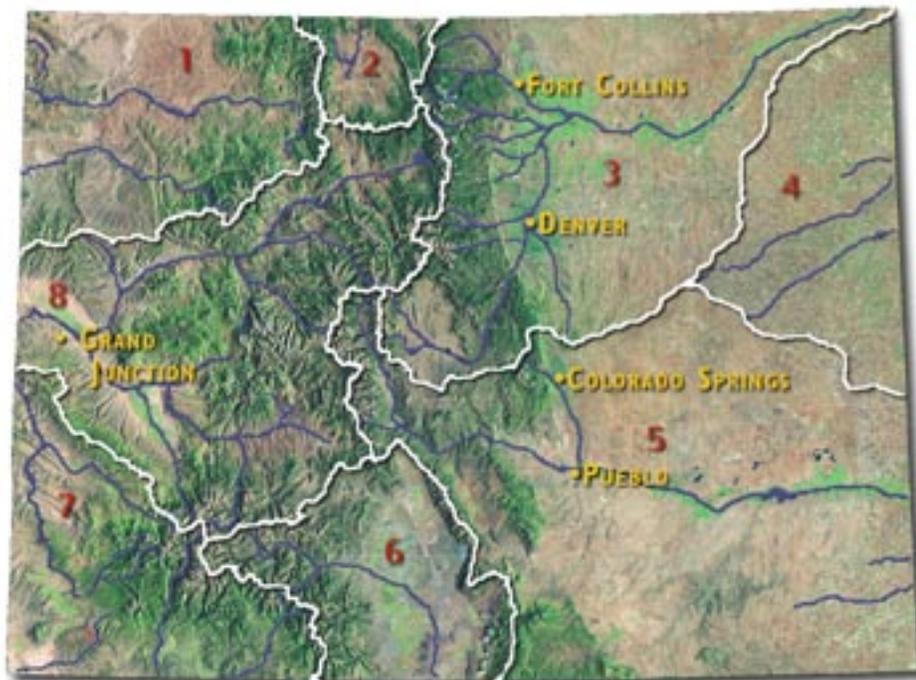
The headwaters of the South Platte River are formed by the combination of several smaller rivers—the north, middle and south forks—that drain the mountainous watersheds of Pike National Forest in Park County. The north fork of the river originates in the peaks around Mt. Evans while the south fork originates in the South Park area.

In South Park, the south fork is impounded by multiple reservoirs: Antero, Spinney Mountain, and Eleven Mile Canyon. It drops many feet in elevation before exiting the mountains and flowing into Cheesman Reservoir. The South Platte then makes its way through Denver to Greeley, where it travels northeast to its confluence with the North Platte River at North Platte, Nebraska, some 450 miles from its start.

In Colorado, many substantial tributaries feed the South Platte. North to south, these include the Cache la Poudre, Big Thompson, St. Vrain, Boulder Creek, Clear Creek, Tarryall Creek, Cherry Creek, Sand Creek, and others.

In the lower South Platte, many off-channel reservoirs store water diverted from the river so that it can be used at a later time. These include: Barr Lake, Riverside, Empire, Sterling, and Julesburg reservoirs.

The South Platte is one of Colorado’s most heavily used river systems, including recreation in the upper elevations, urban and



Colorado’s Major River Basins: 1 – Green River Basin, 2 – North Platte River Basin, 3 – South Platte River Basin, 4 – Republican River Basin, 5 – Arkansas River Basin, 6 – Rio Grande Basin, 7 – San Juan River and Dolores River Basin, 8 – Colorado and Gunnison River Basin

industrial uses in the Denver metro area, and agricultural use on the eastern plains.

Colorado and Gunnison River Basins

The Colorado River begins high in Rocky Mountain National Park near Grand Lake. The Never Summer Range within the park can receive as much as 20 feet of snow yearly. About 85 percent of the Colorado River, originates as snow or rain in Colorado's mountains (Discover a Watershed: the Colorado, 2005).

As the Colorado flows downstream through Kremmling, Glenwood Springs, Grand Junction and into Utah, the river and its tributaries, such as the Gunnison River, are increasingly used for agriculture, recreation and growing cities. In total, the Colorado River and its tributaries provide water to seven states and Mexico, serving more than 25 million people.

Yampa, White and Green River Basins

The river basins drain the northwest corner of the state. The Yampa River rises in the Flat Top Mountains and Routt National Forest. From there it flows past the towns of Steamboat Springs and Craig. At Dinosaur National Monument near the Colorado-Utah line it joins the Green River which eventually meets up with the Colorado River. Major tributaries to the Yampa include the Little Snake, Williams Fork, Elk and Bear rivers as well as Fortification and Elkhead creeks.

The White River also originates in the Flat Top Mountains. Its north fork starts at Trappers Lake; the south fork starts

just a few miles south. They meet up near Buford and flow downstream through a broad valley of hayfields and past the town of Meeker.

The landscape changes as the river flows past the Piceance Basin, the site of significant oil and gas extraction. Changing soils and geology alter the water quality in the river, increasing sediment, salt and other mineral concentrations, as well as increasing the river's temperature. The river continues past the town of Rangely, which uses the river exclusively for its drinking water.

Republican River Basin

In Colorado, the Republican River is formed by the confluence of the North Fork, Arikaree, and the South Fork of the Republican River. All three tributaries come together just east of the Colorado-Nebraska state line. Coalescing on Colorado's high, eastern plains in Yuma County, these tributaries can be intermittent or very shallow in some areas during certain times of the year. Bonny Dam, located in Colorado on the South Fork, was built in 1951 by the Bureau of Reclamation for agricultural irrigation and power. Most homes in the Republican Basin in Colorado rely on groundwater as their main source of water supply.

North Platte River Basin

Descending out of the Mt. Zirkel Wilderness Area in north central Colorado, the North Platte River meanders across the plains of North Park before

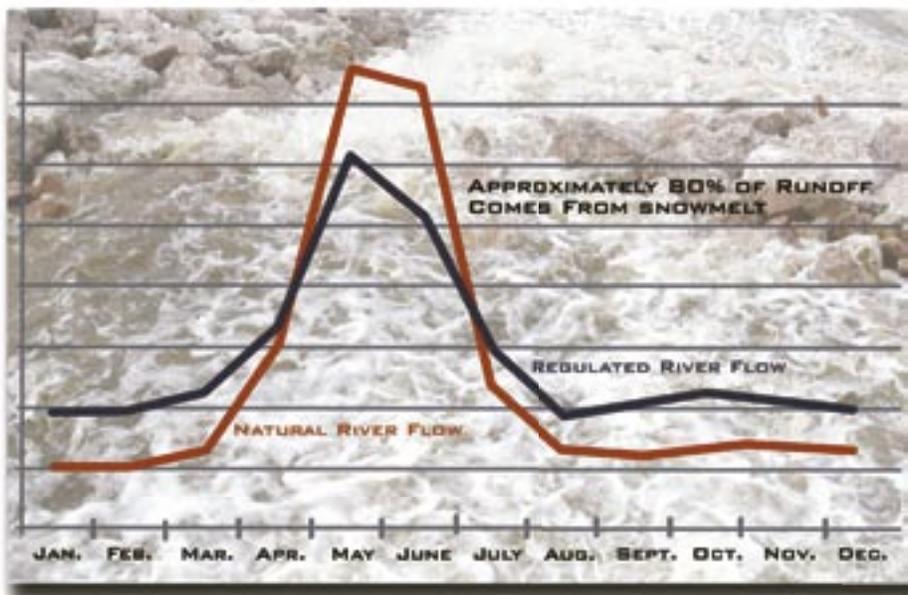
crossing into Wyoming. Approximately 680 miles in length, the river changes significantly on its journey from Colorado to Wyoming and eventually Nebraska where it joins the South Platte River in the town appropriately named North Platte. The North Platte River attracts fishermen and rafters to its cold, swift river in the headwaters region, while its braided channels in western Nebraska are prime habitat for the sandhill crane and its endangered relative, the whooping crane. The river is impounded behind Kinsley Dam in western Nebraska forming Lake McConaughy, Nebraska's largest lake. The North Platte is best known historically for providing the route for westward expansion to pioneers along the Oregon and Mormon Trails.

River Fluctuations

Colorado rivers naturally fluctuate throughout the year. Most notably, spring runoff causes streams to surge in May and June.

Over the past 100 years, dams have been constructed on all major Colorado rivers, except the Yampa River. These dams provide flood control and hydroelectric power. They help ensure water supply for use year-round. Below a dam, peak spring flows are decreased through storage, and low flows increased by releases from storage during the late summer, fall and winter months.

This is illustrated by the diagram on page 21, which shows the timing of spring runoff, and how river flows are regulated by dams.



Headwater rivers naturally fluctuate throughout the year. Most notably, the spring runoff causes streams to surge in May and June. Over the past 100 years, dams have been constructed on all major Colorado rivers (except the Yampa River). These dams provide flood control, hydroelectric power, and help ensure water is available for use year-round. Below the dam, peak spring flows are decreased and low flows increased during the late summer, fall and winter months.

Where Your Water Comes From



Where your water comes from depends on where you are in the state and how you are using the water.

In 2000, a report by the U.S. Geological Survey (USGS) calculated ratios of surface water to groundwater use for Colorado's major water use categories. River water is used much more extensively than groundwater because agriculture—the largest water consumer—relies primarily on river water.

To check what water source your town or city relies on, see the “Water Quality Annual Report” or “Consumer Confidence Report” published by each large treated

water provider. These reports are required by federal law and outline the results of the treatment plant's regular water testing, and show if treated water from the plant does or doesn't meet all standards. These reports also show where the water comes from, often illustrated by a general map of the water collection system. Reports are mailed out to all water customers, but can also easily be requested by contacting your local water provider. For water quality

information from smaller water providers, contact those agencies individually.

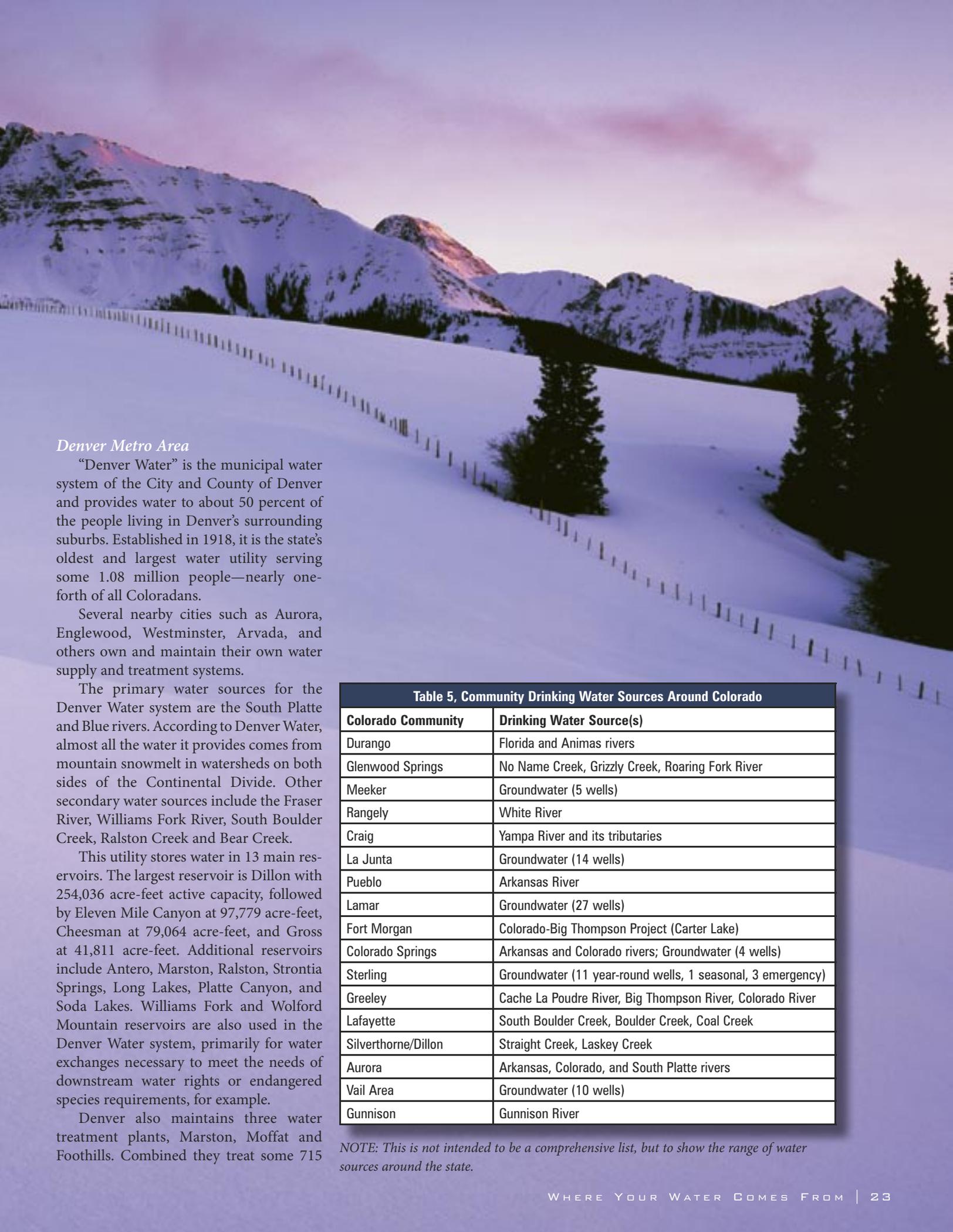
Water supplies for Colorado's diverse communities range from mountain creeks needing little water quality treatment, to towns on the eastern plains relying entirely on groundwater. Some of the larger water supply systems are described in more detail in the sections that follow.

Table 4, Water Sources in Colorado, 2000

	Source
Irrigation	81% rivers 19% aquifers
Public supply	94% rivers, 6% aquifers
Self-served domestic (wells, cisterns)	100% aquifers
Industrial	80% rivers 20% aquifers
Hydroelectric	100% rivers

NOTE: Although irrigation also takes place in homes and cities, the USGS classifies “irrigation” as commercial irrigation for agricultural purposes. In 2000, irrigation water withdrawals in Colorado were 2,420,000 acre-feet from wells and 10,400,000 acre-feet from rivers and creeks. Of this, only 37 percent was actually consumed on average.

Source: Hutson, et. al., 2004.



Denver Metro Area

“Denver Water” is the municipal water system of the City and County of Denver and provides water to about 50 percent of the people living in Denver’s surrounding suburbs. Established in 1918, it is the state’s oldest and largest water utility serving some 1.08 million people—nearly one-fourth of all Coloradans.

Several nearby cities such as Aurora, Englewood, Westminster, Arvada, and others own and maintain their own water supply and treatment systems.

The primary water sources for the Denver Water system are the South Platte and Blue rivers. According to Denver Water, almost all the water it provides comes from mountain snowmelt in watersheds on both sides of the Continental Divide. Other secondary water sources include the Fraser River, Williams Fork River, South Boulder Creek, Ralston Creek and Bear Creek.

This utility stores water in 13 main reservoirs. The largest reservoir is Dillon with 254,036 acre-feet active capacity, followed by Eleven Mile Canyon at 97,779 acre-feet, Cheesman at 79,064 acre-feet, and Gross at 41,811 acre-feet. Additional reservoirs include Antero, Marston, Ralston, Strontia Springs, Long Lakes, Platte Canyon, and Soda Lakes. Williams Fork and Wolford Mountain reservoirs are also used in the Denver Water system, primarily for water exchanges necessary to meet the needs of downstream water rights or endangered species requirements, for example.

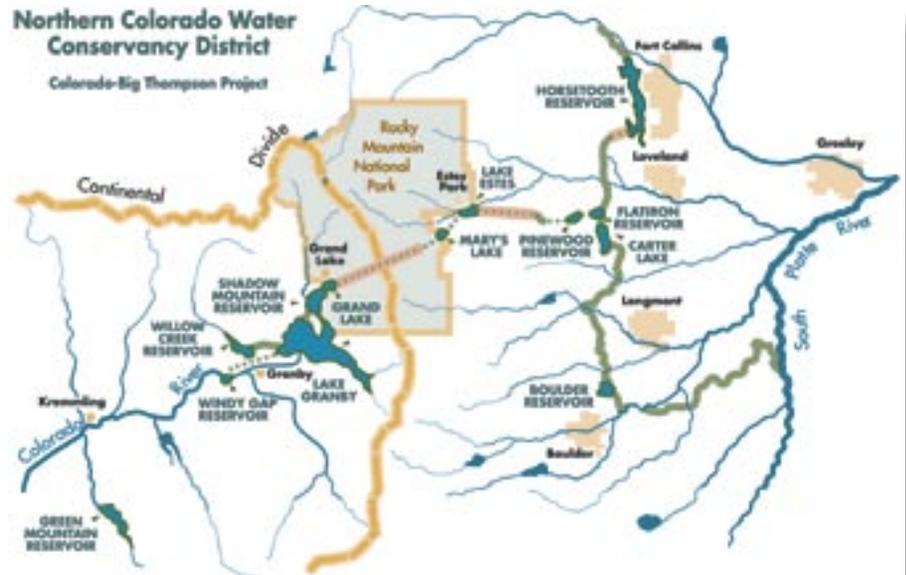
Denver also maintains three water treatment plants, Marston, Moffat and Foothills. Combined they treat some 715

Table 5, Community Drinking Water Sources Around Colorado

Colorado Community	Drinking Water Source(s)
Durango	Florida and Animas rivers
Glenwood Springs	No Name Creek, Grizzly Creek, Roaring Fork River
Meeker	Groundwater (5 wells)
Rangely	White River
Craig	Yampa River and its tributaries
La Junta	Groundwater (14 wells)
Pueblo	Arkansas River
Lamar	Groundwater (27 wells)
Fort Morgan	Colorado-Big Thompson Project (Carter Lake)
Colorado Springs	Arkansas and Colorado rivers; Groundwater (4 wells)
Sterling	Groundwater (11 year-round wells, 1 seasonal, 3 emergency)
Greeley	Cache La Poudre River, Big Thompson River, Colorado River
Lafayette	South Boulder Creek, Boulder Creek, Coal Creek
Silverthorne/Dillon	Straight Creek, Laskey Creek
Aurora	Arkansas, Colorado, and South Platte rivers
Vail Area	Groundwater (10 wells)
Gunnison	Gunnison River

NOTE: This is not intended to be a comprehensive list, but to show the range of water sources around the state.

Where Your Water Comes From



The Colorado-Big Thompson Project is the largest transmountain water diversion project in Colorado. CBT water supplements the water supplies of 30 cities and towns, and also helps irrigate approximately 693,000 acres of north-east Colorado farmland.

million gallons of water per day. Water is treated using a standard water treatment process which includes coagulation/sedimentation, filtration, and disinfection (see Water Treatment, p. 32).

South Metro Area

Highway E-470 which wraps around the southern edge of the Denver metro area, acts somewhat like an imaginary line separating surface water and groundwater users. Some communities like Highlands Ranch are in a transition zone, using surface water when available and groundwater in times of drought.

North of this line, in the Front Range foothills, residents rely primarily on surface water replenished each year by snow. To the south, in Douglas County and surrounding areas, homeowners rely on deep groundwater so far under the earth's surface that it

cannot be replenished from year-to-year.

To supply adequate water to the south metro area, some utilities are forced to drill deep, large-diameter wells into the Denver Basin aquifers. The most productive source of water is the Arapahoe aquifer, with some wells that can pump more than 500 gallons of water per minute. Many subdivisions have been built using this non-renewable groundwater as their sole source of water supply.

To learn more about the Denver Basin aquifers and how they function, see Sedimentary Aquifers, p.16.

North Metro Area

Fort Collins, Greeley and Loveland receive the majority of their water supplies from the Big Thompson and Cache la Poudre rivers. In addition, they also receive supplemental water supplies from

the Northern Colorado Water Conservancy District (NCWCD).

The NCWCD manages water diverted from the Colorado River and under the Continental Divide in a system known as the Colorado-Big Thompson (CBT) project. The CBT imports water from the Colorado River, through the Adams tunnel, and delivers about 220,000 acre-feet of water annually to northern Colorado.

The Colorado-Big Thompson Project is the largest transmountain water diversion project in Colorado. The CBT project features 12 reservoirs, 35 miles of tunnels, 95 miles of canals and 700 miles of transmission lines. Facilities located west of the Continental Divide include Willow Creek and Shadow Mountain reservoirs, Grand Lake and Lake Granby.

In addition, CBT water also generates electricity as flows via gravity dropping almost half a mile through five power plants on its way to the Front Range, where Carter Lake, Horsetooth Reservoir and Boulder Reservoir store its water.

Currently, the CBT Project provides supplemental water to 30 cities and towns in northern Colorado. These include: Fort Collins, Loveland, Greeley, Estes Park, Longmont, and others. CBT water also irrigates more than 600,000 acres of farmland. About two-thirds of CBT water is now owned by cities. When the project started delivering water in 1956, farmers owned two-thirds of the water. Water is transferred from willing sellers to willing buyers through an active water market.

Your Water is Reused Many Times

Reuse is an important component of where your water comes from and where it has been.

In an urban setting, unless a municipality relies exclusively on groundwater or its water supply comes directly from a river's headwaters—you are drinking recycled water. This means that at least some of the river water that enters your city's water treatment plant has already been used by other consumers and been discharged back to the river through their upstream wastewater treatment plant or from irrigation return flows.

Although many people do not like the idea of drinking treated wastewater, many cities in Colorado rely on water recycled in this fashion.

In a rural setting, reuse of water for irrigation is a common practice. Basin-wide water use relies on a continuous cycle of withdrawing water from rivers or aquifers, applying that water to farm fields, and returning what is not used to the river system through groundwater inflows or irrigation runoff.

Water Storage, Treatment and Conveyance Systems

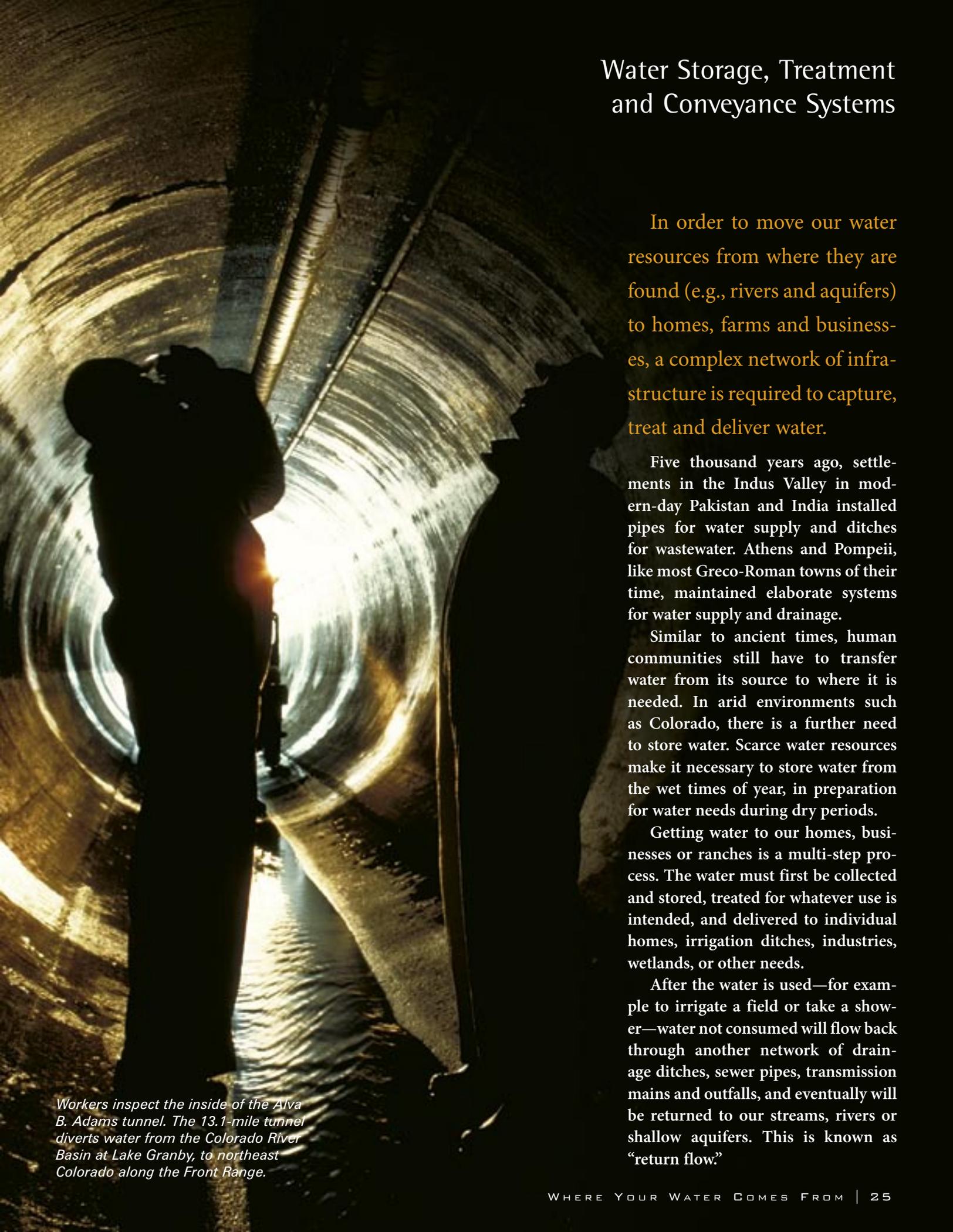
In order to move our water resources from where they are found (e.g., rivers and aquifers) to homes, farms and businesses, a complex network of infrastructure is required to capture, treat and deliver water.

Five thousand years ago, settlements in the Indus Valley in modern-day Pakistan and India installed pipes for water supply and ditches for wastewater. Athens and Pompeii, like most Greco-Roman towns of their time, maintained elaborate systems for water supply and drainage.

Similar to ancient times, human communities still have to transfer water from its source to where it is needed. In arid environments such as Colorado, there is a further need to store water. Scarce water resources make it necessary to store water from the wet times of year, in preparation for water needs during dry periods.

Getting water to our homes, businesses or ranches is a multi-step process. The water must first be collected and stored, treated for whatever use is intended, and delivered to individual homes, irrigation ditches, industries, wetlands, or other needs.

After the water is used—for example to irrigate a field or take a shower—water not consumed will flow back through another network of drainage ditches, sewer pipes, transmission mains and outfalls, and eventually will be returned to our streams, rivers or shallow aquifers. This is known as “return flow.”



Workers inspect the inside of the Alva B. Adams tunnel. The 13.1-mile tunnel diverts water from the Colorado River Basin at Lake Granby, to northeast Colorado along the Front Range.

Water Storage, Treatment and Conveyance Systems

In a municipal system, return flows may go back into the local creek through the city’s wastewater treatment plant. On a farm or ranch, irrigation water not consumed by a growing crop or thirsty livestock will flow through tailwater ditches or shallow aquifers to return to the river for the next user downstream.

Generally, in the case of rural residences or businesses with septic and leach field systems, leach field wastewater percolates into shallow groundwater aquifers and may become available again as either surface water or groundwater.

In addition, Colorado has recently started to work on ways to stretch its water supplies further by capturing water from municipal wastewater treatment plants, treating it, and then reusing it for non-drinking water purposes such as irrigation of golf courses and parks.

Water Storage

Colorado is blessed with high snowy mountains that provide a natural source of water storage—until spring. Left alone, the snowpack will melt and run off suddenly. Providing for humans use requires river management, principally through reservoirs. Arid conditions during most of the year produce little water in rivers during the summer and winter. Historically, many of the rivers in Colorado such as the South Platte and Arkansas, naturally dried up for extended stretches during the late summer and early autumn months.

Reservoirs are important to water sup-

ply systems because they can regulate river flows. A reservoir can both reduce a flood flow and increase low flows during extended dry conditions. Water stored in reservoirs can be used for multiple purposes: municipal and industrial water supply, irrigation, interstate water delivery obligations, fish and wildlife habitat, recreation, flood control, and hydroelectric power.

Early water developers built diversions and reservoirs to capture snow runoff primarily for use in agricultural irrigation systems. A vast network of small reservoirs in eastern Colorado resulted from these historical endeavors.

In the 20th century, growing population and industrial needs led to the construction of trans-mountain diversions and larger reservoirs. The period from 1900 through the 1960’s is often called the era of “big dams.”

But water storage comes with an environmental cost—it changes the natural flow of streams and alters water quality, wildlife habitat and natural stream dynamics.

Transbasin diversions can take water away from one community to give it to another—leaving the donor community with little compensation for its lost resource.

To reduce environmental impacts, water can be stored in aquifers, water storage projects can be re-operated to provide water for environmental and recreational uses, as well as consumptive uses. Construction of smaller off-channel reservoirs or enlargement of existing reservoirs can be less environmentally damaging.

Currently, Colorado has 1,879 reservoirs with a capacity of more than 100 acre-feet or a surface area greater than 20 acres. These reservoirs can hold an average 6.42 million acre-feet of active storage in any given year.

Ditches, Canals and Pipelines

by Karen Rademacher, DARCA

To get water out of its natural river channel and direct it through canals or ditches for agriculture, cities or industry, diversion structures commonly called headgates are needed.

Canals and ditches are open channels that convey the diverted water using the force of gravity as their major source of energy. They often follow the topography

Table 6, The 10 largest reservoirs (by active capacity) in Colorado include:

Name	Acre Feet	Source
Blue Mesa	748,400	Gunnison River
Granby	465,568	North Fork of Colorado River
John Martin	333,912	Arkansas River
Dillon	249,525	Blue River
McPhee	229,000	Dolores River
Pueblo	228,828	Arkansas River
Horseshoeth	139,135	Colorado River (trans-basin diversion)
Vallecito	126,300	Los Pinos River
Turquoise	120,490	Homestake Creek, Fryingpan River (trans-basin diversion)
Taylor Park	106,230	Taylor River

NOTE: Active capacity refers to the amount of water available for seasonal or cyclic storage.

of the land and may wind for many miles from the point of diversion to the point of delivery. At a certain point along the canal, headgates release water into smaller ditches called laterals or into pipelines. Like roads, they require land for their rights-of-way. Most canals have some sort of dam or inlet in the main waterway to help push water into the canal.

The USGS estimates some 81 percent of farmers and ranchers in Colorado rely on surface water diverted into canals and ditches. The remaining 19 percent pump groundwater.

Urban water users also rely on canals. The USGS estimates that 94 percent of Colorado's drinking water comes from a river. Canals and pipelines are absolutely critical to urban water collection and distribution systems. They move river water into storage facilities and into treatment plants.

Agricultural Ditches

Built and historically used by agriculture, irrigation systems make Colorado and the arid West farmable. Before significant improvements in well technology in the 1950s, farmers and ranchers relied almost exclusively on surface water and irrigation ditches.

Canals and ditches are generally earthen. In some areas they may be lined with concrete or more rarely, modernized into pressurized pipelines. Unlined systems lose water to seepage. Seepage water usually recharges the aquifer and returns to the river. Vegetation along ditches and evaporation from open canals also consumes water.

Most agricultural ditches in Colorado are owned by the water users themselves. Smaller ditches are often owned in partnership by a handful of users. Smaller systems are usually loosely organized; maintenance and oversight is often on a volunteer basis. Medium and large canals are often owned by shareholders of a mutual ditch company led by a board of directors and managed by paid staff. Mutual ditch companies are private, non-profit organizations formed to distribute water to their member-owners. Owners generally pay a fee to the ditch company, based on the share of water that they own, to pay for maintenance, upkeep and staff.

In most cases, ditch operations have changed very little since the ditches were

Bona Fide Ditch

by Will Hutchins, Manager

The Bona Fide Ditch was started in 1883 after the Ute Indian Treaty was signed opening the Western Slope for settlement. Farmers and agricultural developers seeing the need for food and feed crops to support the burgeoning mining community in the San Juan Mountains built the 7-mile ditch, irrigating approximately 2,000 acres, to meet that demand.

The system is located in the Gunnison Valley east of the city of Delta, in Delta County. The principal crops produced are corn, alfalfa, pinto beans, white winter wheat and sometimes onions.

Operation of the Bona Fide Ditch is a model of crude simplicity. Headquarters are split between the home offices of the president, secretary-treasurer and ditch rider. The secretary-treasurer keeps the books in order, including stock certificates, does the minutes at meetings and other similar work. The single ditch rider sees to it that the canal is in good order and maintains the water levels in the canal. The 43 shareholders/users turn their own water in and out as their needs require. The ditch company owns no equipment except for file cabinets in the secretary-treasurer's house. All ditch maintenance and improvement work is done by contractors.

The ditch company has an annual meeting the first week in February to elect officers, set assessments and air grievances with the ditch management, neighbors and affairs in general.

dug by horse or ox teams more than a century ago. Most ditches divert water directly from a river, creek or reservoir, or may branch off from a larger canal. Most have some sort of dam or inlet in the main waterway to help push water into the ditch.

Owners appoint or hire a "ditchrider" to supervise the allocation of water from the ditch. The term ditchrider likely originates with the early practice of managing ditches by actually riding on horseback up and down the banks of the ditch throughout the irrigation season. Today's ditchriders patrol ditches behind the wheel of a pickup truck or all-terrain vehicle.

Ditchriders allocate water to farmers and ranchers along the ditch based on their proportionate ownership in the ditch. The ditchrider will release water from the main ditch by means of a headgate—typically a metal gate damming the ditch which is raised and lowered depending on the amount of water to be delivered. Various types of calibrated weirs or division boxes are used to measure water flow and ensure that each owner gets his fair share. During times of shortage, the ditchrider may be forced to rotate the limited supply among the water users. Disputes among water users are common. The folklore image of a ditchrider armed with both a shotgun and a shovel, is not too far from reality.

Urban Ditches

As Colorado's urban areas have expanded onto nearby farm ground, agricultural ditch water has frequently been incorporated into municipal water supply. Often a municipality will buy agricultural water rights and officially change their use by means of a water court process from irrigation to municipal use. Water that formerly irrigated farm fields is diverted to the municipal water treatment plant and is treated, pressurized, and delivered to city residents.

In some cases, the city will elect to leave the ditch in place and use it to deliver raw (untreated) water to parks, greenbelts and golf courses. This strategy works especially well when portions of the ditch are still in agricultural use. The municipality then takes its place as a co-owner of the ditch, and continues to contribute to the upkeep and management of the ditch in the same way that the former agricultural owners did.

Virtually every city in Colorado owns agricultural ditch water rights to some degree. Municipal water managers decide on a case-by-case basis whether to keep particular water rights in the ditch or to divert the water for treatment according to the needs of their customers.

New Trends

A new trend in the western United States involves the use of agricultural ditch systems to deliver raw water, not just to

History of Agricultural Irrigation

Based on recorded documentary evidence, diaries and letters written by early explorers, historians have traced the first recorded attempts at irrigation in present-day Colorado to the summer of 1787. At that time the Governor of the Spanish Province of New Mexico entered into a treaty with the Jupe tribe of Comanche Indians. They were to partner with a team of 20 Spanish farmers and start a colony known as “San Carlos de Jupe” about eight miles east of the current city of Pueblo. Jointly they constructed houses and built a ditch diverting water from the Arkansas River. But changing political appointments and Indian unrest would lead to the abandonment of the settlement several years later.

In subsequent decades there were other temporary attempts to take water from the streams and use it for farming. But not until Spanish settlers founded the town of San Luis in 1852 did a system of continuous irrigation become established (see *Citizen’s Guide to Colorado’s Water Heritage*, CFWE 2004). In April of that year, using pick axes, oxen and shovels, local settlers constructed the San Luis Peoples’ Ditch to divert water from the modest Culebra River. That ditch is still in operation to this day.

When Colorado became a state in 1876, practically everyone in the state was involved in one way or another with either agriculture or mining. Half of all Americans lived on farms and farmers were 53 percent of the labor force. By the year 2000, farm jobs had dropped to less than 3 percent of all jobs and only about 1 percent of Americans lived on farms. In spite of these changes in agriculture, large quantities of water are still required to produce food and fiber for our growing population. It is just applied by a much smaller workforce.



Teams of horses were the only heavy equipment available to help excavate early canals, ditches and reservoirs across the West. Water delivery pipelines (above) originally were made of wood, and had to be replaced often.

Irrigation ditches made arid Colorado farmable (right) as seen in this photo taken near Greeley. Today, many ditches look much as they did 100 years ago; others have been piped or converted to urban use.



large municipal parks and greenbelts, but to individual residential lots. These secondary water systems may operate side-by-side with the treated water pipeline network. In this way, traditionally agricultural ditch companies can revitalize their systems by “re-packaging” their product to conform to the needs of their new suburban customers.

Conversion of agricultural ditch systems to municipal use is not without controversy. Many mourn the loss of traditional farming practices and the irrigation network that supported them.

By the same token, many agricultural producers are counting on cashing in their water rights assets when their land is targeted for development. The water court process ensures that other water rights are not detrimentally impacted by this conversion; mitigation includes re-seeding of dried up land and in-lieu payment of taxes when agricultural water transfers are made from one county to another.

Major Ditch Systems

There are hundreds of ditch companies throughout the state. All are integral to Colorado’s early formation and history (see *Citizen’s Guide to Colorado’s Water Heritage*, CFWE 2004). Each has its own colorful history and cast of characters—unscrupulous land agents, crooked financiers, and visionary engineers and contractors.

The names of the older and larger systems around the state give clues to their location: New Cache la Poudre Irrigation Company, Fort Lyon Canal Company, Grand Valley Irrigation Company, and Rio Grande Water Users Association.

Some of these early systems were constructed and financed by the original landowners and homesteaders. Others were projects promoted by entrepreneurial land developers. A later phase of ditch development involved the Bureau of Reclamation and other state-supported financing programs.

Wells

Groundwater is an important source of water for both drinking water and irrigation. Not only do irrigated farms and ranches rely on it, around half of all Americans rely on groundwater for use in their homes.

Coloradans use groundwater for city water supplies, industry, irrigation, rural

domestic use and livestock watering. In fact, the State Engineer estimates that about 2 million acre-feet of groundwater is pumped and used annually in Colorado. That is equivalent to the natural flow of the South Platte and North Platte rivers combined and amounts to around 20 percent of all water used in Colorado. River flows remain the dominant water source.

When Anglo and Hispanic settlers first arrived in Colorado, irrigation was entirely dependent on diversions of water from local streams. Well pumping technology was insufficient to enable irrigation of large tracts of land. But by the time of the Gold Rush in 1859, steam-powered drills were available to drill deeper and larger wells. Knowledge of well drilling was also transferred from the oil industry. Yet it was not until the 1950s with the advent of greatly improved well pump designs, drilling equipment, diesel motors and expanded electrical service that the number of groundwater wells surged.

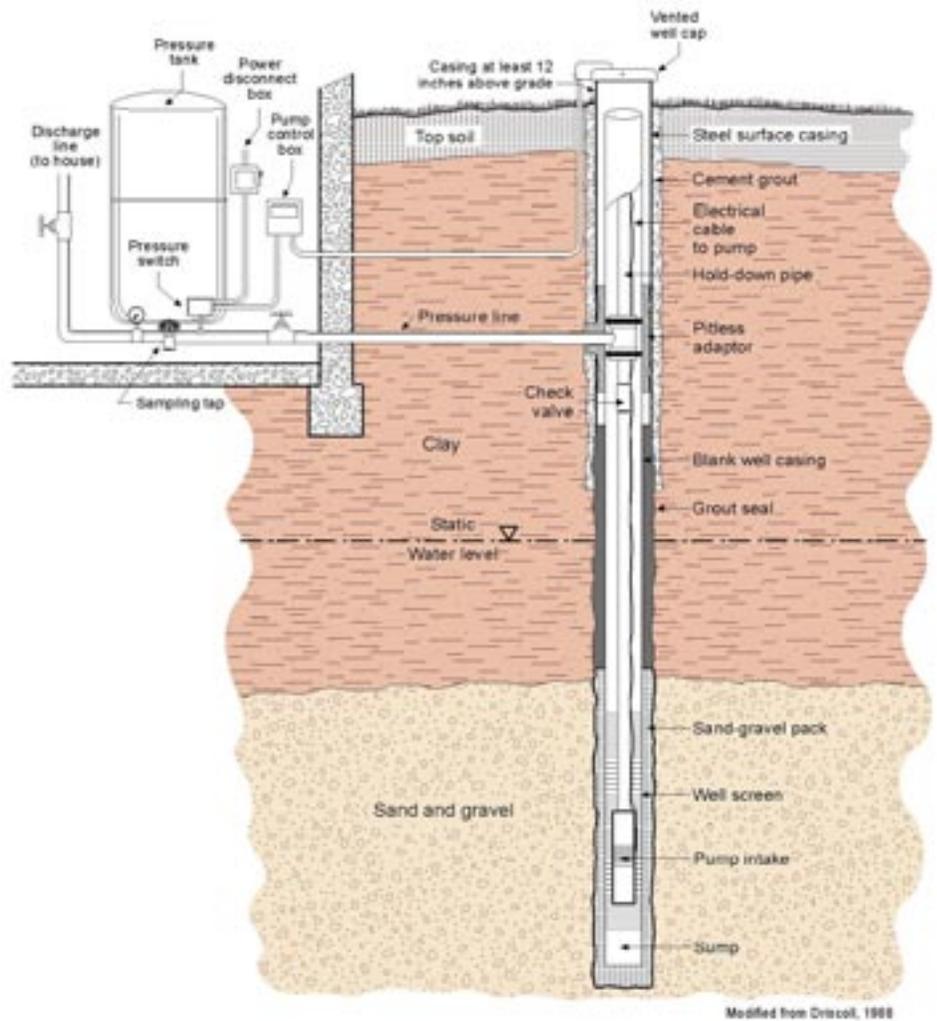
One reason so many wells are used in Colorado and around the world is ease of access to water. Wells can often be drilled in locations that are convenient to homes and farms, where surface water might be located far away.

As of 2005, there were more than 358,000 wells permitted and constructed in Colorado. Almost 300,000 of these wells are small-capacity (15 gallons per minute or less) providing drinking water to individual homes, livestock, and small commercial businesses in rural areas.

The remainder are typically large wells that serve municipal water supplies or for crop irrigation. This large number of wells requires careful oversight to ensure that water users get the water they require and without unsustainably drawing down the aquifer, or taking water away from streams replenished by alluvial aquifers (see Alluvial Aquifers, p.15).

Well Technology

The normal way to extract groundwater from an aquifer is through a water well. Developing a well involves finding the water, drilling, installing the well's components, and operating the well. Features of a typical well are shown on the accompanying diagram.



This diagram shows typical domestic well construction and an in-house water supply system. The well screen is where water enters the well. Wells are cased and grouted to prevent the hole from collapsing, and to prevent cross-contamination of the well with other aquifers and overlying sources of pollution.

New Cache la Poudre Irrigation Company

The New Cache la Poudre Irrigation Company is an example of a large ditch system operating as a mutual ditch company. It is located in Weld County north of Greeley, and was founded by the early settlers of the 1870 Union Colony. The canal diverts water from the Cache la Poudre River and delivers water to approximately 40,000 acres.

Typical crops under irrigation include corn, sugar beets, wheat, brewing barley, alfalfa, pinto beans, carrots, onions, cabbage, and other small vegetables. The company's headquarters are located in Lucerne, where the superintendent and secretary have their offices. Additionally, the company employs four ditch riders to deliver water to its approximately 250 shareholders and to keep some 100 miles of canal in good condition.

The company's board of directors meets monthly to supervise the canal operations, and every year in January the shareholders meet for an annual meeting to elect directors and to agree on assessment to be paid by each shareholder to cover the anticipated operating expenses for the coming year.

Municipal Water Systems

Most Coloradans have their water delivered by a water utility. This organization may either be a municipal or regional system, special district or private water company. Water utilities operate three distinct types of infrastructure: collection and storage, treatment and distribution systems.

Collection

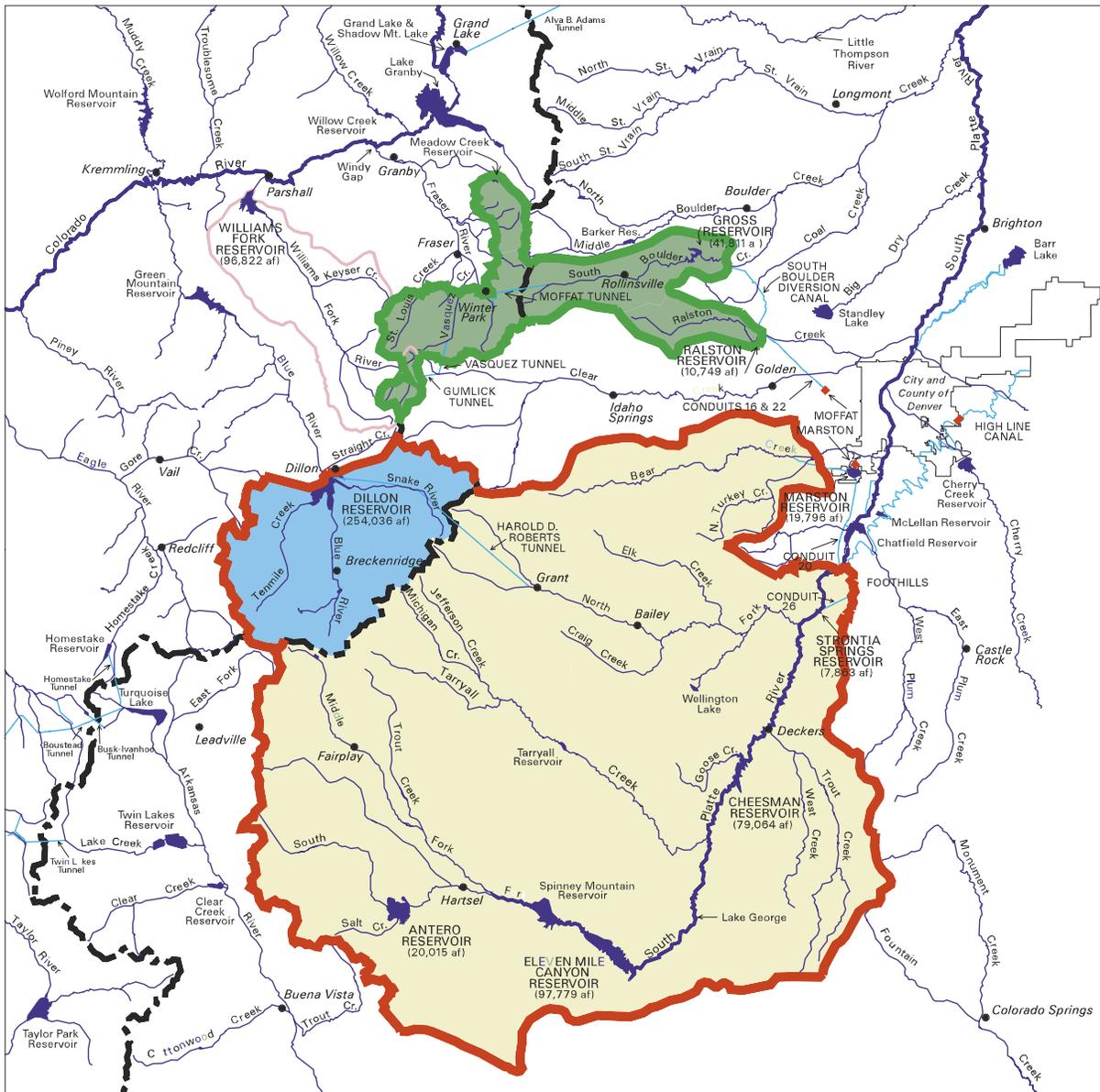
All municipal systems must move water from where it is available to where it is needed. Depending on the sources available, municipal water providers have a system of wells, canals, reservoirs, water towers and pipelines to collect and deliver the water. In some cases, this means transferring water from one river basin to another with tunnels and diversions.

Some communities have also started using aquifers as short-term water reservoirs, injecting water underground in during wet years, and pumping that water back in dry years.

Wells can be used as mechanisms to store water in an aquifer. In a practice known as “conjunctive use” or “aquifer storage and recovery” during wet years, river water is injected into local aquifers. Then during dry periods, when surface supplies are short, it can be extracted for use. This method has also been touted as an alternative to the construction of additional surface reservoirs, where environmental impacts and water loss through evaporation can be significant.



Denver Water's Collection System



LEGEND



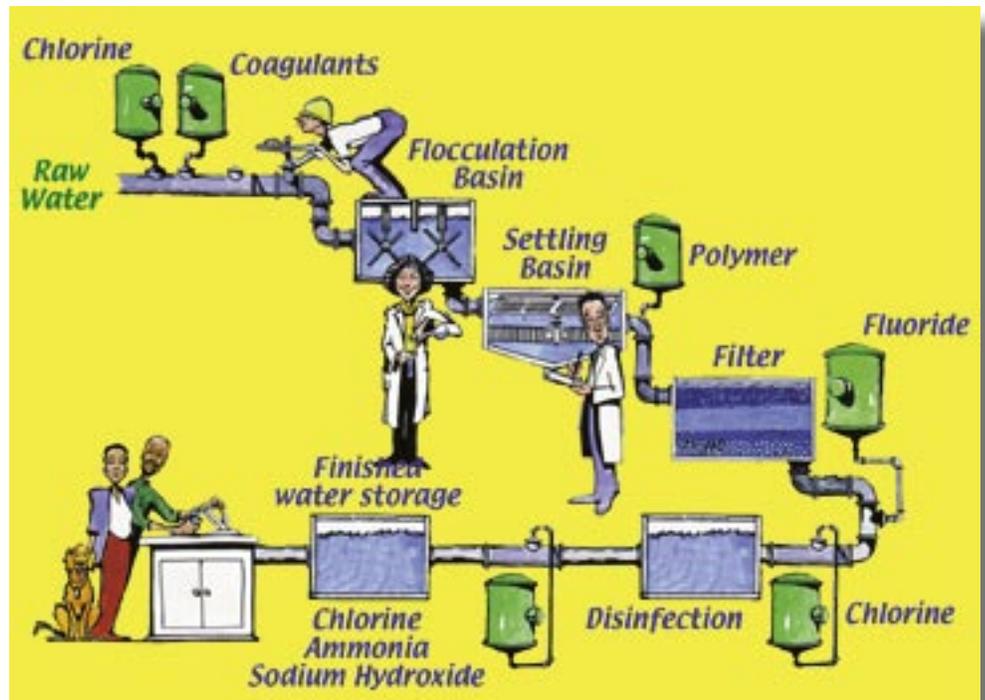
- | | | | |
|--|--|--|-------------------------------------|
| | North System | | Denver Water Treatment Plant |
| | South System | | Continental Divide |
| | South Platte Collection System | | Major Stream or River |
| | Roberts Tunnel Collection System | | Major Canal or Tunnel |
| | Moffat Collection System | | Major Lake or Reservoir |
| | Williams Fork Reservoir Watershed | | Town |



Denver Water supplies water to more than one million people in the metro area via three main collection systems: 1) the South Platte Collection System including many reservoirs in the South Park area 2) the Roberts Tunnel Collection System which diverts water from the Colorado River Basin into the North Fork of the South Platte and 3) the Moffat Collection System which diverts water from the Fraser River valley through the Moffat Tunnel and into reservoirs located in the mountains above the cities of Boulder and Golden.

Municipal Water Systems

Drinking water treatment typically begins with the addition of coagulants to the raw water. Common coagulants are alum and polymers. They create larger particles that settle out. The clarified water is then passed through silica sand or sand/coal filters which further clarify the water. After filtration, fluoride may be added. Finally, the water is thoroughly disinfected with a solution consisting of chlorine, sodium hydroxide and a small amount of ammonia to form the final disinfectant called "chloramine." Now the water is ready for your tap.



Treatment

Drinking water and wastewater treatment plants process raw water for domestic or industrial use (water treatment plant) and process wastewater before it is discharged into a stream (wastewater treatment plant).

Water supply treatment plants may be small, treating only enough water for a few homes, or giant plants treating millions of gallons per day. The treated water must comply with the Safe Drinking Water Act which ensures that the drinking water meets specific standards. Wastewater treatment plants are regulated by state and federal clean water acts.

Every year, large water utilities are required by federal law to publish a "Water Quality Annual Report" or "Consumer Confidence Report" outlining the results of their regular water testing, and showing if water from its plant does or doesn't meet all standards. These reports also describe the drinking water sources used, often with a general map of the water collection system. Water quality information from smaller providers can also easily be requested by calling your local water provider.

As water sources become more heavily used, treatment plants must deal with a great

er range of potential pollutants than in the past. For example, a treatment plant might have to remove constituents ranging from simple sediment particles to complex chemicals that have entered the source waters.

The following diagram shows the standard treatment steps used by a modern water treatment plant. These processes may vary from location to location.

All discharges from wastewater treatment plants must comply with the Colorado and federal clean water act, which aim to ensure that rivers, streams and lakes are fishable, swimmable, and pure enough for their intended uses.

Wastewater treatment plants perform what is classified as primary, secondary or advanced (tertiary) treatment using processes broken down into physical, chemical, and biological. Industrial wastes may also require pretreatment before heading to the wastewater plant. Constructed wetlands provide a special kind of wastewater treatment using natural systems.

Distribution

Distribution systems include pipes, valves, pumps, storage tanks and associated structures that carry water from the water treatment plant to homes, offices,

businesses and industry. These mostly "hidden assets" are expensive. Maintaining them accounts for a significant share of a customer's water bill. Protecting them is important to maintaining drinking water quality and to minimize losses due to leaks and structural failures.

At the Tap

The customer's plumbing system represents the privately-owned part of the water supply system. People are familiar with plumbing systems because they use them daily, but they are only the end of the chain of facilities that provide our water.

Generally, once water leaves the treatment plant, it receives no further treatment. But in large systems, outlying pipelines may receive additional doses of chlorine to help control bacterial growth. Some industrial customers further treat the water once it enters their private plumbing systems.

After it is used in a private residence or business, wastewater is collected by drains which flow into a sewer line. This is generally a combination of graywater (wash, unused and rinsewater) and so-called blackwater (raw sewage.) These combined streams of wastewater are then directed back to a wastewater treatment plant for processing.



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An Invisible Resource

For a resource so vital to our health, economy and very sustenance, water may be one of the most invisible natural resource commodities. To a certain extent, this transparency is our own fault—a product of our technological efficiency and progress.

Throughout the developed world, in recent centuries we have developed highly sophisticated systems to deliver water from where it originates to where we need it, water treated to such high standards that water-borne diseases are extremely rare. Once delivered, this resource is then generally so inexpensive to consume, few amongst us feel the need to budget our own use.

Yet as populations grow and water supplies become increasingly scarce, especially in arid regions such as Colorado, questions of where our water comes from and how it is used, will become harder to ignore. This guide is designed to give readers basic tools to start evaluating these questions—for their own communities, and for their own lives.

Reflections on Where Your Water Comes From, By Thomas Hornsby Ferril

Excerpted from “High-Line Ditch”

To the left when you're riding north along the ditch
Are the Rocky Mountains standing as if some child
Had cut the mountains out of purple cardboard,
And propped them far and cool behind the hayfields.
Some of the mountains are made to look like mountains.
The hayfields and the mountains and the sunflowers
Smell of going away and never coming back.

Excerpted from “Waltz Against the Mountains”

The prairie twinkles up the Rocky Mountains.
Feel how the city sweeps against the mountains;
Some of those higher lights, I think, are stars.
Feel how the houses crowd and crack uphill.
The headlands buckle with too many houses.
They're trying to find a place where they can stand
Until the red lights turn to green again.

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