

# **Mojave Groundwater Bank**

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## **Overall Conclusion**

Based on my professional expertise and the data I have analyzed, considering the persistent climate extremes and the escalating water crisis in the Southwestern United States—with groundwater sources diminishing and lakes and rivers reaching critical thresholds—I regard the Mojave Groundwater Bank and the capture and storage of water, that would otherwise evaporate, as an urgent and essential strategy.

## **Overview**

The Mojave Groundwater Bank will provide up to 50,000-acre feet per year to the service area which encompasses the Cadiz region and lands to the west of Cadiz, as far as Barstow, CA (Figure 1). The project also offers up to one million acre-feet of storage capacity for imported storage of surplus water for banking for future dry years. The aquifer at the center of this project is estimated to hold between 30 to 50 million acre-feet of water in storage today.

The initial length of this project is 50 years.

The source of the water is an aquifer which underlies approximately 2300 square miles of land, some of which Cadiz owns, in San Bernardino County, CA. This area and the other areas which are all connected hydrologically by the one aquifer and can be thought of as a giant bowl. The ground water from that bowl ultimate drains through Fenner Gap to the dry lakes.

Unlike surface water rights, in California, water rights pertaining to ground water and aquifers, ruled primarily through "overlying rights," which allows landowners to use groundwater beneath their property for reasonable, beneficial purposes. These rights are correlative, meaning users must share the resource pro rata during shortages. Groundwater management is further regulated by the Sustainable Groundwater Management Act (SGMA) of California, (<https://water.ca.gov>), signed in 2014. This simplifies the issue of water in the Cadiz "bowl."

The Mojave Groundwater Bank is a unique public-private partnership between public water agencies, Native American Tribes and Cadiz Inc. to provide clean, reliable, and affordable water supplies to underserved communities in Southern California and the Southwestern United States.

The overarching goal of the project is to conserve water in the aquifer by reducing evaporation as it discharges into the dry lakes and thus achieving a sustainable source of water.

**Objectives:** The stated objectives of the Mojave Groundwater Bank Project are:

- Maximize beneficial use of groundwater in the Bristol, Cadiz, Fenner Valleys and surrounding areas in the “bowl,” by conserving and using water that would otherwise be lost to brine and evaporation.
- Improve water supply reliability for Southern California water providers by developing a long-term source of water that is not significantly affected by drought.
- Reduce dependence on imported water by utilizing a source of water that is not dependent upon surface water resources from the Colorado River or the Sacramento-San Joaquin Delta.
- Enhance water supply reliability within the service areas of Southern California water provider Project Participants.
- Enhance water supply opportunities and delivery flexibility for participants.
- Participating water providers through the provision of carry-over storage in Phase 2.
- Support operational water needs of the Arizona and California Railroad (ARZC) in the Project area.
- Create additional water storage capacity in Southern California to enhance water supply reliability.
- Locate, design, and operate the Project in a manner that minimizes significant environmental effects and provides for long-term sustainable operations.

The topography of the area is low plains and mountains that are up to 7,500 feet. It is in these regions, above 5,000 feet elevation, where most of the precipitation occurs between November and March and is a major source of recharge to the aquifer. (see Figure 2)

## **Background**

As that slow relentless movement of global warming grips the planet, one thing is for sure, we must confront it, recognize that we are the culprit and provide solutions.

This project is ambitious and complex, but not impossible. Solutions in these times require “out-of-the-box” thinking to solve issues where population is growing and global warming is impacting climate change. In general, the US is facing decreasing water availability.

Climate modelers predict that as the US southwest warms the effect it will have on the hydrological cycle is that it will become drier; however, precipitation data for this area has shown an increase in precipitation in recent years. (Todd *et al.*, 2025)

In fact, the Southwest United States is currently facing its worst megadrought of the past 1,200 years. According to a recent study by the University of Texas at Austin, published in *Nature Geoscience* the drought could continue at least until the end of the century, if not longer.

**Bold solutions** are necessary to solve these issues; the Mojave Groundwater Bank is one such solution.

## **The Mojave Groundwater Bank Location**

The location of the project is shown in Figure 1.

As mentioned, the Mojave Groundwater Bank location is a closed basin with the ground water converging at Fenner Gap, between the Marble and Ship mountains. Precipitation, and snow, not lost to evaporation, recharges the aquifer. The groundwater flow of the project area converges at Fenner Gap and ultimately discharges to the two dry lakes, Bristol and Cadiz Lakes.

It is obvious from Figure 2 that the area is a mixture of flatlands and mountains.



Figure 2. Overview of the area where the Cadiz Water Project will be located showing the mountains and flat lands.

Figure 2 shows the surface features and general outline of the “bowl.” All the precipitation, minus evaporation, which falls in this bowl will be recharged to the aquifer.

The surficial and subsurface geology form a closed water basin system with the terminus converging at Fenner Gap. Groundwater flows through the Fenner Gap and discharges to the two dry lake systems, Bristol Dry Lake and Cadiz Dry Lake.

## **Aquifers**

An aquifer can be best described as an underground “river.” The areal extent of the Mojave Groundwater Bank aquifer is approximately 2320 square miles. There are no surface streams in the area unless there is an unusual rain or precipitation event. Therefore, a natural solution to conserve water is to maximize recharge to the aquifer that would minimize water lost by evaporation from Bristol Dry Lake and Cadiz Dry Lake.

A major driver of this project is to conserve water for beneficial purposes which is presently lost because of evaporation from Bristol Dry Lake and Cadiz Dry Lake. An extensive study was undertaken to determine how much water is lost from evaporation of water in the two dry lakes. That study estimated that 7,860-acre feet per year are lost from the Bristol Dry Lake and the 23,730-acre feet per year is lost from Cadiz Dry Lake for a total of 31,590-acre feet per year.

Considering that the project's goal is to withdraw 50,000-acre feet per year, minimizing evaporation would be a major portion of making the project sustainable. It is not reasonable to think that the project could totally eliminate evaporative losses; however, any modification to minimize evaporative losses would lead to a more sustainable project.

Let's step back and define what an aquifer is. The first concept is the same as surface rivers; water always runs downhill. In the case of aquifers, it is the "empty" spaces in the soil where water flows. Of course, water flow (permeability) is always impeded by the composition of the aquifer. There have been several studies that examine the "permeability" of the soil/aquifer in the area.

Aquifers are defined as confined or unconfined. An unconfined aquifer only has a layer at the bottom of the aquifer and is otherwise free to flow laterally. A third case is referred to as a "perched" aquifer, where the bottom is an impermeable layer. Figure 4 (National Ground Water Association) depicts types of aquifers.

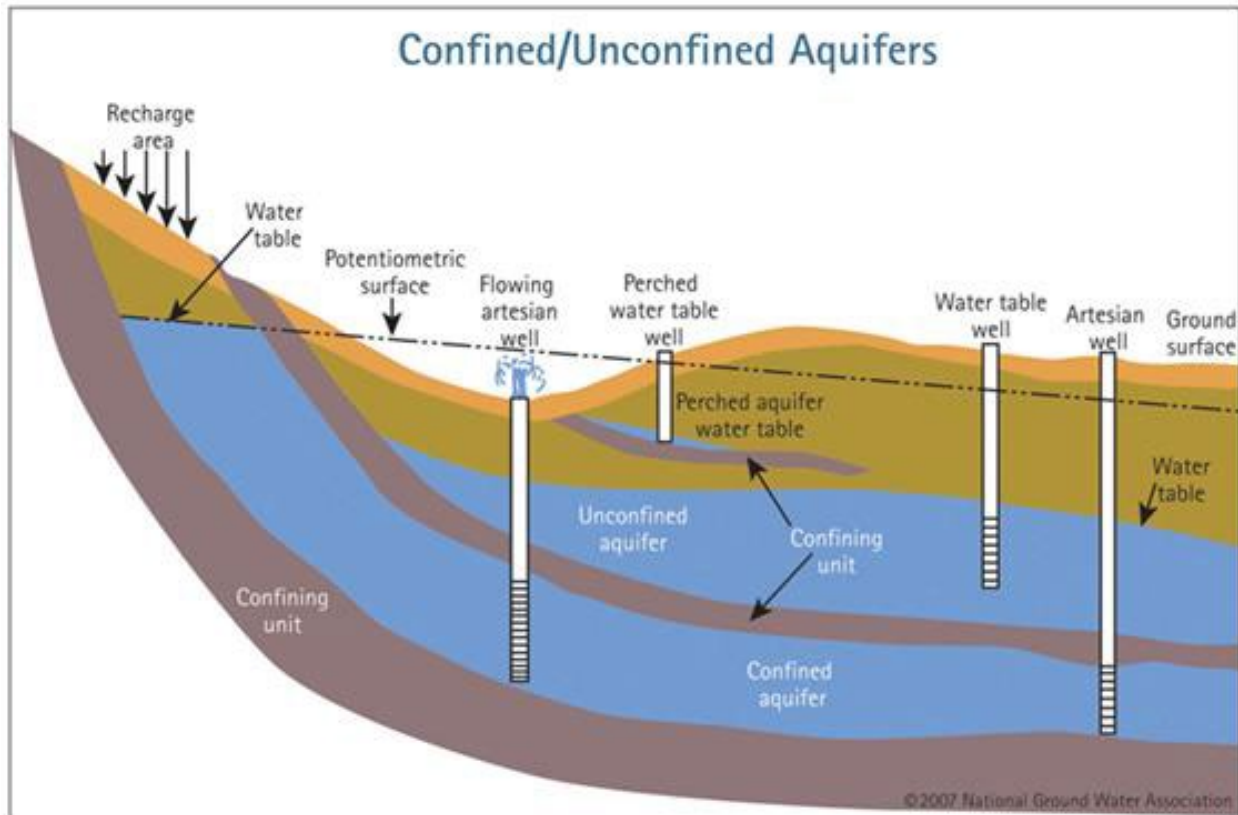


Figure 4. Diagram of different types of aquifers. (2007 National Ground Water Association)

An unconfined aquifer is not necessarily a surficial aquifer (see Figure 4) where there is a lower confining layer at depth which stops the downward vertical flow of water. When pumping an unconfined aquifer, either at the surface or at depth, a cone of depression is formed. The cone of depression is determined by the rate of pumping and the permeability of the geologic strata.

Knowing the permeability of the formation is critical to estimate the extent of the cone of depression.

It is the cone of depression that could affect other wells in the vicinity and cause groundwater to move towards the well. In the wells for the Cadiz project the top of the water saturation zone is below the land surface. In that case the extraction wells will be cased (not allowing water to enter the well) to a certain depth. At depth the well is not cased, and water is extracted from the aquifer. It is at this depth that the “cone” will be formed. The only way to determine the extent of the subsurface cone of depression is to have observation wells.

Relative to this project there have been several studies that estimated the permeability of the aquifer. The estimates from wells in the Fenner Vally basin have yielded as much as 200 gallons per minute. In a study conducted by the Metropolitan Water District of Southern California (1999) in the Fenner Gap area the wells yielded between 1,000 and 3,000 gallons per minute. In another study the yield was 3,500 gallons per minute. These test wells and flow rates suggest that the surrounding geology is extremely porous and the more porous the aquifer the less it is affected by water withdrawals. (aquilogic; Appendix B: Cadiz Project Overview, Table 2; p. 145)

The importance of these results demonstrated that the unconfined aquifer is porous, and the cone of depression will not extend far from the placement of the well; however, for a long-term project it would be wise to drill observation wells in the vicinity of the project water withdrawal wells to monitor the extent of the cone of depression. (In this case where the water withdrawal will be at depth it would be a suggestion to change the description from “cone of depression” to “cone of influence.”)

The County of San Bernadino placed a requirement that limited the draw down of 80 feet within two miles of the Cadiz well-field cone of depression for the first 15 years and 100 feet over the life of the project.

### **The Mojave Groundwater Bank Aquifers**

The report addressing the aquifers for the Cadiz Project area, (aquilogic, Appendix B: Cadiz Project Overview, Jan 2019, page 143) divided them into five aquifers:

- Upper alluvial aquifer
- Lower alluvial aquifer
- Tertiary fanglomerates
- Carbonate bedrock aquifer
- Granitic aquifer

An alluvial aquifer is “a shallow, underground water-bearing layer of loose material (sand, grave, silt and clay) deposited by rivers.” The alluvial aquifer, although divided above, in the case of Cadiz, were combined as the upper and lower were intermittently divided but not throughout the aquifer. It was reported that the alluvial aquifers can vary from 200 to 800 feet in thickness.

In the Cadiz Project area, the alluvial and carbonate aquifers are in hydraulic continuity and differentiated mostly by porosity. Granitic rock is the “basement” rock and is 150 to 400 feet thick at Fenner Gap.

Although mentioned, the tertiary fanglomerate was not discussed. A fanglomerate is defined as formed on alluvial fan characterized by large, often poorly sorted, gravel, pebbles and boulders.

### **Cadiz Aquifer and Annual Recharge**

One of the more controversial issues is annual recharge. Considerable effort has been expended to quantify the recharge in the system which is critical for planning for the 50-year lifetime of the project (Table 1). One aspect which is not controversial is most of the precipitation occurs in the mountains from November to March.

Six basins make up the area of the Cadiz Aquifer. Table 1 Summarizes the surface area (ft<sup>2</sup>) and estimates of the volume of precipitation, acre-feet-per year, in the six basins. (ACF).

Table 1. Water shed size and precipitation volume annually. (aquilogic, Appendix B: Cadiz Project Overview, Jan. 2019)		
Watershed	Area (ft <sup>2</sup> )	Precipitation Volume (AFY)
Bristol	22,141,717,000	170,541
Cadiz	16,482,012,982	131,042
Fenner (East)	16,625,535,879	234,753
Fenner (West)	13,700,280,036	173,716
Lanfair	7,831,938,617	123,806
Orange Blossom Wash	4,736,693,394	46,232
<b>Total</b>	<b>81,518,177,907</b>	<b>880,090</b>

### **Bristol and Cadiz Dry Lakes**

The groundwater in the Cadiz Aquifer flows generally south and west and, after transiting Fenner Gap, feeds Bristol and Cadiz Dry Lakes. The elevation of Bristol Dry Lake is 600 and Cadiz Dry Lake 541 feet above sea level, respectively, and they are at the lowest level in this system. These two lakes are the only area in the entire aquifer system where water is lost solely by evaporation.

The footprint of Bristol Dry Lake is 33,038 acres and Cadiz Dry lake is 43,537 acres. In 2012, the Desert Research Institute (DRI) conducted extensive measurements of evaporation rates from the Bristol and Cadiz Dry Lakes in California’s Mojave Desert to evaluate the water balance of the surrounding aquifer system.

The Desert Research Institute (DRI) measured the evaporation of Bristol and Cadiz Dry Lakes to be 7,860 and 23,730 acre-feet per year for a combined total of 31,590 acre-feet pre year. (DRI (2012). Quantifying Evaporative Discharge from Bristol and Cadiz Dry Lakes. March 16.)

The only loss of water in the entire Cadiz Aquifer is evaporation at Bristol and Cadiz Dry Lakes . Therefore, a major thrust of the Cadiz Project is to minimize evaporative losses from Bristol and Cadiz Dry Lakes.

There are ongoing salt recovery operations both at Bristol and Cadiz Dry Lakes. These data were reported to consume 500-acre feet per year and 250-acre feet per year for a total withdrawal of 750-acre feet per year. (ESA, 2012a)

### **Natural Springs**

The Cadiz aquifer is an unconfined surficial aquifer, recharged by water (rain or snow) falling on the surface. Unconfined surficial aquifers have no “head” pressure and as such there is little chance that the springs at the surface are connected to the deep Cadiz Aquifer. (See Figure 4) The spring closest to the production wells for the Cadiz Project is Bonanza Spring. This spring is 1,000 feet above groundwater suggesting that no hydrologic connection exists. It is speculated that Spring is fed by water from the surrounding surficial area and not the Cadiz Aquifer.

A 2025 study of Bonanza Spring, the largest spring in the southeastern Mojave Desert, found that its chemistry differs from nearby agricultural wells, suggesting no or poor hydraulic connection between them. This research supports the protection of regional aquifer systems and indicates that the spring is likely sustained by a distinct, perhaps more distant, source rather than local groundwater pumping.

A possible explanation for Bonanza Spring is that there is a “perched aquifer” feeding the spring. It doesn’t seem that any of the studies have reported on this possibility and it remains an open question. The other springs that were mentioned, Hummingbird, Chuckwalla, and Honeymoon all have at least 1,100-foot elevation difference to the aquifer and the same argument holds.

In the report by “aquilogic, Appendix B, Jan 2019, page 138” they mention the fact that the springs at high altitudes are likely the result of perched aquifers.

### **Summary of Cadiz Valley Water Conservation, Recovery, and Storage Project**

The summary covers the Mojave Groundwater Bank as stated in the “Cadiz Valley Water Conservation, Recovery, and Storage ” Addendum No. 2, to the 2012 Environmental Impact Report Checklist are summarized below by subject:

Table 2. Summary of the 2025 CEQA Final Environmental Impact Review, Addendum.		
Environmental Check List	Comments	Approval
	The Proposed modifications in combination with the as evaluated in the Final EIR	Accepted
Aesthetics		Yes
Agricultural and Forestry Resources		Yes
Air Quality		Yes
Biological Resources		Yes
Cultural Resources		Yes
Energy		Yes
Geology and Soils		Yes
Greenhouse Gas Emissions		Yes
Hazards and Hazardous Material		Yes
Hydrology and Water Quality		Yes
Land Use and Planning		Yes
Mineral Resources		Yes
Noise		Yes
Population and Housing		Yes
Public Services		Yes
Recreation		Yes
Transportation		Yes
Tribal Cultural Resources		Yes
Utilities and Service Systems		Yes
Wildfire		Yes

**Plants and Animals**

The plant and animal resources have been extensively reviewed, and protections have been integrated in the project plan.

Root zones of plants in the area do not extend more than 100 feet below ground surface and water table starts at about 200 feet below ground surface. Therefore, no adverse impacts are expected.

## **Desert Tortoise**

In 2015 Cadiz Water established the Fenner Valley Desert Tortoise Conservation Bank and designated 7,500 acres as a permanent habitat for the desert tortoise, a State and Federally listed threatened species. The project is using “avoidance” strategy to ensure no take of tortoise. The Fenner Bank was approved by the California Department of Fish and Wildlife. This Bank is the largest “land bank” in the United States and serves as the gold standard for keystone species preservation.

### **Subsidence**

It is possible that because of pumping the aquifer, subsidence of the surface could occur. The issue is the railroad tracks where the maximum allowable subsidence is 1 (one) inch per 62-foot string of track.

Land subsidence will be monitored using ground-level surveys, InSAR (interferometric Synthetic Aperture Radar; for mapping ground deformation using radar images of Earth’s surface collected from orbiting satellites and comparing images taken at different times) or installing extensometers.

It appears that the best option is to work with the InSAR team to evaluate any ground deformations.

### **Conclusions & Recommendations**

1. The surficial sediments in Fenner Gap have a high transmissivity.
2. The possibility exists, however remotely, that subsidence might result from the removal of ground water. There are a series of new satellites that might be useful for measuring ground elevation. I am not sure that any of them could be used to look at subsidence and might be something to examine in the future.
3. There have been no (or few) talks at national meetings, citizens and interested user groups. This may be a “next step” to spread the word about the project for example:
  - a. AWWA – American Water Works Association
  - b. American Chemical Society – Environmental Chemistry Division
  - c. Association of Environmental Engineers and Science Professors
  - d. Local, southern California groups, for example the universities and colleges
  - e. Rotary Clubs

Therefore, one approach is to develop a “canned” talk for non-professionals to acquaint the public with the Mojave Groundwater Bank project.

## References

For additional information and copies of the studies and reviews that have been published on this project refer to the website: [www.mojavegroundwaterbank.com/permitting](http://www.mojavegroundwaterbank.com/permitting)

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## Appendix A – Important points

### Cadiz Water Project

Bold solutions are necessary to solve these problems. The Mojave Groundwater Bank is one such solution.

#### Aquifer(s)

And it's been right under our feet all the time – who knew that the Cadiz aquifer system deep down in the ground is estimated to hold between 30 and 50 million-acre feet of water! (An acre foot of water is 326,000 gallons.)

The Cadiz Aquifer is fed by an isolated surface basin with an area of 2,320 square miles.

The earth surface topography above the Cadiz Aquifer is such that all the precipitation that falls in rain or snow (minus evaporation) recharges the aquifer.

Much of the precipitation that will recharge the aquifer falls on the higher mountains which form the Cadiz Basin.

Most of that precipitation falls in the winter when evaporation is at a minimum.

The Cadiz Aquifer holds more water than Lake Mead, which when full has a capacity of 30 million acre-feet of water.

#### Lake Powell

Lake Powell, when full, holds a little over 24 million acre-feet of water.

Lake Powell, February 2026 is at 35 % of the maximum volume.

As of Early February 2026, the inflow to the Lake Powell was 4,997 cubic feet per second and the outflow is 9,553 cubic feet per second.

The average **inflow** between January 27, 2026, and February 9, 2026, was 4,280 cubic feet per second, while the average **outflow** was 9,701 feet per second.

Lake Powell, of the 17 boat launches, only two are useable due to low water in the Spring 2026.

#### Lake Mead

Today, Spring 2026, the volume of water in Lake Mead is below 10 million acre-feet of water.

Southern California, which supports a population of nearly 24,000,00, imports about 60 % of the water that it needs to support a GDP of \$1.95 trillion per year.

California is the 4<sup>th</sup> largest economy in the world, approximately \$4.1 trillion per year.

## About the Author



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1968 B. S. in Chemistry	Allegheny College
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1997 – 2006 Professor	Uni. of North Carolina Wilmington
2006 – 2013 Professor	U. of California, Irvine
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1997 – 1999 Chair, Dept of Chemistry	Uni. of North Carolina Wilmington
1997 – 2006 Professor	Uni. of North Carolina Wilmington
2006 – 2017 Director, Urban Water Research Center	U. California, Irvine
2013 – 2017 Program Director, Environmental Engr.	National Science Foundation
2011 Elected Fellow American Association for the Advancement of Science	
2014 Elected Fellow Association of Environmental Engineering and Science Professors	

His research interests include: carbon cycling in oceanic and fresh waters  
sunlight mediated photochemistry in natural waters  
formation of reactive oxygen species  
environmental fate of pharmaceuticals

At U of Florida: treatment of landfill leachate with ferrate (Fe VI)  
treatment of landfill leachates in constructed wetlands

Hobbies Nature Photography and Videography  
The Butterflies of Iguazu Falls, Argentina, Cooper and Cooper Publishers, 2010, 88 pp.  
YouTube Channel – “William James Cooper – YouTube”