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WATER AND IRRIGATED AGRICULTURE IN ARIZONA

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Introduction

Why is so much of Arizona's water used to irrigate crops in the desert? A partial answer to this question is that Arizona provides at least two of the three prerequisites for producing crops: ample sunshine, high-quality soils, and adequate water. Although the desert lacks sufficient rainfall to grow most crops, Arizona's rivers have supported agriculture for thousands of years, and aquifers in Arizona's desert valleys hold vast quantities of groundwater. Ongoing drought, coupled with the water demands of a growing population, however, threaten those rivers and aquifers. In this context, it is useful to reexamine irrigated agriculture: its benefits, water using practices, constraints, and trends.

This *Arroyo* seeks to provide a comprehensive picture of Arizona's irrigated agriculture, presenting first a brief history of the state's desert agriculture, followed by profiles of agricultural regions in Arizona, their water sources, uses, and crops. Following sections offer background and discussion on the two major sources of water for irrigated agriculture in Arizona: groundwater and the Colorado River. A description of agricultural water use efficiency and conservation, including new crops that may reduce water application follows. Voluntary fallowing of farmland for water conservation and transfer to other uses is discussed. Collaboration opportunities with university and government agencies on conservation and water efficiency improvements are outlined. The reader will come away with a deeper understanding of how Arizona achieves sustainable food and fiber production in a desert climate.

What is Irrigated Agriculture?

Irrigated agriculture involves the controlled application of water to a crop. In semi-arid environments, such as Arizona, irrigation is essential because there

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is insufficient precipitation to meet the water needs of most crops. Water is used primarily to supply the water needs of the crop, but it is also used to flush accumulated salts from the soil, to increase humidity and lower temperature surrounding crops, and to protect crops from frost. In 2014 the Arizona Department of Water Resources (ADWR) reported that agriculture accounted for approximately 68 percent of Arizona's total water use. This percentage is in line with the worldwide average, estimated at 70 percent.

Why is Irrigated Agriculture Important to Arizona?

As world population grows, advances in irrigated agriculture will be needed to increase yields. The United Nations projected in 2009 that farmers world-wide will need to produce 70 percent more food by 2050 to keep up with population growth. A 2015 report by the Family Farm Alliance argues that a strong agricultural economy in the western United States helps to keep food affordable for consumers.

Arizona's irrigated agriculture provides food and other goods to meet regional, national, and global demand. A 2017 study by University of Arizona economists estimated that agriculture contributes $23.3 billion to the Arizona economy. Of this, $14.8 billion comes directly from sales of farm products, the manufacture of crop inputs, crop processing, marketing and distribution. An additional $8.5 billion comes indirectly from economic activity generated as a result of agricultural income, such as retail sales.

	Irrigated Acres	
Crop	**2012***	**2017†**
Forage (e.g. hay or alfalfa, excluding sorghum)	322,816	315,000
Cotton	197,455	175,000
Vegetables/melons	130,345	134,600
Wheat	102,581	115,000
Orchards	46,176	no data
Barley for grain	44,662	20,000
Dry beans (excluding lima beans)	12,461	no data
Sorghum for grain	10,412	no data
Oats for grain	2,304	no data

Figure 1: Number of irrigated acres in Arizona for major crop types. Sources: *USDA 2012 Census of Agriculture; †USDA 2017 State Agriculture Overview

Arizona is the second largest producer of lettuce and spinach in the US, with 72,100 acres of land in production for all types of lettuce. Fresh vegetables (including lettuce) and melons, mostly grown in Yuma County, contributed $2.5 billion to the state's economy in 2015. Arizona melon growers produce about 25 percent of U.S. cantaloupe and honeydew melons. Southern Arizona, with a climate favorable for growing cotton, had approximately 175,000 acres in production in 2017. Grain, including barley and wheat, are also grown throughout central and southern Arizona. In terms of quantity produced, the state ranked 3rd nationally for production of durum wheat in 2014. Figure 1 shows the common crops grown in Arizona and the acres in production for each type of crop for 2012, the year of the latest published Census of Agriculture. The 2017 Agricultural Survey contains estimates that are approximately comparable for some crop types.

Specialty crops, including pecans and grapes, are important to local, national, and international markets. In 2017, the state had 17,061 acres of pecan trees and was ranked fourth in the nation for the production of pecans. Production of Pima cotton, a high quality, extra-long fiber cotton, varies from year to year, with 3,127 acres in production in 2012 and about 15,000 acres in production in 2017. The Lower Colorado River area is a top world-wide producer of Medjool dates, with 5,000 acres in Arizona. The expanding wine industry had 950 acres in production in 2013, with clusters of vineyards in the Willcox and Sonoita/Elgin areas of Cochise and Santa Cruz County and the Verde Valley in Yavapai County. The limited water needs of grapes make this crop ideal for Arizona. Arizona has shared in the recent growth of organic farms nationwide. In 2012, Arizona had 42 USDA certified organic farms; by 2015 that number had grown to 140.

The substantial growth of dairy farming in Arizona has had an impact on irrigated agriculture. In 2017, there were approximately 160,000 milk cows in Maricopa and Pinal Counties, while in 1990 there were fewer than 100,000 milk cows in the entire state. The need to produce feed for dairy cows changed how and what crops are grown, with alfalfa replacing cotton in some areas.

History of Irrigated Agriculture in Arizona

Indigenous Agriculture

Archeological evidence suggests that irrigated agriculture first arrived along the Santa Cruz River in southern Arizona around 1200 BCE. During this time, irrigation canals were constructed along the river near the current Interstate-10 corridor just west of Tucson. These early farmers irrigated corn, tobacco, and squash.

Between 300 BCE and 1450 AD, native people constructed a network of canals near the Salt and Gila Rivers in South Central Arizona, where they developed a distinct culture known as "Hohokam." Evidence of these canals exists today throughout the Salt River Valley, including the site of the Pueblo Grande Village on the east side of Phoenix. These canals are also found throughout the Gila River Valley, including large canals near the Casa Grande Ruins west of Florence. The disappearance of this civilization may have been due to changes and variability of the local climate.

Following the demise of the Hohokam culture, the Akimel O'odham (Pima), as likely descendants of the complex Hohokam culture, became established in southern and central Arizona. The Pima later allied with the Xalychidom Piipaash (Maricopa), and these tribes continued using irrigated agriculture. By the mid-19th century, when American and Europeans made the trip across the deserts of the Southwest to reach the California gold fields, the Akimel O'odham were diverting water from the river to agricultural fields in the valley of the Middle Gila, creating a virtual breadbasket in Arizona. By 1860, they were cultivating nearly 15,000 acres of land and supplied large quantities of wheat, corn and other foodstuffs to the U.S. military and traded farm products, such as corn, beans and squashes, to travelers and settlers.

By the late 1800s, American settlers had diverted much of the water of the Gila River that supported native agriculture, causing the Pima and Maricopa tribes to lose their livelihood, ushering in the "forty years of famine" and hardship for the tribes. Throughout the 20th Century, they struggled to gain recognition of their water rights and a water supply based on those rights. Despite tribal water rights being considered in various court cases in the first half of the 20th century, and water rights settlements with the Salt River-Pima Maricopa Indian Community, Fort McDowell Yavapai Nation, and Ak-Chin Indian Community, the Pima and Maricopa from the Gila River Indian Community continued to struggle in securing their water. In 2004, the Arizona Water Settlements Act, settled the water claims of multiple parties, including the Gila River Indian Community (GRIC). The GRIC intends to use its right to 653,500 acre-feet of water to rebuild tribal agriculture, among other uses, with a goal of more than 77,000 acres of irrigated farmland. Most of Arizona's 22 tribes engage in some level of irrigated agriculture, including the Ak Chin, the Tohono O'odham, Ft. Mohave, Navajo, Cocopah, and the Colorado River Indian Tribes.

Agricultural Development 1850 - 1968

Settlers from the eastern United States began to arrive in Arizona during the 1850s, and in 1863, the state became a U.S. territory separate from New Mexico. For these settlers, irrigation for agriculture was challenging to implement because rivers in the Southwest are prone to droughts and long periods of low flow as well as floods that overwhelm and destroy irrigation infrastructure. Despite these challenges, Jack Swilling built the first community irrigation ditch in the Phoenix area using the remains of original Hohokam canals. Other private irrigation projects in the Phoenix area soon followed. By the 1880s, crops such as fruit trees, alfalfa, and grain made farming profitable in the Salt River Valley. The development of irrigation systems allowed for 113,000 acres of Maricopa County to be brought into production by 1900. By this time, the Salt River Valley needed a more reliable water supply; however, it lacked the financial resources to build a large reservoir.

The Reclamation Act of 1902 permitted the federal government to fund the construction of dams and other irrigation projects in semi-arid western states, such as Arizona, through interest-free loans. The Salt River Valley Water Users' Association, formed in 1902, was made up of Salt River Valley farmers and landowners who were willing to pledge their lands as collateral for a reclamation project. The Association applied to the Reclamation Service for construction of Roosevelt Dam on the Salt River, and Roosevelt Dam became one of the first storage projects completed under the federal reclamation program. Construction of the dam was completed in February of 1911, despite delays in construction caused by flooding during the several winter seasons. Operation and maintenance of Roosevelt Dam and other project facilities, which later became part of what is now the Salt River Project (SRP), was transferred by the Reclamation Service (now the U.S. Bureau of Reclamation) to the Salt River Valley Water Users' Association in 1917. SRP and the Bureau of Reclamation later constructed three more dams on the Salt River, while the two Verde Rivers dams were constructed by SRP and other entities (Figure 2).

Although in 1903 landowners paid ten cents per acre in expectation of becoming shareholders in the project, subscription of lands did not begin until 1917.

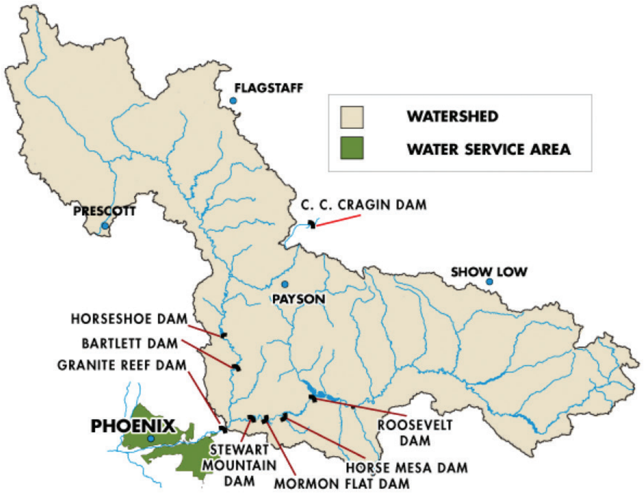


Figure 2: Salt and Verde River watersheds, the Salt River Project (SRP) water storage dams, and water service area. Image: Salt River Project

Subscriptions ultimately reached roughly 248,000 acres. Historically, SRP provided over a million acre feet of annual water supply to a predominantly agricultural economy. Today, because of water conservation efforts and increased water use efficiencies, SRP provides central Arizona with approximately 800,000 acre-feet of water per year, primarily for municipal and industrial use in the Phoenix Metro Area. Urbanization of the Project area has reduced the farmland remaining in cultivation to just 20,000 acres.

The dams and major irrigation projects on the Lower Colorado River were also constructed by the U.S. Bureau of Reclamation. Hoover Dam, which forms Lake Mead (the largest reservoir in the United States), was completed in 1936, during the Great Depression. Water stored in Lake Mead is used by Arizona, Nevada, California, and Mexico. Further downstream, on the Colorado River are Davis Dam (Lake Mohave), Parker Dam (Lake Havasu), and Imperial Dam. These structures were completed in 1950, 1938, and 1938, respectively. Irrigation canal systems constructed by Reclamation in Arizona include the Yuma Project, Yuma Auxiliary Project, and Gila Project.

The Yuma Project was built between 1904 and 1912. Water for the Yuma Project is diverted at Imperial Dam. Its Valley Division now reaches 53,415 acres of land in Arizona. The Yuma Auxiliary Project (now Unit B Irrigation District) first delivered water to farmers in 1905. This project diverts water, also from Imperial Dam, to 3,400 acres east of Yuma Project land. The Gila Project was completed in 1957, as a response to excessive groundwater pumping and increased soil salinity in the Gila Basin. The Gila Project includes several irrigation districts that collectively serve 98,000 acres

Groundwater Use, the Groundwater Management Act, and Central Arizona Project

As the state of Arizona grew, agriculture and urban development began to rely on groundwater. According to the Arizona Department of Water Resources, in 2014 groundwater accounted for 40 percent of the state's annual water use. Large portions of central and southern Arizona are favorable for groundwater pumping, as deep aquifers in these areas hold substantial amounts of water, although in some areas pumping in excess of recharge has resulted in significant declines in groundwater levels. Pumping more water from aquifers than is naturally recharged is called groundwater overdraft or mining.

Arizona's groundwater overdraft problem was most severe from the late 1940s through the passage of the 1980 Groundwater Management Act (GMA). In 1937, the invention of the centrifugal turbine pump permitted extraction of groundwater from greater depths. This contributed to rapid growth of irrigated agriculture throughout Arizona between 1940 and 1953. This rapid growth in irrigated agriculture resulted in over pumping throughout the groundwater dependent agricultural regions of the state. During that time, the state of Arizona was using 2.3 million acre-feet per year of groundwater in excess of natural recharge. In a 1963 report Congressman Morris K. Udall stated ominously, "Eventual water bankruptcy is the guaranteed result of this kind of policy." In this context, securing federal funding for construction of a canal to divert water from the Colorado River to the farms and cities of Central Arizona was considered imperative. Congress passed and President Lyndon B. Johnson signed that act authorizing the Central Arizona Project (CAP) in 1968. Groundwater overdraft in the 1960s and 1970s was so severe, however, that then Interior Secretary Cecil Andrus threatened to eliminate funding for CAP if Arizona did not implement policy to manage its shrinking groundwater supplies. Under this threat, the Arizona legislature passed the 1980 Groundwater Management Act (GMA).

Since the passage of the GMA and the arrival of CAP, overdraft has decreased within areas of the state designated for active management, including Phoenix, Pinal, Prescott, Santa Cruz, and Tucson. Within these Active Management Areas (AMAs), groundwater withdrawals for irrigated agriculture are limited. In the Phoenix, Pinal and Tucson AMAs, which are within the CAP service area, irrigated agriculture has transitioned to more use of renewable CAP water. Issues relating to potential Colorado River shortage, however, are threatening to push some irrigators back onto groundwater (see section on the Colorado River, on page 8). In farming areas that lack both regulation of groundwater extraction and access to Colorado River water, the problem of overdraft is a continuing concern.

A Profile of Irrigated Agriculture in Arizona

This section relies heavily on the Arizona Water Atlas compiled by ADWR, which generally covers the period from 2001 to 2005. Data from the U.S. Department of Agriculture's 2017 Agricultural Survey suggests that in most areas the picture of irrigated agriculture has not changed substantially, but exceptions will be noted. Trends in agricultural water use for groundwater basins are shown in Figure 3.

Water use for irrigated agriculture varies throughout the state. The Water Atlas defines seven regions or "planning areas" (Figure 4), which are used in this section. (The seven Water Atlas planning areas should not be confused with the 22 "planning areas" delineated by ADWR in 2014 to identify and develop strategies to address water use and supply imbalances throughout Arizona.) Figure 5, which shows all irrigated areas throughout Arizona, indicates that most agriculture is concentrated in South Central Arizona south of Phoenix and in the southwest corner of the state near Yuma.

Southwest Arizona

A substantial concentration of irrigated agriculture in Arizona is in the southwest corner of the state near the city of Yuma. Designated the Lower Colorado River Planning Area in the Arizona Water Atlas, this region extends from the southwestern corner of Arizona through the Lower Gila Basin and includes part of the Tohono O’odham Nation on the east. The Atlas reported more than 2.8 million acre-feet of water use per year for non-Indian irrigated agriculture between 2001 and 2005. This represents 98 percent of the Planning Area water use and 36 percent of Arizona’s total annual water use of 6.9 million acre-feet for the period. Most of the water used in this area came from Colorado River diversions (63 percent) and groundwater (33 percent). Much smaller amounts came from the Colorado River via the Central Arizona Project and from Gila River surface flow.

The Lower Colorado River Planning Area comprises 11 basins, several with significant agricultural water use. The Yuma Basin used 994,200 acre-feet of water per year, 77 percent from Colorado River diversions and the rest from groundwater. The Yuma Basin relies on two U.S. Bureau of Reclamation irrigation projects: the Yuma Project and the Gila Project. Farms within the Yuma Project, rotate crops between seasons, irrigating wheat, cotton, hay, melons, and seed crops in the summer and vegetables during the fall and winter. Crops grown within the Gila Project districts include alfalfa, cotton, melons, citrus, vegetables, Bermuda grass, and grain.

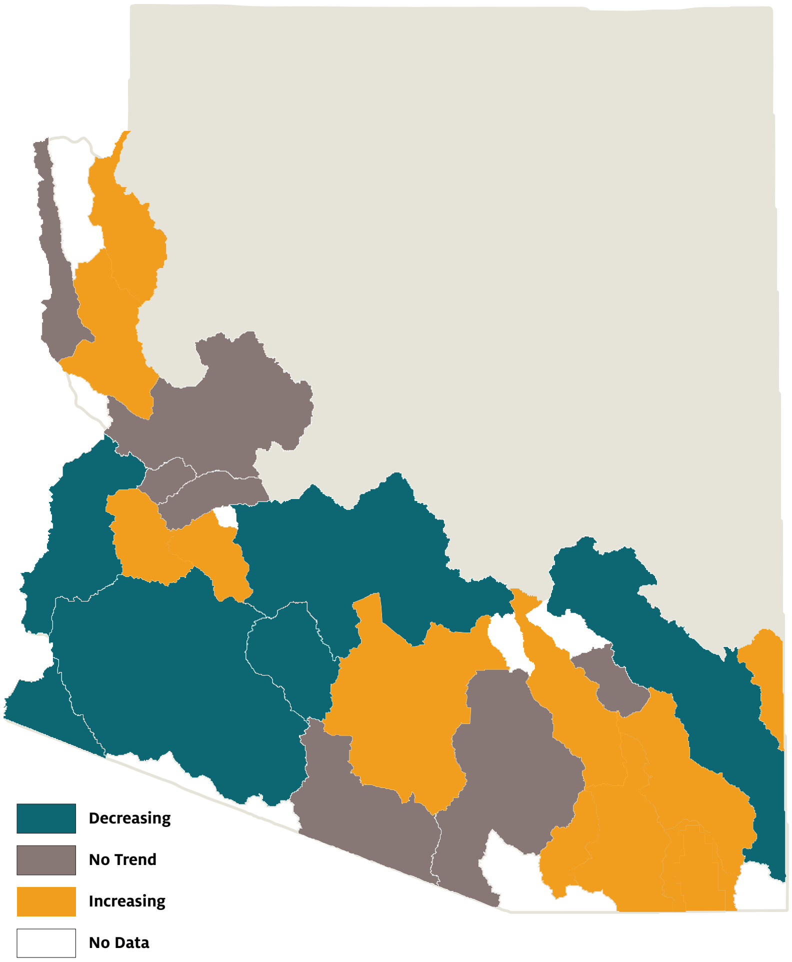


Figure 3. Trends in agricultural water use in groundwater basins 2006-2016 and Active Management Areas 2006-2009. Data sources: U.S. Geological Survey and Arizona Department of Water Resources

The Lower Gila Basin, east of Yuma, used 629,000 acre-feet per year from 2001-2005 for agriculture, of which, 60 percent was from the Colorado River. Most of the irrigation in this area is located along the Gila River and water is supplied through the Wellton-Mohawk Irrigation and Drainage District. Primary crops grown include vegetables, alfalfa, melons, and wheat.

North along the Colorado River, Parker Basin agriculture used an average of 630,600 acre-feet per year in 2001-2005, almost exclusively Colorado River water. Most of this water was used by the Colorado River Indian Tribes (CRIT) for alfalfa, cotton, and durum wheat. The Cibola Valley Irrigation and Drainage District owns the canal system that serves much of the non-Indian irrigated agriculture in the basin. Crops include alfalfa, Bermuda grass, cotton, vegetables, wheat, and barley.

Away from the Colorado River, irrigators rely primarily on groundwater. In the Gila Bend Basin, growers use groundwater to grow alfalfa and other hay, sorghum, and wheat. In the McMullen Valley Basin, water demand for irrigated agriculture fluctuated around 90,000 acre-feet during 2001-2005 and has trended slightly lower since. Crops in this basin, which rely on groundwater, include melons, cotton, sorghum, vegetables, oats, alfalfa and other hay, corn, guayule, pistachios, date palms, and oats. In the Gila Bend Basin, groundwater wells supplied about 289,000 acre-feet of water per year to grow mostly cotton, alfalfa, and grain.

The Harquahala Basin is designated as an Irrigation Non-Expansion Area (INA), which means that no new lands may be irrigated. Irrigation has varied substantially in the Harquahala INA from only about 37,000 acre-feet in 1991 to about 150,000 acre-feet in 2016, with CAP water supplying about 25 percent of the total. Primary crops include alfalfa and hay, cotton, wheat, melons, corn, sorghum, grasses, oats, and trees. Elsewhere in the Lower Colorado Planning Area, irrigated agriculture is limited and produces primarily alfalfa.

Central Arizona

South Central Arizona, designated the “Active Management Area Planning Area” in the Arizona Water Atlas, has the second-largest agricultural water demand in Arizona. Non-Indian agriculture used an average of 1.8 million acre-feet of water per year between 2001 and 2005. Most irrigated agriculture in the AMA planning area is in the Phoenix and Pinal AMAs. Major

Figure 4. Arizona Water Atlas Planning Areas. Image: Arizona Department of Water Resources

crops are alfalfa and hay, cotton, wheat, barley, corn, and vegetables, and citrus, although very little, if any, citrus is grown in Pinal County. Further south, pecans and cotton are grown in the Tucson AMA. In the 2001-2005 period the AMAs together used groundwater (46 percent), CAP water (38 percent), in-state river water (14 percent), and treated effluent (2 percent) for agriculture. More recently, with the availability until 2017 of 400,000 acre-feet of Agricultural Settlement Pool water, the CAP irrigation districts were using 60 percent surface water (mostly CAP) and 40 percent groundwater.

Within the Phoenix AMA, there are 33 irrigation districts; however, 80 percent of the water in the AMA is managed by seven districts including SRP. Agricultural water use in SRP and in the Roosevelt Water Conservation District declined between 1984 and 2002 due to urbanization in the Phoenix Metro Area, while water use in other irrigation districts either remained stable or increased.

In the Pinal AMA, four irrigation districts manage 87 percent of the water, and their water use exceeds 800,000 acre-feet per year. Most districts supplement CAP water with pumped groundwater. The Maricopa-Stanfield Irrigation & Drainage District (MSIDD), one of the two largest irrigation districts in the Pinal AMA, operates the Santa Rosa Canal, which delivers CAP water to MSIDD, the Ak-Chin Indian Community, and about one-third of the Central Arizona Irrigation and Drainage District (CAIDD). The MSIDD also produces groundwater from 150 irrigation wells, 80 of which are connected directly to its canal system. The San Carlos Irrigation and Drainage District is able to use surface water from the Gila River.

Further south, Tucson AMA agriculture used approximately 96,600 acre-feet of CAP and groundwater, or only about 5 percent of Arizona's total agricultural use. The Cortaro-Marana Irrigation District, near the town of Marana, supplies water to grow cotton and grain in the Avra Valley through its system of wells and canals. The Avra Valley Irrigation District, BKW Farms, and other irrigators also operate in this area. Pecan production by Farmers Investment Company near Green Valley uses groundwater as there is no CAP infrastructure in the Green Valley area at this time.

Native American communities used an additional 377,600 acre-feet of water per year in the AMA Planning Region. The Ak-Chin Indian Community, Fort McDowell Yavapai Nation, Gila River Indian Community, Salt River Pima-Maricopa Indian Community, and Tohono O'odham Nation all use water for irrigated agriculture.

Other Regions of Arizona

There is little irrigated agriculture on the sparsely populated and largely undeveloped Eastern Plateau and Western Plateau of Arizona. Major crops include alfalfa and rye grass. On the Eastern Plateau there are some orchards and pasture. The Central Highlands have irrigated pasture.

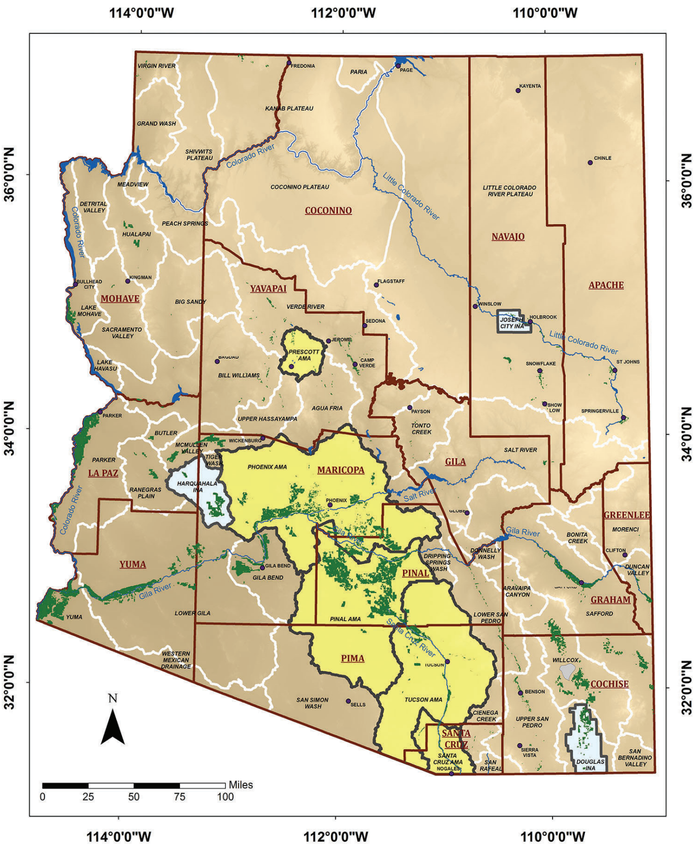


Figure 5. Areas of irrigated agriculture in Arizona are shaded in green. Image: U.S. Geological Survey

Agricultural demand in the Upper Colorado Planning area, which comprises the southern half of Mohave County and parts of Maricopa, La Paz, and Coconino Counties in western Arizona, has increased in recent years. Between 2001 and 2005, agricultural water demand was 99,550 acre-feet per year. Most of the water for irrigation is used by the Fort Mojave Indian Tribe in the Lake Mohave Basin. Other water users within the basin operate wells and distribution infrastructure to irrigate cotton, alfalfa, other hay, and wheat. Since publication of the Water Atlas, irrigated agriculture in the Hualapai and Sacramento Basins east of the river has grown on groundwater. More recent data for these basins show that agricultural water use increased from zero in 2001-2005 to more than 32,000 acre-feet in 2016, and irrigated agriculture continues to grow. In 2016, in order to forestall explosive growth in water demand for new irrigated agriculture, Mohave County asked ADWR to designate the Sacramento Valley groundwater basin and Hualapai Valley groundwater basin as separate INAs. The ADWR found that the evidence it possessed on groundwater conditions in the basins did not support the initiation of INA designation procedures.

Within the Southeastern Arizona Planning Area, farmers in the Safford Basin irrigated cotton, grain, and alfalfa with 181,700 acre-feet per year of groundwater and surface water. Surface water is distributed through the Gila Valley Irrigation District. In the Willcox Basin, 167,000 acre-feet per year of groundwater were used to irrigate primarily corn, alfalfa, orchards, and vegetables. The Douglas Basin, an INA, uses approximately 47,300 acre-feet of water per year for corn and alfalfa. Irrigated agriculture also occurs in the Duncan Valley and Upper and Lower San Pedro Basins of the Southeastern Planning Area. Groundwater overdraft has become a major challenge throughout the area, and it is leading to some environmental problems, such as subsidence and the formation of land fissures.

The Cochise Planning Area, one of the 22 planning areas ADWR defined in 2014, lies within the Water Atlas's Southeastern Arizona Planning Area (Figure 6). Throughout the Cochise Planning Area, well owners reported 18 wells to have gone dry between 2008 and 2014, however this number probably far underestimates the actual number of wells that went dry. In 2015, residents of the San Simon Valley sub-basin within the Safford groundwater basin petitioned ADWR to have the sub-basin designated as an INA; however, ADWR declined to designate an INA after its groundwater modeling study and other evidence showed sufficient groundwater for irrigation of the cultivated lands in the area at the rates of withdrawal current at the time of the study.

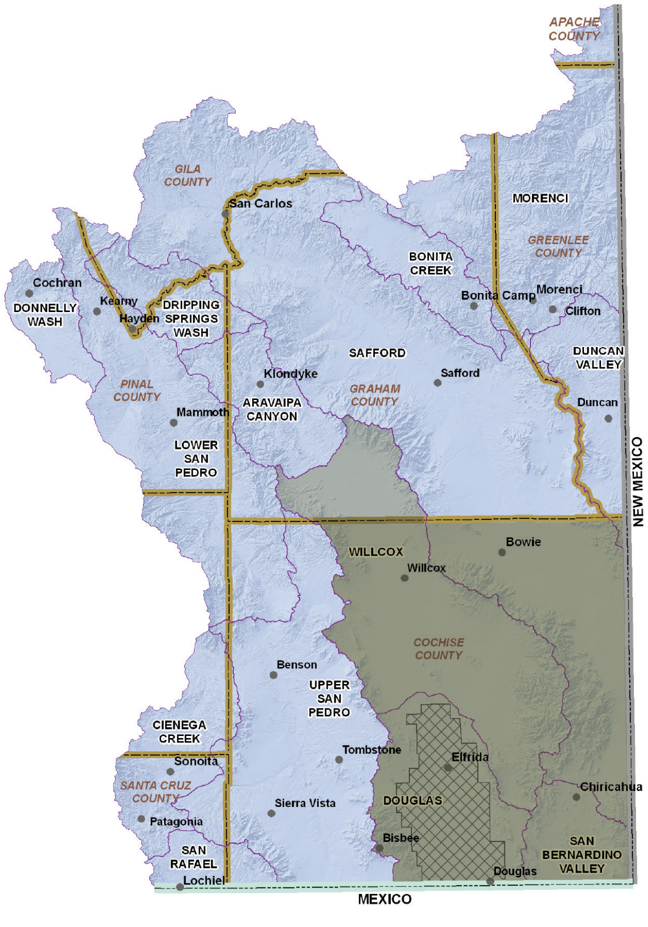


Figure 6. Cochise Planning Area within the Arizona Water Atlas's Southeastern Arizona Planning Area. Image: Arizona Department of Water Resources

Regulation of Groundwater Use for Agricultural Irrigation

The GMA effectively divided Arizona into three categories. Areas within the state that are subject to the most regulations are AMAs, as these were the areas that experienced the worst groundwater overdraft during the mid-20th century. Within an AMA, irrigators have quantified grandfathered irrigation rights. Wells with a pumping capacity of 35 gallons per minute or less are exempt from most AMA regulations, but cannot be used for large-scale irrigation. Grandfathered irrigation rights are tied to specific parcels of land that were irrigated between 1975 and 1980. The quantity of the right is based on the water use and crop types grown on that land at that time. No new land in an AMA may be brought into agricultural production. An owner of land with an irrigation right may extinguish that right in exchange for transferable water credits, but once extinguished the right to irrigate may not be reestablished. Holders of irrigation rights are regulated under either the base conservation program, which is associated with an annual allotment of water but allows some flexibility through transfer of credits between farms; or under the Best Management Practices conservation program, requiring implementation of a number of BMPs designed to improve efficiency of water use. All users of wells with capacities of 35 gallons per minute or more in AMAs must pay groundwater withdrawal fees, and users of these wells must also report withdrawals, so that water use in the AMA can be tracked.

Less actively managed than AMAs, INAs are areas where no new lands may be brought into agricultural production. Irrigation groundwater rights are not quantified and no withdrawal fee is charged for groundwater pumping. Elsewhere in the state, groundwater withdrawal is not regulated by the GMA, although wells must still be registered with ADWR.

The GMA allows for the creation of new AMAs and INAs when needed for a number of reasons, including protection of the groundwater supply. In the Willcox Basin, local residents explored the option of forming either an AMA or INA but rejected both options. The prohibition against bringing new lands under cultivation was a major sticking point. Stakeholders favored establishing new vineyards, which thrive in soils where other crops would fail and are a high value and relatively low water use crop compared to other agricultural commodities. The local stakeholders realized a new "third way" was needed, and they developed a concept that incorporated some of the AMA conservation requirements but allowed for expansion of irrigated land for new low water use crops. Although this concept was not adopted in the Willcox Basin, it illustrates the kind of new ideas that may be needed in areas dealing with overdraft.

Issues with Unregulated Groundwater Use

Despite Arizona's vast stores of groundwater, overdraft of the state's aquifers is not sustainable in the long-term. Groundwater overdraft is a challenge for irrigated agriculture in Arizona, as drilling deeper wells and pumping from greater depths can become prohibitively expensive. The problem of groundwater overdraft has become severe enough in the Willcox area that irrigation wells are often drilled to over 1,200 feet deep. In 2017, the cost to drill a well to 1,200 feet was approximately $420,000. In addition, an irrigator's most expensive input is energy, and the energy needed to pump water from ever greater depths can be significant. In areas like Willcox, where severe groundwater overdraft is occurring, the costs to extract water may eventually exceed the farm revenue, making irrigation too expensive for farmers.

In the Willcox Basin, existing agricultural groundwater uses and new farm pumping have caused problems for homeowners with relatively shallow wells. Drilling costs to deepen wells can be too high for some residents to afford, meaning that they have to live without a reliable supply of water. Groundwater overdraft has also recently caused concern in Mohave County, where new farming businesses have purchased land in recent years and started to pump groundwater. Residents in Kingman are concerned that the increased pumping may threaten their wells and property and that the community could eventually run out of water. Because this level of groundwater pumping is a relatively new phenomenon in Mohave County, there is an opportunity for local residents, farmers, and the state government to work together to find a sustainable long-term solution before substantial groundwater overdraft occurs.

Timothy Lahmers, a Hydrometeorology PhD candidate at the University of Arizona, prepared the initial draft of this Arroyo as the **2017 Summer Writing Intern at the WRRC**. His areas of current research include atmospheric modeling, distributed hydrologic modeling, and hydrometeorology in semi-arid environments. He hopes in the future to apply this research to understanding the effects of climate change on extreme weather and water resources in the western US.

Lowering of the groundwater table can also have negative environmental consequences. The geology across most of southern and western Arizona is associated with areas of high mountains and deep valleys where sediments have accumulated in some areas to depths of over 5000 feet. These sediments are filled with groundwater that can be easily pumped; however, depending on geologic conditions, overdraft may cause pore spaces between sediment particles to collapse as water is removed. This compaction of the sediments causes the land to sink, a process called subsidence, which can permanently reduce the storage capacity of the aquifer. One of the possible consequences of subsidence is the formation of fissures or cracks in the ground. Fissures generally occur where an aquifer boundary meets bedrock, so they seldom open within irrigated fields; however, they can damage canals and well casings. In addition, subsidence can cause regional and local flooding and alter the slope of land used to grow crops, changing the flow direction of irrigation water, and thus reducing irrigation efficiency. Farmers on subsidence prone lands may therefore need to relevel fields to keep them in production.

Reliance on Colorado River Water

To reduce the effects of overdraft, many farms in Central Arizona have turned to CAP for water. Arizona is allocated 2.8 million acre-feet per year of consumptive use from the Colorado River, and approximately 1.6

million acre-feet per year are transported through the CAP system. The rest of the state's allotment is diverted from the river, mostly for irrigated agriculture along the mainstem and adjacent areas.

The priority of water rights for different Colorado River water users in Arizona varies based on when the water was first used or the rights were acquired. First priority water rights predate the Boulder Canyon Project Act of 1928. Second and third priority water users established their rights by secretarial reservation or contract before September 30, 1968. Second and third priority rights are coequal. Fourth priority water rights were established by contract after September 30, 1968. Most CAP water is fourth priority, and fourth priority water will be the first to be cut in the event of a shortage on the river.

CAP Water Use by Arizona Irrigators

The CAP transports water from the Colorado River at Lake Havasu in western Arizona to water users in Maricopa, Pima, and Pinal Counties. The 336-mile long canal and associated structures were authorized by Congress in 1968. Originally envisioned as the salvation of irrigated agriculture in Central Arizona, CAP has become a major water source for municipalities, water companies, industrial users, and Native American tribes, as well as farms and irrigation districts in Maricopa, Pima, and Pinal counties.

The CAP was completed in 1993. It became clear at that time that the original structure for payments by CAP customers had problems, including an unsupportable burden on agricultural subcontractors. Efforts to solve these problems included negotiations and litigation. Issues were largely resolved in 2004 by the Arizona Water Settlement Agreement, in which non-Indian CAP agricultural subcontractors relinquished their long-term CAP entitlements in exchange for a commitment by CAP's governing board to deliver a declining pool of Excess Water through 2030 at energy-only rates. Known as the Agricultural Settlement Pool or "Ag Pool", this pool supplies a large portion of the irrigated agriculture in the CAP three-county service area.

Since 1983, CAP water has been divided into the following pools (Figure 7): some Priority 3 water, Indian Priority and Municipal and Industrial (M&I) Priority Pools, Non-Indian Agricultural (NIA) Pool, and excess water. The Agricultural Settlement Pool (Ag Pool) was added in 2004. Assigning a low priority to the Ag Pool means that Central Arizona agriculture will be the first to feel the effects of a shortage on the Colorado River. The purchase of water in the Ag Pool is subject to availability and decreases over time. It decreased from 400,000 to 300,000 acre-feet per year in 2017. In 2024, the pool will shrink to 225,000 acre-feet per year, and it is scheduled to be eliminated entirely after 2030.

Per the 2004 settlement, water sold to farms and irrigation districts from the Ag Pool is priced based on the energy cost of CAP water delivery. Even this reduced price began to look high to growers when the Central Arizona Water Conservation District (CAWCD), the entity created by the state to repay the federal government reimbursable costs for CAP construction and contract for the delivery of CAP water, began projecting increased costs for power. In 2009, the CAWCD began an agricultural incentive program to further reduce CAP water costs for agriculture. In exchange for incentive pricing, growers were required to meet specific CAWCD goals for water use, storage, and recovery.

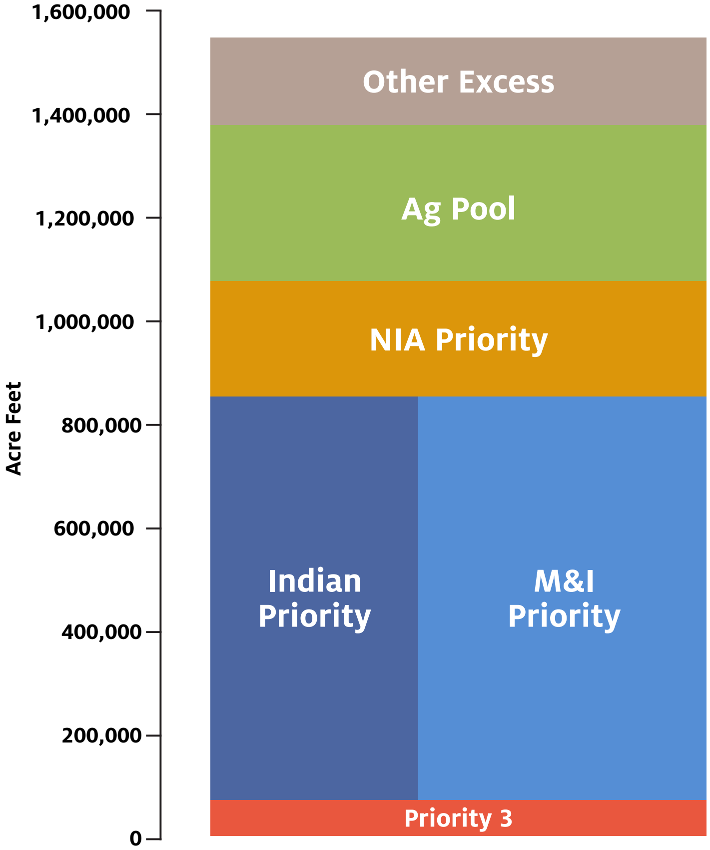


Figure 7. Current use of Central Arizona Project water priority pools, prior to system conservation activities top to bottom shows lowest to highest priority. Image: Central Arizona Project

The CAP had good reason to provide incentives for the agricultural use of project water. By the Reclamation Act of 1902, agricultural districts are not required to pay interest on the debt incurred to the federal government for construction of reclamation projects. Because irrigated agriculture uses Ag Pool water, CAP's interest payment obligation was reduced.

In addition to buying water from the Agricultural Settlement Pool, another way for agricultural water users to take CAP water is by becoming a permitted Groundwater Savings Facility (GSF). A GSF is typically an individual farm or irrigation district in an AMA. In lieu of pumping groundwater, the GSF uses CAP water supplied by a CAP subcontractor or entity created to bank (Arizona Water Banking Authority) or replenish water (Central Arizona Groundwater Replenishment District). This water is also known as "in lieu" water. In order for a GSF to be permitted, the farm or irrigation district must prove that without "in lieu" water, groundwater pumping is the only feasible way to obtain water. A GSF is permitted to substitute in lieu water on a gallon-for-gallon basis for groundwater that otherwise would have been pumped.

Potential Colorado River Shortages and Impacts on Agriculture

The eventual elimination of the Ag Pool is only one challenge that farmers who rely on CAP water will face in the coming years. Water use in the Lower Colorado River Basin exceeds normal inflows to Lake Mead each year. When combined, a normal release of 8.23 million acre-feet from Lake Powell and approximately 0.7 million acre-feet of inflow from tributaries yields a total average operational inflow into Lake Mead of 9.0 million acre-feet. Given the basic apportionments to the Lower Basin states, the allotment to Mexico, and evaporation losses, Lake Mead annual outflow is about 1.2 million acre-feet more than the annual inflow. The result is an imbalance that causes Lake Mead to drop by 12 feet or more every year. This "structural deficit" is leading to consistent declines in the water storage in Lake Mead such that the status quo is not sustainable (Figure 8). This problem is likely to get worse given warming climate trends. Streamflow on the Colorado River is projected by multiple studies to decrease by at least 10 percent in the next century. In addition, severe drought conditions are highly likely to occur in the coming decades.

In 2007, an agreement among the Lower Basin states and the Bureau of Reclamation was codified in the Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead. Commonly known as the 2007 Interim Guidelines, it established a shortage sharing framework for the Lower Basin, incentives storing water in Lake Mead, and coordinated operations of Lake Powell and Lake Mead. The shortage framework contains three shortage tiers based on Lake Mead elevations. If the Bureau of Reclamation's August 24-Month Study projection for Lake Mead is at or below an elevation of 1075 ft. on December 31st in any year, a Tier 1 shortage is declared and Arizona's allocation is reduced by 320,000 acre-feet. This reduction increases to 400,000 and 480,000 acre-feet per year if the Lake Mead elevation drops to 1050 feet and 1025 feet, respectively. In the event that a Tier 1 shortage is declared, CAP's excess water pool will be eliminated and a portion of the Ag Pool water will be reduced. As Lake Mead falls, more CAP water users will be affected, including municipal and industrial (M&I) and Indian priority water users. At Lake Mead falls below 1075 feet, the secretary of the interior will consult with the Basin States on measures to be taken. Only if Lake Mead drops below 1025 feet, are Arizona's senior water rights holders, such as irrigators in the Yuma area, potentially affected.

Over the past two decades a severe drought has exacerbated the water situation on the Colorado River. During this time, the Lower Basin has experienced its lowest 16-year period of inflow in over 100 years of record keeping The volumes of water left in Lake Mead under the various incentive programs have slowed but not stopped Lake Mead's decline. As a result, the Lower Basin states and the Bureau of Reclamation began discussing new incentive programs and a new framework for shortage sharing.

In this context, the Lower Basin Pilot Drought Response Actions Memorandum of Understanding (MOU) was signed on December 10, 2014. This MOU committed Arizona to use its best efforts to create 345,000 acre-feet of water in Lake Mead between 2014 and 2017. To meet this goal, several programs were

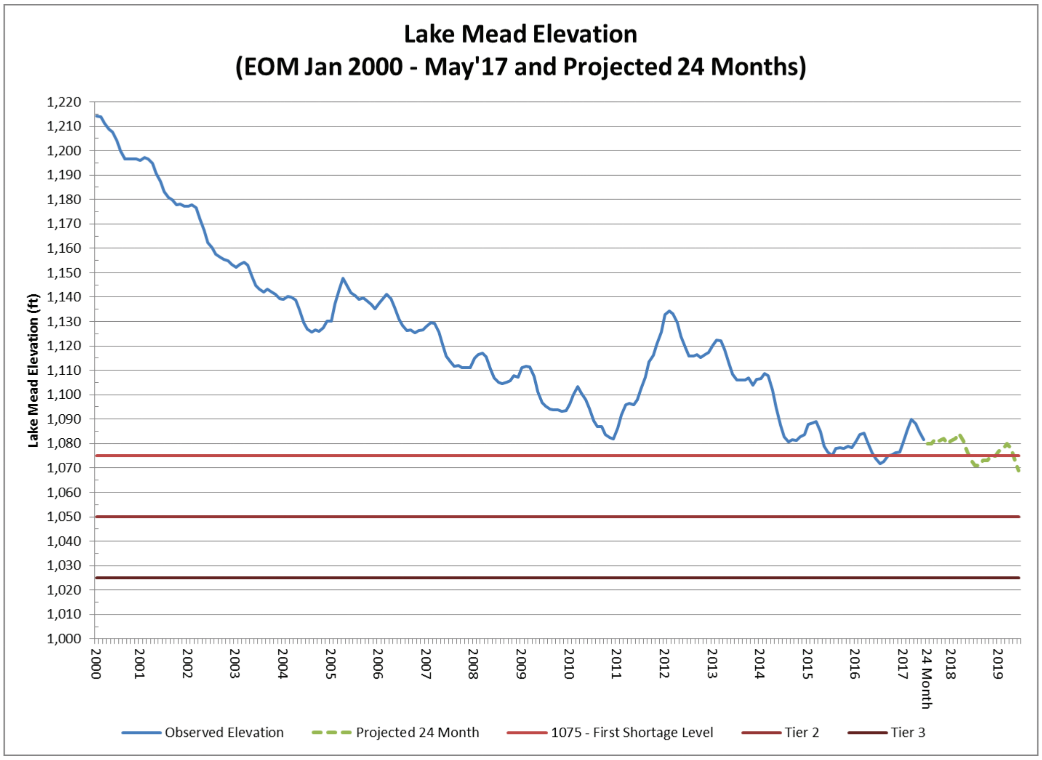


Figure 8. Lake Mead elevation from 2000 through May 2017 showing consistent reduction in storage interrupted by wet years. (EOM=End of Month) Image: Central Arizona Project

developed within Arizona, including two agricultural forbearance programs that allowed Central Arizona agricultural districts to leave part of their CAP allocations in Lake Mead. With the voluntary participation of SRP and 11 irrigation districts and farms, these two programs together resulted in an estimated 216,000 acre-feet of water left in Lake Mead from 2014 through the end of 2017. Other system conservation activities left over 475,000 acre-feet in the reservoir over the same period, including almost 170,000 acre-feet from the Tohono O'odham, CRIT, and GRIC.

The Lower Basin Drought Contingency Plan (LBDCP) is a policy proposal that includes cooperation among Arizona, Nevada, California, Mexico, and the U.S. Bureau of Reclamation to prevent the elevation in Lake Mead from dropping to elevations that might trigger draconian reductions. The details of the LBDCP are still being debated among Lower Colorado River Basin states. Under the LBDCP, cuts would begin sooner, and later cuts would be deeper. The LBDCP effectively would reduce CAP deliveries by 192,000 acre-feet per year when the Lake Mead elevation drops below 1090 feet eliminating the excess water pool. Below 1075 feet the total reduction in CAP deliveries is schedule to be 512,000 acre-feet per year. These reductions would essentially eliminate the Ag Pool at elevation 1075. If shortages are averted, agricultural water users will continue to have access to Agricultural Settlement Pool water, at least until 2030.

Agricultural Water Conservation

Improvements to Irrigation Systems

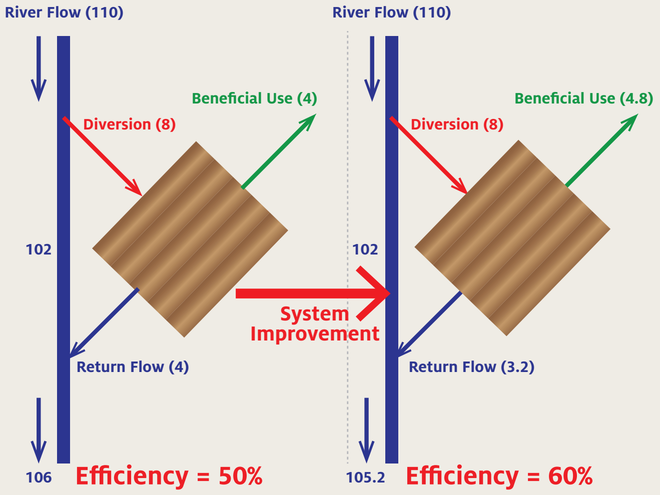
Farmers across the Southwest have been able to reduce water use, while increasing yields, by making improvements to irrigation systems. In the Yuma area for example, crop yields have increased while water use for irrigated agriculture has decreased by 15 percent since 1990, due to reduction in irrigable acres, expanded use of multi-crop production systems, and improvements in crop and irrigation management and infrastructure. Similar water-savings achieved across Arizona agriculture can be attributed to these same factors. In Central Arizona, where GMA conservation and management rules apply, irrigation districts have reached a remarkable efficiency of 85 percent.

Taking improvements in irrigation infrastructure first, water savings have resulted from improvements to surface irrigation systems combined with the more recent introductions of sprinkler and drip irrigation systems where feasible and affordable. Surface irrigation is the most common type of irrigation used in the Southwest. Surface irrigation may either use furrows to apply water to crops planted on rows, or flood irrigation to apply water to flat areas surrounded by borders.

Irrigation Efficiency v. Water Conservation

The irrigation efficiency of an agricultural operation may be defined as the ratio of water beneficially used to the total amount of water applied. As more of the applied water goes to beneficial uses rather than non-beneficial uses, efficiency increases. Non-beneficial uses of water include evaporation, deep percolation, and tail water runoff.

An example offered by Noel Gollehon (USDA) at the WRRC 2017 conference demonstrates that efficiency is not necessarily the same as conservation. Conservation means a reduction in the amount of water consumed. In Gollehon's example, eight units of water are legally allocated to a farmer and diverted from a river. Of these eight units, four are beneficially used and the other four are returned to the river as tail water. This system would have an irrigation efficiency of 50 percent. Suppose that the farmer is able to increase irrigation efficiency to 60 percent by improving irrigation technology. With this change 4.8 units of water are used beneficially and the farmer returns only 3.2 units of water to the river. The increased efficiency may benefit the farmer in terms of increased yields, but less water is available for downstream users.



Surface irrigation is advantageous because it requires minimal equipment and energy; however, it is typically less efficient than other methods of irrigation. Vegetable growers throughout the Yuma area, however, have refined the method to achieve an average efficiency of 80-85 percent.

Improvements to surface irrigation systems include laser-leveling fields, shaping furrows, lining ditches, and using high-flow irrigation gates. Fields are kept level so that water spreads evenly and does not pond in low places. Shorter furrows or borders also help water spread evenly. Fields are typically leveled at least once per year.

Figure 9. Center pivot irrigation system at work in Arizona. Image: U.S. Geological Survey

Furrows are optimized to a trapezoidal shape, which conveys water more evenly. To eliminate losses from infiltration, irrigation ditches and canals are lined with concrete, and high-flow irrigation gates flood fields more quickly, pushing water efficiently to the end of the field. These practices are recommended by the ADWR Best Management Practices (BMP) program for use by farmers in Arizona's AMAs and can also result in efficiencies greater than 80 percent. By the early 1990s, most farms in Central Arizona had adopted these improved surface systems.

Sprinkler irrigation: solid-set, center pivot and linear move systems, can reduce water use compared to flood irrigation (Figure 9). These systems consist of an outlet-studded water pipe suspended over an agricultural field. The entire system may be fixed (solid-set) or self-propelled to rotate around a central point (center pivot) or to move along a line over a plot of land (linear move). Water can be distributed evenly across a field to achieve efficiencies over 80 percent. Sprinkler systems are effective in areas where soil infiltration rates are too high for flood irrigation or where, because of the topography, ground leveling would damage the topsoil.

One of the ways sprinkler irrigation has been used in Southwest Arizona is to germinate vegetable crops. With furrow irrigation, germination is achieved through the practice of keeping furrows filled with water for up to 10 days. Sprinkler irrigation reduces the amount of water needed for germination from between 18 and 37 inches to 8.5 inches. Sprinkler systems are also becoming more common throughout Arizona.

Drip irrigation (also known as micro-irrigation) consists of low pressure water lines that release water at or below the land surface. Drip irrigation can be customized for different crop types and applied in fields with steeper topography than surface or sprinkler systems. Subsurface drip irrigation is highly efficient because it releases water uniformly within the root zone of a crop. This added efficiency means that less water has to be applied to the crop. Drip irrigation, once installed, may require less labor than other systems, although they require more intensive management than conventional systems. Drip irrigation is used throughout Arizona, including Mohave County, Central Arizona, and the Yuma area. Drip irrigation is also used to grow fruit and nut trees in Cochise County and within the Fort McDowell Indian Community.

While drip irrigation is one of the most efficient ways to irrigate crops in the southwestern United States, it has some notable drawbacks. Drip irrigation systems have a high installation cost up to $2500 per acre), making it impractical for farmers who lease land. Increased soil salinity can be a problem with drip irrigation and the salts must be flushed from the soil to below the root zone by applying additional water. A practical downside of drip irrigation for farms that rotate crops is that dripline systems cannot be changed or moved once installed. If crop spacing varies for different crops that are rotated throughout the season, uniform water distribution will not always be possible with a drip system. For germination of some vegetables, sprinkler irrigation must be used in addition to drip irrigation, which means increased costs. In addition, drip irrigation reduces or eliminates return flows used to calculate a farmer's water diversion. It is for these reasons that drip irrigation is used on less than 2 percent of agricultural land in the Yuma area.

Other Innovations to Conserve Water

Changes to agriculture practices have also been able to reduce water use throughout the state. In the Yuma area, farmers have been able to reduce their water use by avoiding the need to irrigate during the warmest part of the year, when evaporation is the highest. They do this by growing leafy green vegetables in the winter and warm season crops that mature in early summer, such as durum wheat, spring melons, Sudan grass, and early season cotton. Alternating these two types of crops can actually use less than growing a single perennial crop that must be irrigated through late summer. As shown in Figure 10, water deliveries during late summer have been greatly reduced since the 1970s, while water deliveries have increased much less during the late fall months, when vegetable crops are germinated.

Water use has also been reduced through improvements to the timing of irrigation application. Monitoring the soil to irrigate just before maximum allowable depletion is reached helps farmers avoid using more water than is needed to maintain crop yields. Adding too much water reduces yields. Application of water to keep soil moisture above maximum allowable depletion is relatively simple with sprinkler systems, but saving can also be achieved with surface systems.

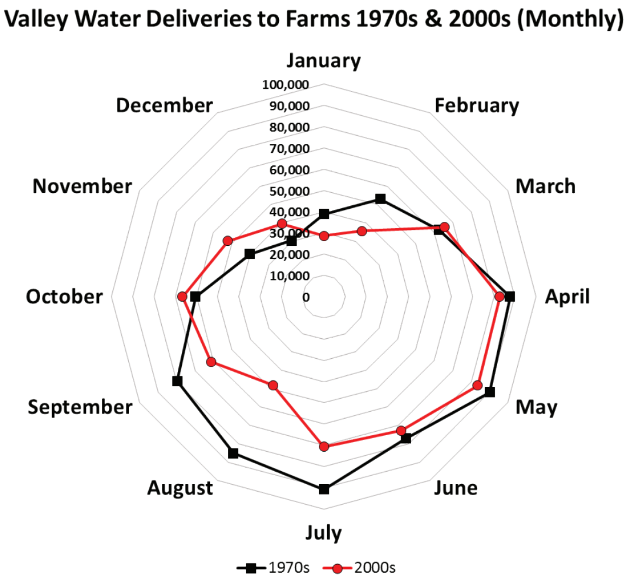


Figure 10. Mean water deliveries by month to irrigation districts in Yuma contrasting 1970s and 2000s. Image: Figure 3.5, A Case Study in Efficiency – Agriculture and Water Use in the Yuma, Arizona Area, Yuma County Agriculture Water Coalition

The introduction of genetically modified crops that are resistant to herbicides has made possible the adoption of no-till farming in Arizona. With no-till agriculture, farmers can leave biomass from harvested crops on fields, which lowers soil temperature, reducing soil evaporation and soil salinity. It can also prevent soil erosion. As of 2016, 94 percent of soybeans and 89 percent of cotton and corn grown nationwide were herbicide tolerant. Shorter season varieties of cotton have also been introduced that produce similar yields using less water. Despite concerns of some consumers, GMO crops are widely accepted as safe among scientists and farmers.

The use of cover crops is another way that farmers are able to reap the benefits of no-till farming without the use of herbicides. In Arizona, Duncan Family Farms grows cover crops that are eventually shredded to add organic material back to soils and control weeds for their entirely organic farm. Note that USDA certified organic products do not contain GMO crops. Recent growth of Arizona's organic food production industry has benefitted smaller farm operations like *McClendon's Select*, which specializes in providing locally grown organic produce to farmer's markets and locally owned restaurants throughout Phoenix, Tucson, Flagstaff and Sedona, AZ.

Other niche crops in Arizona are crops that were grown by Native Americans prior to the arrival of European settlers. One example of a traditional crop is the Tepary bean, which was originally grown by the Akimel O'Odham (Pima tribe) and the Tohono O'Odham people. Tepary beans are tolerant to low water conditions and contain high amounts of protein and fiber. Heritage crop varieties of the "Three Sisters" – corn, beans, and squash – are associated with Native American communities, where pre-European tribal farming and growing techniques are used, such as open-pollination or companion planting for high yields, low water input, and overall soil and plant protection.

Potential New Crops

Efforts to find new crops to grow are constant. For example, there are a few Arizona farmers trying to grow agave, which may be marketable for tequila, fiber, and/or biofuel. Cultivation of agave for the tequila industry has been successful in Mexico.

Industrial hemp has also been considered as a possible crop to grow in Arizona. With multiple uses including textiles, industrial hemp requires less water than cotton. A 2005 study by the Stockholm Environment Institute showed that hemp required less water per pound of useful matter than cotton. The study also noted, however, that the technology for producing hemp cloth is limited and currently requires significant manual labor.

Another limit to commercial hemp production is the misperception that the hemp plant contains the mind-altering chemical THC, which resulted in its designation as a federal Schedule 1 narcotic. As in many states, growing industrial hemp is illegal in Arizona. In 2017, legislation that passed the Arizona House and Senate would have legalized and regulated industrial hemp with a THC concentration of less than 0.3 percent. The measure was vetoed by Governor Doug Ducey. but reintroduced in 2018. Regardless of Arizona's actions, however, districts receiving water from federal projects such as CAP are prohibited from using it to irrigate industrial hemp.

Another industrial crop with potential to help desert farmers in the future is the guayule plant (Figure 11), which can be used to produce commercial rubber. The amount of water needed to grow guayule is still an active area of research. Early findings suggest that guayule water use may be comparable to sorghum and alfalfa. There have been some attempts to introduce guayule in Arizona. In 2014, Bridgestone Americas opened a facility in Mesa to test and optimize guayule growing techniques. Bridgestone intends to use guayule for future production of rubber tires. More research is needed to evaluate the viability and potential profitability of growing guayule in Arizona. Viability may depend on whether by-products not related to rubber production are marketable.

Impediments to Agricultural Water Conservation

Conserving water in agricultural operations in Arizona can be an expensive task. Since 2015, net farm incomes across the country have fallen from a peak of over $120 billion in 2014 to an estimated $62.3 billion

Figure 11. Guayule plant in the U.S. Image: (Soratana, 2013) from Rasutis et al., A sustainability review of domestic rubber from the guayule plant, *Industrial Crops and Products* 70 (August 2015) p. 384

for 2017. Most farm households earn income outside of farming, as median farm income has been negative (- $1,437 per year for 2017). This drop in farm income is primarily due to reduced crop prices. Reduced crop prices are also affecting irrigated agriculture across Arizona, and financially difficult times for farmers can make additional investments in water conservation on farms difficult.

A 2013 USDA report, based on information from the 1998 and 2008 Farm and Ranch Surveys, revealed some of the reasons farmers do not update their irrigation systems to conserve water. In Arizona, the greatest reason farmers did not install water conserving irrigation systems was the lack of financial ability to do so. A related reason was concern over whether the installation costs of a new irrigation system could be recovered from increases in crop yield or reductions of water use. Landlords of leased land were not interested in upgrading their irrigation systems, while farmers of leased land were reluctant to install an expensive irrigation system when they were unlikely to recover the cost of the system before their lease expired. In addition, the uncertain future of water in Arizona discouraged investment in new irrigation systems.

In general, farmers worried that using conservation practices will reduce their yields or profits. There is concern by some in the agricultural community that water saved from conservation practices will be permanently diverted to non-agricultural uses.

Temporary Fallowing for Conservation and Transfer

One way that farmers have worked with other water users to save water is through fallowing programs. Several such programs exist in which farmers are compensated for taking some fields out of production so that the water saved can be put to another use, usually municipal water supply. One example of fallowing is the 2003 agreement between California's Imperial Irrigation District (IID) and the Metropolitan Water District of Southern California. This agreement enabled the transfer of up to 100,000 acre-feet of water per year of IID's 3.1-million-acre-foot allotment of the Colorado River to the metropolitan areas of Southern California for 15 years. With the funds generated through fallowing, IID was able to modernize its canals and other infrastructure, which reduced the amount of irrigation system losses. Farmers also tended to fallow less profitable fields. Improved efficiency has allowed IID to bring fallowed land back into production. Importantly, the agreement included compensation for farm workers in IID and local retailers (e.g. fertilizer, seed, and equipment providers) who could expect reduced sales as a result of the program.

Because fallowing can harm agricultural communities through loss of economic activity, fallowing programs for conserving water need to include some type of community-wide compensation, in addition to individual payments to landowners. The Palo Verde Irrigation District (PVID), which is in Southern California near the Arizona border, made a 35-year water transfer agreement with the Metropolitan Water District in 2004. The deal benefited participating landowners by giving them a one-time payment of $3,170 per acre plus $604 per fallowed acre per year. Over the years, the percentage of fallowed land in the District ranged from 7 to 29 percent. The local community received $6 million; however, projected community losses were estimated to far exceed $6 million over the 35 years of the agreement.

Fallowing has also been used to conserve water in Arizona, but on a smaller scale. In 2014, Yuma Mesa Irrigation and Drainage District (YMIDD) made an agreement with the Central Arizona Groundwater Replenishment District to fallow 1,500 acres to save 7,000 acre-feet per year of Colorado River water. The water not used by YMIDD was left in Lake Mead to forestall shortage.

In rural areas there is considerable resistance to fallowing agreements because of their impacts on local communities. In addition, many farmers are concerned that fallowing for the purpose of temporary water transfers may result in the permanent loss of water rights. Furthermore, many in the agricultural community also dislike the idea of fallowing because it implies that farming is a less valuable water use than other uses. Because of these concerns, the 2015 Family Farm Alliance report on agriculture in the Colorado River Basin states that fallowing is only acceptable as a means of drought mitigation and it should not be used to support the growth of urban areas.

Collaboration Opportunities for Farmers

The agricultural industry is constantly challenged to achieve better irrigation efficiency and reduce water use. Farms are privately-owned businesses, frequently in competition with one another, which means that data on production practices are proprietary and have value. Farmers are not obligated to share information that gives them a competitive advantage. As a result, many of the advances made by farmers, from improved irrigation practices to low water use crops, have come through collaborations with the research and government communities. Public-private collaboration has been successful through research consortiums, even as public sector funding for agricultural research has declined. The Yuma Center of Excellence for Desert Agriculture (YCEDA) was formed in 2014 as a partnership between the private agricultural industry in the Southwest and the University of Arizona College of Agriculture and Life Sciences (CALS) with the goal of addressing the pressing challenges of desert agriculture.

Arizona Cooperative Extension has several programs that share research and technology with local farmers. An outreach arm of the University of Arizona and CALS, Cooperative Extension serves as a statewide network of scientists and educators who "engage with people through applied research and education to improve lives, families, communities, the environment, and economies in Arizona and beyond." In the area of agriculture and natural resources, Cooperative Extension has assisted farmers, ranchers, agency personnel, and others involved in natural resource management for over 100 years by making science useful.

The topic for this edition of the annual *Arroyo* was chosen to align with the 2017 WRRC Annual Conference, "Irrigated Agriculture in Arizona: A Fresh Perspective." This *Arroyo* contains Information presented at the conference – and much more. We are grateful to our two Conference Partners, Agribusiness & Water Council of Arizona and BKW Farms, for supporting the *Arroyo* Summer Writing Intern. Information about the 2017 Conference, including a listing of all our conference sponsors, can be found at https://wrrc.arizona.edu/conferences/2017. We expect to connect future *Arroyos* to our annual conference topics.

Another organization that works with farmers in the southwestern United States to reduce water use is the USDA Natural Resources Conservation Service (NRCS). The NRCS helps farmers to protect the environment and conserve water through both financial assistance and technical assistance and helps farmers plan and implement conservation actions, improve efficiency, and manage natural resources on their land and to comply with federal, state, or local laws.

Conclusion

The agricultural industry has a significant impact on Arizona's economy, and it is a dominant force in many rural communities across the state. Because different regions have different water conditions, farmers must consider location-specific factors in their water management decisions. Along the Colorado River and Lower Gila River, growers hold some of the oldest and most secure water rights in the state. With this water they have developed a nationally important region for vegetable production. In Central Arizona, CAP water has alleviated groundwater overdraft problems, but the potential for shortage in CAP's supply is increasing uncertainty in this region. Here, farmers and irrigation districts face the real possibility of being forced to go back to the groundwater pumps or to take lands out of production. Beyond the reach of the CAP, agriculture reliant on groundwater is watching water levels fall as communities struggle to find acceptable regulatory solutions to the threat of depletion.

Growing demands for water, food, and fiber, coupled with near-term likelihood of Colorado River shortage, have led to increased focus on Arizona's agricultural water use. Water efficiency gains have been substantial in recent decades, reducing total water use while increasing agricultural production statewide. There is still room for efficiency improvements, with the help of science and technology and financial assistance. As they continue to grow, cities and other water users will continue to look for ways to supplement their water supplies through voluntary water transactions with farmers that include attention to impacts on rural communities. Although sometimes contentious, this process can yield mutual benefits. The need for food and fiber will grow locally and globally; and because it is more reliable and productive than dryland farming, irrigated agriculture will supply this need. Finding the right balance among competing water demands in Arizona will take continued collaborations among growers, government, the scientific community, and concerned citizens.

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