Water for Arizona

Investing in Arizona's Water Future

CONSIDERATIONS FOR CONSERVATION AND AUGMENTATION PROJECTS

Water is Arizona's most precious resource.

We use it for drinking and cleaning, for spiritual and cultural practices, for recreation. We use water to grow plants that shade our cities and feed our communities. Water sustains our wildlife and habitats, our businesses and industries, and our ways of life.

However, longstanding and languishing water issues have come to a head, and threats to water supplies are here, and becoming more dire. As availability of Colorado River water decreases–some 40% of the state's water supply—our reliance on other in-state surface water and groundwater supplies will intensify. Therefore, we must strengthen and modernize our water management approach to ensure the long-term viability of a prosperous Arizona. It is critical that all water supplies in our portfolio across the state are well managed to ensure their reliability and sustainability for generations to come.

Environmental Defense Fund | wra Western Resource Advocates | Audubon | Business for Water Stewardship | American Rivers

In 2022, the Arizona Legislature increased the authorities and the level of state funding for the Water Infrastructure Finance Authority, providing Arizona with a once-in-a-generation opportunity to make high-impact monetary investments in water sustainability that support counties, municipalities, Tribes, rivers, farmers and ranchers, and businesses across the state. In order to achieve sustainable multi-benefit projects that are favorable for people and wildlife in Arizona, these investments require thoughtful planning and decision-making.

This report describes some of the potential areas for water conservation and augmentation investments, seeking to illuminate the costs, water benefits, and important considerations for different types of projects. The report is not exhaustive, but explores areas for potential investment in water projects.

Other potential projects not specifically analyzed in this report include crop-switching (growing lower-water-use crops); direct potable reuse (treating wastewater to drinking water quality standards); improved water management and efficiency technology of cooling towers (cooling towers are often used at industrial or large building facilities and consume high volumes of water); and landscape water budget programs (creating site-specific landscape watering targets for customers).

To illustrate, a crop-switching pilot project indicated that a conversion of 100,000 agricultural acres from a water-intensive crop like alfalfa to guayule (a low-water-use plant producing a rubber-like material) in Pinal County could save an estimated 150,000 acre-feet of water per year. The City of Scottsdale is successfully pioneering direct potable reuse in Arizona. A cooling tower water efficiency technology pilot project at Phoenix Sky Harbor Airport resulted in an average water savings of 48 acre-feet per year between 2018 and 2021. And the Town of Gilbert's Landscape Water Budget Program achieved water savings of 575 acre-feet in 2019.

The costs and water benefit figures included in this report are not all-encompassing and may not reflect the entirety of the costs and benefits of implementing a project going forward. The report summarizes potential project options from existing available research, sources, and literature.

Contributing Authors

Anélyse Regelbrugge, Environmental Defense Fund

Rachel O'Connor, Environmental Defense Fund

Corresponding Author

Haley Paul, National Audubon Society, Haley.Paul@audubon.org

Definitions

PROJECT TYPE

The way in which water benefits are achieved, either conservation or augmentation

Conservation: water benefits are achieved through a reduction in demand/usage

Augmentation: water benefits are achieve through an increase in supply

WATER BENEFIT ACCRUAL

The longevity of the water benefits or savings gained from the project

Annual: water benefits or savings accrue only in the year the project was implemented and/or there are continued annual operational needs in order to derive water benefits

Perennial: the project provides ongoing water benefits or savings year after year without additional investments or operational needs

TIMEFRAME

The length of time needed to implement the project, including planning, permitting, and construction

●○○ **Near-term**: the project could be implemented within three years or less

●●○ **Mid-term**: the project could be implemented within the four to nine years

●●● **Long-term**: the project would take ten years or more to implement

Note: Planning, permitting and construction times can be difficult to estimate and unforeseen circumstances could result in delays that would extend the time needed for implementation

COST

The estimated dollar-per-acre-foot cost range for each project type calculated from project cost and water benefit data

Note: there is a lack of comprehensive sources from which to determine the true cost of projects. The figures in this report pull from readily available and publicly accessible information, but may not reflect all of the costs associated with project development, implementation, and maintenance.

Colorado River. Photo: herdiephoto/Flickr (CC-BY-2.0)

System Conservation

$170-$400/acre-foot

System conservation is an approach specific to the Lower Colorado River states (Arizona, California, Nevada) that utilizes water conservation methods to offset declining water levels in reservoirs. By using less water, water users bolster water levels in Lake Mead. Participants enrolled in system conservation programs sign a voluntary agreement to implement specific and temporary water conservation measures for a set duration of time in return for monetary compensation.[1] The philosophy of system conservation is to **make voluntary, compensated reductions in water use now, in order to reduce the risk of more severe (and uncompensated) shortages later**.

ON THE GROUND: WHAT DOES IT LOOK LIKE IN PRACTICE?

Parties to an agreement–usually states, government agencies, and organizational partners–negotiate the terms including the target amount of water to be conserved, time frame, budget, and other logistics. The parties then establish funds to pay enrolled participants–municipalities, Tribal nations, and farms and irrigation districts, for example. Enrolled participants implement conservation measures to leave water in Lake Mead through activities such as using less water in urban areas, irrigation efficiency improvements, forgoing delivery of water for underground storage, and the temporary fallowing of farmland.

COSTS AND WATER BENEFITS

The budget for any given system conservation project is tailored to that project, but the costs for system conservation projects already implemented in the Lower Colorado River Basin range from **$170-$400 per acre-foot.**[2,3,4]

In 2014, the Bureau of Reclamation initiated a Pilot System Conservation Program to address drought in the Lower Colorado River Basin by engaging multiple stakeholders in testing a range of water conservation techniques. The Pilot Program is expected to conserve 175,347 acre feet of water in Lake Mead by 2035 for an average cost of **$170.14 per acre-foot** or $29.8 million in total. And the Federal/non-federal (funding from Lower Basin municipal water utilities, for example) cost share is 47/53 percent, respectively.[2]

1 *AMWUA. (2021, October 21). Protecting the Colorado River with system conservation. AMWUA. Retrieved February 5, 2022, from https://www.amwua.org/blog/protecting-the-colorado-river-with-system-conservation#:~:text=The%20most%20recent%20effort%20of,up%20to%20180%2C000%20acre%2Dfeet*

2 *Bureau of Reclamation. (2021, August 31). Lower Colorado Region Pilot System Conservation Program. Lower Colorado Region | Bureau of Reclamation. Retrieved February 6, 2022, from https://www.usbr.gov/lc/region/programs/PilotSysConsProg/pilotsystem.htm*

In 2020, the Colorado River Indian Tribes (CRIT) signed a System Conservation Agreement to help the State of Arizona fulfill its obligations under the Drought Contingency Plan. The CRIT Pilot System Conservation Project will conserve 150,000 acre-feet over the course of three years and cost $38 million at $253/acre-foot.[3]

In 2022, the Department of Interior announced the creation of the Lower Colorado River Basin System Conservation and Efficiency Program. Funded through the Inflation Reduction Act, this program seeks to stabilize the water levels in the reservoirs of Lakes Powell and Mead. Participants can choose to enter into a one, two, or three-year system conservation agreement and receive **$330 per acre-foot, $365 per acre-foot,** or **$400 per acre-foot,** respectively.[4]

WATER BENEFIT ACCRUAL

System conservation focuses on **leaving water in the reservoir system,** allowing the water conservation benefits to start accruing instantly. These water benefits accrue on an annual basis, meaning that system conservation provides water benefits in the year that it occurs.

With this current model and ongoing financial support, a system conservation plan can remain in place for as long as is collectively desired to reduce the risk of reaching catastrophically low lake levels; this is accomplished by paying water users to not to take water each year for a set amount of years in order to bolster water levels in Lake Mead.

CONSIDERATIONS

- There are federal cost-share opportunities and options for non-federal third-party funding.
- Fosters partnership among stakeholders including tribes, farmers and ranchers, municipalities, NGOs, etc.
- As greater volumes of system conservation are needed–and from higher priority water users–this may cause the price per acre-foot to increase.
- System conservation can be an important stop-gap measure, but it is not a permanent solution to addressing long-term declines in water availability.

3 *Colorado River Indian Tribes. (2020). Colorado River Indian Tribes Assumes Major Role in Drought Relief Efforts in Arizona and Western U.S. [Press release]. Retrieved from* https://www.crit-nsn.gov/post%20release.pdf

4 *U.S. Department of Interior. (2022, October 12). Biden-Harris Administration Announces New Steps for Drought Mitigation Funding from Inflation Reduction Act [Press release]. Retrieved from* https://www.doi.gov/pressreleases/biden-harris-administration-announces-new-steps-drought-mitigation-funding-inflation

Xeriscape urban landscape. Photo: Arizona Municipal Water Users Association

Urban Landscape Conversion Programs

$1,600–$6,500/acre-foot

Outdoor landscaping in Arizona accounts for as much as 70% of residential water use with millions of additional gallons used for non-residential spaces such as common area landscaping in Homeowners Associations, parks, and schools.[5] **Landscape conversion programs create opportunities to increase low-water use landscaping, and ultimately, reduce outdoor water use.** Such programs typically involve offering financial incentives, such as rebates, to property owners for transitioning to landscaping that requires less water. One common example of this is to offer a rebate for removing lawn (also called turf) and replacing it with low-water landscaping (xeriscaping).

ON THE GROUND: WHAT DOES IT LOOK LIKE IN PRACTICE?

Once a municipality or other jurisdiction or water provider decides to initiate a landscape program, it establishes the parameters of the program. For a turf removal program, for example, this can involve setting the rebate rate per square-foot of turf removed, the minimum amount of turf removal necessary to be eligible, the maximum amount of compensation per applicant, as well as establishing some guidelines for what to do with the land post-turf removal.

As soon as the program is in place and advertised to the public, rebates are delivered to applicants based on program standards. The municipality usually establishes mechanisms to verify compliance with the program requirements. An additional rebate may be offered to participants who replace turf with certain types of low-water-use plants.

COSTS & WATER BENEFITS

Based on existing turf removal rebate programs, rates vary from **$0.25 to $1.00 per square foot of turf removed.** Program specifics may also vary depending on whether the applicant is a residential or commercial customer. And municipalities will typically set maximum rebate caps, which can range from $750 to $5,000 per customer.

5 *ADWR. (2022). Landscaping - Residential and Professional. Arizona Department of Water Resources. Retrieved February 10, 2022, from https://new.azwater.gov/conservation/landscaping*

Turf removal, especially when bolstered by xeriscaping, can **reduce a household's outdoor water use by 50%.**[6] This **saves an estimated 24.6**[7] **to 55.8**[8] **gallons of water per square foot per year for each household.**

Paying $0.25-$1.00 per square-foot of turf removed adds up to $10,980-$43,560 per acre of turf removed. If there is an average annual water savings of 50 gallons per square-foot of turf removed, that converts to a savings of 2.2 million gallons of water per acre of turf removed, or 6.7 acre-feet. Therefore, a rebate that pays $0.50 per square-foot of turf removed, that yields a annual water savings of 50 gallons per square-foot, then costs around **$3,260 per acre-foot of water savings.**

Municipal landscape programs can adapt to each unique municipality. Examples of Arizona municipalities that have already adopted turf removal rebate programs are Chandler, Scottsdale, Tempe, Glendale, Flagstaff and Mesa, as well as several others.

WATER BENEFIT ACCRUAL

Municipal landscaping programs can start saving water as soon as they go into effect, and the actual turf removal and xeriscaping is typically complete in less than a year. Furthermore, the water savings continue to accrue over time, meaning total water benefits can increase the longer the program is in place. This is a one-time cost in the rebate yields and ongoing, year-over-year water savings. The ongoing water savings helps justify the higher up front costs.

Because **water benefits accrue over time,** the cost per acre-foot of water saved is reduced each year. For example, if turf is permanently removed from an acre of land, over five years there will be a total savings of 33.4 acre feet, reducing the initial cost of $3,260 per acre-foot to $651 per acre-foot by year five (with continued savings after that).

CONSIDERATIONS

- Turf removal and xeric, or low-water-use landscaping, have been shown to quickly pay off the up front costs by reducing the participant's water bills and decreasing expenses spent on lawn maintenance (in addition the rebates given).[8]
- Landscape conversion can support native plants while reducing water demands, landscape maintenance, and the use of lawn chemicals.
- Public communications about the importance of water conservation and the household savings made possible by xeriscaping are important to promoting program participation.[8] Many homeowners and renters want to know how they can help with the water crisis, this is one of those ways.
- In addition to landscape conversion, there are other municipal water savings rebate programs that may be paired, such as rainwater harvesting programs like the one offered by the City of Tucson.

6 *AMWUA. (n.d.). Good Reasons to Take Out Your Grass. Arizona Municipal Water Users Association.*

7 *Tull, C., Schmitt, E., & Atwater, P. (2016). (rep.). How Much Water Does Turf Removal Save? Applying Bayesian Structural Time-Series to California Residential Water Demand. California Data Collaborative.*

8 *Sovocool, K., Morgan, M., Bennett, D. (2006). An in-depth investigation of Xeriscape as a water conservation measure. Journal - American Water Works Association, 98(2), 82–93. https://doi.org/10.1002/j.1551-8833.2006.tb07590.x*

Drip irrigation on wheat fields. Photo: Hugo Gomez, CIMMYT/Flickr (CC BY-NC-SA 2.0)

Agricultural Drip Irrigation

$640–$2,500/acre-foot

Irrigated agriculture accounts for roughly 74% of Arizona's water use,[9] with more than 945,000 acres of irrigated agriculture in the state.[10] The most commonly used techniques to irrigate crops are flood, sprinklers, and drip. Flood irrigation generally uses gravity to thoroughly cover a field in water which then soaks into the soil. Similar to residential irrigation, sprinkler irrigation uses hoses, pipes, and pressurized heads to apply water. Drip irrigation, sometimes called micro-irrigation, uses low-pressure water pipes to deliver water that slowly drips onto the crop roots and stems[11], resulting in successful percolation into the soil and very little evaporation. In Arizona, roughly 88% of irrigated acres have a flood system, 16% have a sprinkler system, and 8% utilize a drip system (the total percentage is greater than 100% because there can be multiple systems covering the same acreage).[10]

ON THE GROUND: WHAT DOES IT LOOK LIKE IN PRACTICE?

Drip systems vary and need to take into account specifics of the field including crop type, soil type, and topography. Drip systems are highly efficient, however efficiency does not always equate to conservation or water savings, because farmers can take the water saved from efficiency and then apply it to more land or higher water use crops. Real savings are highly dependent on place, irrigation system, and hydrologic context.

Installation of drip usually involves a pump unit with controls for moving water from the source and through the pipe system, water lines to transport the water across the field, and water emitters to apply the water directly to the plants' roots. Because water lines are usually buried underground, filtration systems may be required as well.[12]

Some types of drip irrigation use gravity instead of a pump to efficiently distribute water, and drippers can be designed to be more resilient to dirt particles so there is no need for filtration, reducing expenses and maintenance requirements.[13]

9 *ADWR. (2022). Conservation: Agriculture. Agriculture | Arizona Department of Water Resources. Retrieved February 13, 2022, from https://new.azwater.gov/conservation/agriculture*

10 *U.S. Department of Agriculture. 2019. Table 28. Method of Water Distribution if Fields in the Open. 2017 Census of Agriculture, 2018 Irrigation and Water Management Survey. Volume 3, Part 1. Retrieved from: https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Farm_and_Ranch_Irrigation_Survey/fris.pdf*

11 *Lahmers, T., & Eden, S. (2018). Water and Irrigated Agriculture In Arizona. Arroyo.*

12 *FAO Land and Water Division. (n.d.). Irrigation Water Management: Irrigation Methods - Drip Irrigation. Chapter 6. Drip Irrigation. Retrieved February 11, 2022, from https://www.fao.org/3/s8684E/s8684e07.htm#chapter%206.%20drip%20irrigation*

13 *N-Drip Gravity Micro Irrigation. "N-Drip - Frequently Asked Questions." Accessed October 4, 2022. https://ndrip.com/faq/.*

COSTS & WATER BENEFITS

Drip irrigation systems typically cost **$1,500 to $2,500 per acre installed,**[11,14] with cost variances due to the type of drip system as well as crop type and field layout. Depending on the type of drip system, additional costs may be associated with pumps, filters, and energy requirements.

After the 2020 Irrigation Efficiency Pilot Program—a collaboration between the Central Arizona Water Conservation District (CAWCD), the Colorado River Indian Tribes (CRIT), and the University of Arizona—demonstrated a 30-50% water savings when converting to drip irrigation compared to flood irrigation for a comparable crop yield.[15]

There is limited publicly available data that quantifies the cost per acre-foot for drip conversion, but available data can be used to determine an estimated range. In Arizona, the state average water application rate for irrigated agriculture is 4.7 acre-feet of water per acre of land.[16] In a conservative scenario, if the drip system costs $2,500 per acre to install and yields a water savings of 22%, which equates to 1 acre-foot per acre, the cost will be $2,500 per acre-foot for the first year. Since the water benefits continue to accrue after the up-front investment has been made, the cost would reduce to $500 per acre-foot after five years of operation, and would continue to reduce over time. If the drip system costs $1,500 to install and results in a 50% water savings, the cost per acre-foot is $640. These values assume that the water saved from increased efficiency is not put to a new use, resulting in true water conservation.

WATER BENEFIT ACCRUAL

Water savings can begin immediately after installation of the drip irrigation system, depending on local conditions and context, and water benefits can continue to accrue year over year. However for water benefits from drip conversion to be realized it is critical that conserved water actually results in reduced water use on the farm. As long as any conserved water is not then used to grow more crops, the water benefits will continue to accrue the longer the system is in place. Drip irrigation allows for water savings when less water is used to grow the same amount of crops (conservation); versus the same amount of water but using it to grow more crops (efficiency).

CONSIDERATIONS

- Without proper mechanisms in place, conversion to drip irrigation can sometimes result in more water leaving the system. Highly efficient drip minimizes percolation, meaning that water applied to a field is not likely to recharge an aquifer or flow back into a stream. In order to achieve water benefits, conversion to drip needs to result in a net reduction in the amount of water pumped from the ground or diverted from a river or stream; to achieve an actual reduction in water use, water savings cannot be used to increase irrigated acreage or support new municipal or industrial uses.
- The CAWCD/CRIT Irrigation Efficiency Pilot Study showed that drip irrigation led to similar or higher crop yields, and reduced input costs as less water and fertilizer were needed.[15]
- The burden of high upfront costs for installing drip irrigation can be alleviated by lower total spending on water year-over-year and investing in pilot and incentive programs where some of the upfront costs

14 *Mendoza, A. (2018, February 14). Arizona farmers look for ways to save water. Cronkite News - Arizona PBS. Retrieved February 24, 2023, from https://cronkitenews.azpbs.org/2018/02/09/arizona-farmers-look-for-ways-to-save-water/*

15 *Cullom, C. (2022). (rep.). Irrigation Efficiency Pilot Study Agreement with N-Drip in Partnership with Colorado River Indian Tribes for 2022 Milo. Central Arizona Project.*

16 *USDA National Agricultural Statistics Service. (2019). 2017 Census of Agriculture Highlights: Irrigation and Water Management. USDA. Retrieved November 26, 2022, from https://www.nass.usda.gov/Publications/Highlights/2019/2017Census_Irrigation_and_WaterManagement.pdf*

are subsidized and not the sole responsibility of the farm owner/ operator. For example, the On-Farm Irrigation Efficiency Grant Program could soon allocate $30 million to the University of Arizona's Cooperative Extension to assist with the installation of irrigation efficiency projects.[17]

- Converting to drip irrigation may not be appropriate for every type of crop or every type of field.
- Farmers who lease the land on which they grow may be hesitant to invest in drip irrigation if they do not know how long they will be farming on that land.

17 *SB 1564, Fifty-Fifth Legislature, 2022 Second Reg. Sess. (Ariz. 2022). Retrieved October 25, 2022, from https://www.azleg.gov/legtext/55leg/2r/bills/sb1564h.htm*

Cathedral Rock and Oak Creek. Photo: Coconino National Forest

Invasive Plant Removal and Replacement with Native Species

$260–$1,050/acre-foot

Many invasive plant species grow along Arizona's rivers, including the Colorado, Salt, Verde, and the Gila. These non-native species–such as tamarisk (also known as salt cedar) and arundo–often thrive in degraded river systems, outcompeting native species such as cottonwood and willow. In some situations, invasive plants can use more water than native plants; invasive plants also have the detrimental effects of channelizing rivers. Therefore, removing invasive plants in key stretches may help increase groundwater levels and improve river health. Once invasive plants are removed, the properly selected native plant species can be planted, contributing to beneficial ecosystem functions while potentially consuming less water.[18]

Although invasive plant removal could have far-ranging benefits, it is still a relatively untested method of water conservation. Additional funding for research and pilot programs is needed to quantify potential available water savings and its impact on improving river health and function.[19]

ON THE GROUND: WHAT DOES IT LOOK LIKE IN PRACTICE?

After a river site is selected based on careful study, the invasive plant removal can begin. There are many methods of removing invasive plants, including chemical, mechanical/physical, or biological methods.

After removal, replacement vegetation should be planted to maintain streambank stability, soil health, biodiversity, and prevent the resurgence of invasive plants. The chosen plant varieties should be native and appropriate for the existing hydrology of the area. For instance, upland plant varieties such as mesquite, palo verde, or native desert shrubs might be more appropriate in some locations if the depth to groundwater near the river would be unlikely to support cottonwoods and willows, which need consistent access to water to thrive. Taking this all into consideration could help increase streamflow, restore groundwater levels, and improve river health and function.

18 *Carollo Engineers. (2019). Long-Term Water Augmentation Options for Arizona. Arizona Department of Water Resources.*
19 *Porter, S. (2020). Summary of Research on Management of Invasive or Encroaching Plant Species as a Water Augmentation Strategy.*

COSTS & WATER BENEFITS

The cost of invasive plant removal and native species replanting varies greatly depending on the method of removal, the extent of removal, maintenance requirements, resulting hydrologic and ecosystem changes, and the method and type of native vegetation replanting. For this reason, experts recommend case-by-case cost benefits analysis be included in any invasive plant removal project.

A study of tamarisk and Russian olive tree removal in the Colorado River Basin estimated **a cost range from $260 to $1,050 per acre-foot.**[20]

WATER BENEFIT ACCRUAL

The amount of water savings from invasive vegetation removal depends on several factors, including transpiration rates of both the removed vegetation and the replanted vegetation, depth of the groundwater table, change in evaporation rate from microclimate changes, change in hydrologic conditions from ground cover removal and soil disturbances from the removal process.[21] The water savings accrue year over year, meaning there are increasing water benefits as time passes after removing invasive plants and replacing them with native plants.

One study on the benefits of tamarisk removal estimated **evapotranspiration savings of 50-60%** over the first few years of removal and replanting, amounting to about 1 acre-foot of water saved for every 1.85 acres of invasive plant removal.[20] However, constant management is often required to prevent invasive vegetation regrowth in the restored ecosystem and the long-term water benefit of invasives removal is dependent on circumstances such as site maintenance and the water demands of the native plants that replace the invasives.

CONSIDERATIONS

- Co-benefits include: soil and river health improvement, reduction of flood and wildfire risk, and potential to improve wildlife habitat.
- Uncertainties include: risk of soil erosion, negative hydrologic alteration, sedimentation, and increased evaporation.
- It may not always be feasible to replace invasives like tamarisk with cottonwood and willow, for example, if the river's water levels are insufficient or have been greatly altered.
- Removal sites should be selected based on the additional co-benefits that could be achieved by removal at that location.
- Specific site characteristics should be evaluated when determining which native plants to replace the removed invasive plants with. Invasives should not be removed without consideration of which native plants to replace them with. Consider the wildlife species impacted by invasive plant removal as well.
- It is important to fund and support interdisciplinary research and pilot programs in order to understand the full range of costs and benefits of applying invasive plant removal at any location.
- Invasive plants thrive in our water-stressed rivers, therefore, ongoing maintenance is often essential to prevent regrowth.
- Invasive plant removal is a time-intensive process due to the research, planning, permitting, and careful removal and restoration work required.

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20 *Tamarisk Coalition. (2009). Colorado River Basin Tamarisk and Russian Olive Assessment. https://riversedgewest.org/sites/default/files/files/TRO_Assessment_FINAL%2012-09.pdf*

21 *Nebraska Natural Resources Department. (2017). Riparian Evapotranspiration and Removal of Invasive Vegetation.*

Storm near Sedona, Arizona. Photo: Trey Radcliff/Flickr (CC BY-NC-SA 2.0)

Aquifer Recharge

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$270–$1,500/acre-foot

Aquifer recharge projects involve capturing water and storing it underground to replenish the aquifer. Aquifer recharge can occur with stormwater, reclaimed water (treated wastewater, sometimes called effluent), or surface water, such as the Colorado River. Water can be recharged into built infrastructure, such as infiltration basins, or natural infrastructure, like existing stream and river beds. The recharged groundwater can help replenish what is pumped out by water users and can also augment existing groundwater supplies by storing additional water underground.[18]

ON THE GROUND: WHAT DOES IT LOOK LIKE IN PRACTICE?

In Arizona, managed recharge is the process of putting surface water or reclaimed water into dry stream channels in order to percolate into the aquifer. An added benefit to this method of recharge is that it can also create and restore riparian habitat.

Constructed recharge allows for water to be stored in an aquifer by using some type of constructed device, such as an injection well or percolation basin.

Stormwater capture involves digging dry wells, channels, and/or water detention or spreading basins to channel stormwater and facilitate rapid percolation underground, benefitting groundwater and potentially benefiting nearby streamflows if sited appropriately.

In urbanized areas, where the built environment is paved and covered with homes and buildings, stormwater is prevented from being absorbed into the ground and instead flows along paved surfaces. This is known as Urban Enhanced Runoff, which creates flood and water pollution risks. When it rains, water that runs off of streets, rooftops, and other impervious surfaces can be directed into the stormwater capture infrastructure and then delivered to a recharge site, in turn replenishing the aquifer.

COSTS & WATER BENEFITS

Project costs will vary greatly depending on the type of recharge project, the recharge site, and the volume of water to be recharged. The cost of aquifer storage, if it also comes with well recovery and treatment may vary **between $800 and $1,500 per acre-foot of water.**[18] It is less expensive if considering solely the costs to construct aquifer recharge sites to get reclaimed water or surface water into the ground.

The Santa Cruz River Heritage project is an example of managed recharge. The Santa Cruz River in Tucson previously flowed year-round, but due to groundwater withdrawals, drought, and climate change, the river is often dry. The Santa Cruz River Heritage Project puts reclaimed water into the river channel to create a flowing river, restore habitat, and recharge groundwater. The City of Tucson earns long term storage credits for the water that is recharged, which they can pump it out at a later date if needed. The construction cost was about $850,000 and the project can add up to 3,150 acre-feet of water per year,[22] translating to **$270 per acre-foot**, with the per acre-foot cost of recharge decreasing each year that water is recharged through the project (since the cost is high upfront, to construct the recharge facility).

Portions of the Santa Cruz River can now flow year-round, resulting in the restoration of an important cultural site. The managed recharge project has also created riparian habitat, attracting bird and fish species while also replenishing the aquifer.

In 2020, the Arizona Department of Transportation (AZDOT) conducted a promising stormwater recharge pilot project in the Prescott Active Management Area.[23] The AZDOT study estimated a project total of around $95,000 from the evaluation to reporting stages.

For other examples, see the Arizona Water Banking Authority's list of groundwater storage and savings facilities across the state, and this storymap on the Central Arizona Project's Recharge Program.

WATER BENEFIT ACCRUAL

Water savings begin as soon as the project is complete and generally accrue on an annual basis. The benefits accrue annually only if water is directed to the aquifer recharge facility to be stored underground. Some projects may include a donation, or cut, to the aquifer that is either a percentage of the water recharged, or the full amount (meaning some groundwater that is recharged is never allowed to be pumped back out; it is left there for the overall health of the groundwater system and nearby rivers). Different types of projects require various levels of infrastructure and permitting, which may affect how the water benefit accrues.

The City of Chandler and Cochise County demonstrate two notable examples of stormwater capture programs. In 2005, the Chandler stormwater recharge project reported a recharge average of **2,100 to 3,100 acre-feet per year.**[24] This water is considered "donated" to the aquifer as it cannot be pumped back out in the same manner as the managed and constructed groundwater recharge sites. Stormwater put into the ground differs from reclaimed water or Colorado River water put underground because legally, stormwater captured and recharged underground does not accrue long term storage credits that a water user can pump back out at a later time. The Cochise Conservation Recharge Network projects have recharged about 17,169 acre-feet over a six-year period starting in 2015, **averaging 2,863 acre feet per year.**[25]

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22 *The Santa Cruz River Heritage Project - frequently asked questions & fast facts. City of Tucson. (2019, August 13). Retrieved October 25, 2022, from https://www.tucsonaz.gov/water/wwe201908*

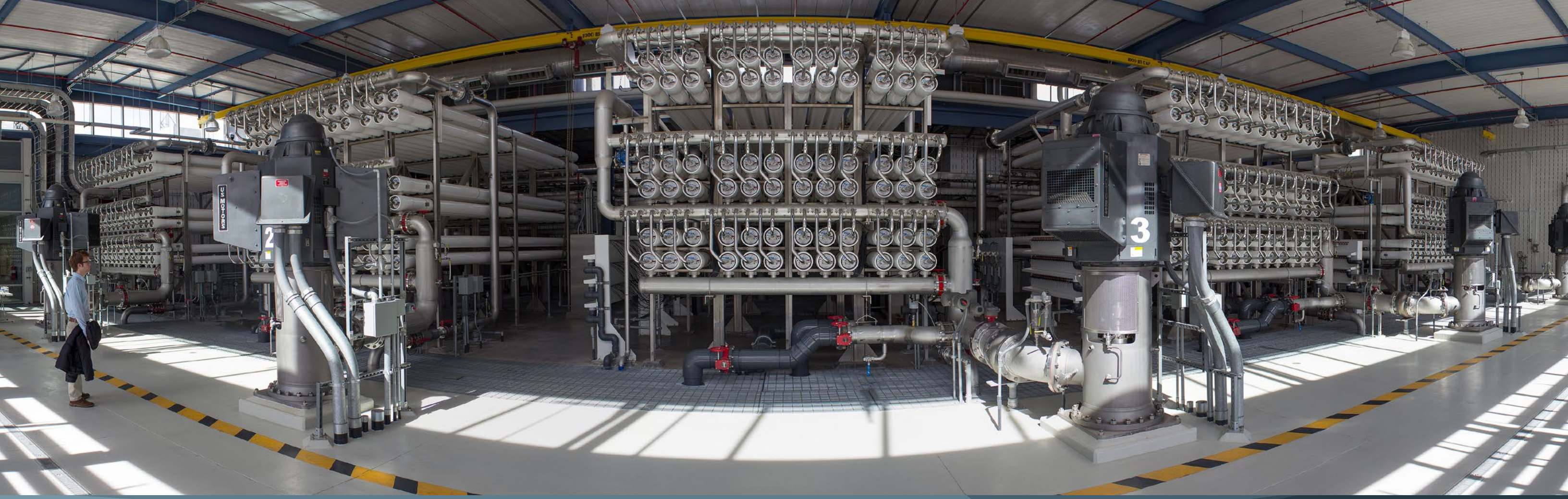
23 *AZDOT. (2020) SR 89 Stormwater Recharge Pilot Program. Arizona Department of Transportation*

24 *Geosystems Analysis Inc. (2005). Preliminary Assessment of Increased Natural Recharge Resulting from Urbanization and Stormwater Retention within the City of Chandler. https://www.researchgate.net/publication/299579764_Preliminary_Assessment_of_Increased_Natural_Recharge_Resulting_from_Urbanization_and_Stormwater_Retention_within_the_City_of_Chandler*

25 *Cochise Conservation and Recharge Network. (2020). Five-Year Review and Annual Report 2020. https://ccrnsanpedro.org/wp-content/uploads/2021/06/CCRN-Annual-Report-2020.pdf*

CONSIDERATIONS

- For new stormwater capture/water infrastructure projects, it is often necessary to purchase or lease land. Costs can be reduced by repurposing existing flood control infrastructure or natural infrastructure for water capture and recharge.
- The amount of water that can be recharged at any location is highly variable and dependent on site features, the amount of water available to be recharged, and the permitted volume of water.
- Groundwater modeling helps to get a better sense of the unique features and status of the groundwater dynamics in the proposed recharge area. This analysis can inform what infrastructure and other methods the project should employ.
- Depending on location (within an Active Management Area or outside one) there may be differing levels of support and guidance from the Arizona Department of Water Resources to quantify, measure, and permit groundwater recharge sites and their potential impact to the aquifer.
- Outside of Active Management Areas, there are few rules limiting groundwater withdrawals. This means that an aquifer recharge project could be constructed, but the ongoing benefits to the groundwater system are at risk because there is nothing to stop large groundwater users from pumping unlimited amounts of water, even if that water was stored by the recharge project.
- Long-term monitoring and maintenance of recharge and recovery infrastructure are also required.



Desalination plant. Photo: Jeffrey Phillips/Flickr (CC BY-NC-SA 2.0)

Desalination

Brackish: $1,500–$2,000/acre-foot
Ocean: $2,500–$3,000/acre-foot

Desalination is the process of removing salts from saline water so it can be used as freshwater. In Arizona, there are two types of desalination projects generally being discussed: intrastate brackish groundwater desalination and binational seawater desalination in cooperation with the country of Mexico. Brackish groundwater desalination involves pumping and desalinating groundwater that contains high levels of mineral salts, whereas seawater desalination involves withdrawing water from the ocean for treatment.

ON THE GROUND: WHAT DOES IT LOOK LIKE IN PRACTICE?

A site for a desalination facility is chosen—usually based on a range of factors including the saline water source, environmental impacts, proximity to and impact upon the intended water users, and access to significant energy sources. Agreements about saline water withdrawals/diversions are made with the relevant jurisdictional authorities.

Next would be the construction of the desalination infrastructure consisting of saline water extraction mechanisms and the desalination facility itself, as well as required infrastructure for other purposes including energy and water transportation and brine management.

Binational seawater desalination was explored in detail in a 2020 study by the Binational Desalination Work Group.[26] As proposed by the 2020 study, an exchange agreement between the U.S. and Mexico would need to be developed so that the U.S. could use some agreed upon portion of Mexico's allotment of Colorado River water, while Mexico uses the desalted water.

Recently, the company IDE proposed a desalination plant in the Gulf of California with a pipeline to directly deliver the desalted water into Arizona.[27] A facility would be built in Mexico to extract saline water from the Gulf of California, then a pipeline hundreds of miles long would need to be constructed to transport the desalted water to the Central Arizona Project canal for distribution to Arizona water users.

26 *Binational Desalination Work Group. (2020, April). Binational Study of Water Desalination Opportunities in the Sea of Cortez. Retrieved February 6, 2022, from* https://library.cap-az.com/documents/departments/planning/colorado-river-programs/Binational-Desal-Study-Executive-Summary.pdf

27 *Loomis, B. (2022, December 21). Arizona gets serious about piping water from Mexico in nonbinding desalination resolution. The Arizona Republic. Retrieved January 5, 2023, from* https://www.azcentral.com/story/news/local/arizona-environment/2022/12/21/arizona-piping-mexico-water-desalination-colorado-river-dwindles/69745907007/

COSTS & WATER BENEFITS

Intrastate brackish aquifer water desalination is estimated to cost $1,500 to $2,000 per acre-foot[18] and typically costs several million dollars to develop in total.[28] Seawater desalination, on the other hand, can cost upwards of $3,000 per acre-foot. In 2023, water delivered from the Claude "Bud" Lewis Carlsbad Desalination Plant in San Diego, California is estimated at $3,050 per acre-foot, which covers fixed and variable costs associated with plant operations and water production.[29] These costs are estimated costs for water and do not include capital construction or ongoing energy costs.

In the recently proposed IDE desalination project, the initial phase has an estimated cost of $5.5 billion. This figure does not include long term energy and maintenance costs. Water delivered from the plant has a current estimated cost of at least $2,500 per acre-foot.[27]

WATER BENEFIT ACCRUAL

The amount of freshwater converted via desalination depends on a variety of factors such as the condition of the saline water source.

The seawater desalination plant currently operating in San Diego provides between 48,000 acre feet and 56,000 acre-feet per year.[29]

The 2020 binational desalination study anticipates that desalination facilities would be able to produce about 100,000 acre-feet of treated water per year. It was noted that the maximum size of any opportunity (or combination of opportunities) is 200,000 acre-feet per year.[26] The 2020 binational desalination study also estimated the total capital costs alone at around $3.5 billion, and the annual operating and maintenance costs at around $70 billion to $100 billion.[26]

In the first phase of the IDE proposal, a desalination facility would purportedly produce 300,000 acre-feet per year, with the capacity to reach a maximum of 1,000,000 acre-feet per year in close to a decade.[27] The water benefits of desalination accrue on an annual basis because water would need to be treated and delivered every year to produce the augmented water.

Although it depends on the degree of legal and technical complexities involved for each site, because of the high costs, intensive capital requirements, energy needs, and regulatory technicalities, most desalination projects take many years to plan, develop, and eventually implement.

CONSIDERATIONS

- Both brackish and seawater desalination are projected to take up to 30 years to implement.[18]
- Desalination is energy-intensive and, depending on the need for transporting the water, the capital costs of energy infrastructure could reach $200,000,000 and operational energy costs could reach $80,000,000.[26] The U.S. Department of Energy estimates that the energy costs of desalination pumps alone account for around 25% to 40% of the cost of the desalinated water.[30]

28 *Public-private partnerships recommended for desalination financing. wrrc.arizona.edu. (2016, December 10). Retrieved February 7, 2022, from https://wrrc.arizona.edu/awr/s11/financing*

29 *San Diego County Water Authority. (2022). (rep.) Seawater Desalination: The Claude "Bud" Desalination Plant And Related Facilities. https://www.sdcwa.org/wp-content/uploads/2020/11/desal-carlsbad-fs.pdf*

30 *Office of Energy Efficiency and Renewable Energy. (2019, April). Powering the Blue Economy: Exploring Opportunities for Marine Renewable Energy in Maritime Markets: Desalination. United States Department of Energy. Retrieved February 7, 2022.*

- The U.S.-Mexico desalination plants explored in the 2020 binational desalination study were projected to produce about 100,000 acre-feet of water.[26] This would not be sufficient to fully offset Arizona's Colorado River water use reductions, which were already up to 800,000 acre-feet in 2022.[31]
- The desalination process generates significant brine as a waste product of the process, which could pose a threat to the environment if not properly managed. Brine management infrastructure for Arizona desalination options is estimated to cost up to nearly $130,000,000.[26]
- Among the jurisdictional or regulatory considerations to accessing and/or transporting the water is the potential for encroachment on Indigenous lands or communal lands (ejidos), as well as designated wildlife areas and natural parks.[26]

31 *Arizona Department of Water Resources. (2022, July). AZ water leaders lay out plans for facing the emerging crisis in the Colorado River system . Arizona Department of Water Resources. Retrieved January 13, 2023, from* https://new.azwater.gov/news/articles/2022-22-07

Water pipeline. Photo: LoggaWiggler

Mississippi/Missouri Pipeline

$2,300/acre-foot

In 2021, the Arizona Legislature requested funding for a feasibility study of building a diversion dam and pipeline to harvest floodwater from the Mississippi River and transport it to the Colorado River Basin. This request was included in HCM 2004.[32] Although the requested study has not been completed, a 2012 study by the U.S. Bureau of Reclamation (USBR) considered the possibility of importing water from either the Missouri River or Mississippi River to the Colorado River Basin.[33] And in 2022, the Arizona Legislature passed legislation that authorized a newly-boosted Water Infrastructure Finance Authority (WIFA) of Arizona, with a directive that 75% of the available funds (projected to be $1 billion total) be devoted to projects that import water into Arizona from out of state.[34]

ON THE GROUND: WHAT DOES IT LOOK LIKE IN PRACTICE?

With federal funding, a dam would be built to divert floodwater from the Mississippi River. A complex pipeline system would, in theory, transport and deliver the Mississippi River water. The destination of this water is unknown at this time. The 2012 USBR study identified the potential destination as "areas adjacent to the (Colorado River) Basin." The recently proposed HCM 2004 says the water would be used to "replenish the Colorado River." In either case, the pipeline would likely have to be around 700-900 miles long at minimum to cover the distance between the Mississippi River and the Colorado River (or one of its tributaries). By comparison, the CAP pipeline that currently delivers Colorado River water to Central Arizona is 336 miles long.[35]

Systems for integrating, treating, and distributing the Mississippi water would also likely require funding and construction.

32 *HCM 2004, 2021. Fifty-fifth Legislature, 2021 First Reg. Sess. (Ariz. 2021)* https://apps.azleg.gov/BillStatus/BillOverview/75036

33 *USBR. (2012.) Colorado River Basin Water Supply and Demand Study Report F-Development of Options and Strategies. RECLAMATION: Managing Water in the West. Retrieved January 16, 2023, from* https://www.usbr.gov/lc/region/programs/crbstudy/finalreport/Technical%20Report%20F%20-%20Development%20of%20Options%20and%20Stategies/TR-F_Development_of_Ops&Strats_FINAL.pdf

34 *SB 1740, 2022. Fifty-fifth Legislature, 2022 Second Reg. Sess. (Ariz. 2022)* https://www.azleg.gov/legtext/55Leg/2R/laws/0366.pdf

35 *Central Arizona Project FAQ. Central Arizona Project. (2021, August 6). Retrieved February 14, 2022, from* https://www.cap-az.com/about/faq/#:~:text=How%20much%20did%20the%20project,billion%20has%20to%20be%20 repaid

COSTS & WATER BENEFITS

The 2012 USBR study estimated the cost of water delivered from a Mississippi/Missouri River pipeline to be as high as $2,300 per acre-foot per year. Meanwhile, the cost of capital for such a project was estimated between $9 billion and $14 billion.[33] These costs were estimated in 2012 and have likely increased.

For comparison, the CAP canal cost $4 billion (construction began in 1973 and finished 20 years later). The $4 billion cost does not include annual maintenance and operation costs, and Arizona still owes $1.65 billion on that debt.[35]

WATER BENEFIT ACCRUAL

The exact water benefits of the Mississippi pipeline proposed in HCM 2004 are unknown, but the 2012 USBR study estimated a delivery of 600,000 acre-feet per year would be possible by the year 2060.[33] Subsequent water benefits would accrue on an annual basis.

USBR estimated a Missouri River or Mississippi River pipeline would take at least 30 years before any water delivery would be possible.[33] Some of the additional time-intensive factors include multi-states cooperating on even sharing their water in the first place, permitting and regulations, as well as Congressional approval and funding.[18]

CONSIDERATIONS

- The 2019 Long-Term Water Augmentation study discarded the Missouri pipeline idea, noting it is too expensive, time-intensive, and would have significant regulatory barriers
- Water from the Mississippi or Missouri rivers is muddier and contains sediments. Therefore, water quality and a risk of silting are of concern and would require additional water treatment.
- In 2022, the Mississippi River was experiencing extremely low water levels, casting uncertainty on its reliability as a water source for Arizona.[36]
- As with the CAP, evaporation and leakage would diminish the amount of water delivered.
- There are significant barriers to acquiring the land needed for the canal, including unknown cultural and environmental impacts.

36 *Lombardi, R., Antipova, A., & Burnette, D. J. (2022, December 14). Record low water levels on the Mississippi River in 2022 show how climate change is altering large rivers. The Conversation. Retrieved January 10, 2023, from https://theconversation.com/record-low-water-levels-on-the-mississippi-river-in-2022-show-how-climate-change-is-altering-large-rivers-193920#:~:text=During%20the%20recent%20flash%20drought,20%20feet%20over%2011%20weeks*

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