How Water Management in Tucson, Arizona Has Affected the Desert's Landscape

*Sharon B. Megdal, Ph.D.**

October 2003
Paper based on presentation made at the
Urban Design in Arid Zones Symposium
Santiago, Chile May 2003

Introduction

Tucson, Arizona, located in the southwestern United States, is an area known for its natural beauty (Figures 1, 2 and 3). Like much of the Southwest, the region is growing rapidly. With little annual rainfall and no nearby surface water supplies, a key objective for the region is ensuring that growth is based on sustainable water supplies. This paper discusses how regulations concerning the use of groundwater and the manner in which water is supplied have influenced the region's landscape.

Figure 1 - Map of North America showing Tucson

Figure 2 - Downtown Tucson

The City of Tucson is a political subdivision of the state of Arizona. The city is governed by an elected mayor and six elected city council members. Tucson, along with other cities and towns, is wholly located in Pima County. Like each of the 15 counties in Arizona, Pima County is governed by an elected board of supervisors. Tucson has a population of just under 500,000 people within the city limits, with a geographic reach of over 225 square miles. The larger area known as Metropolitan Tucson covers approximately 495 square miles and is home to approximately 850,000 people.

Figure 3 - Thunderstorm over Tucson

Tucson is located in the Sonoran Desert and is at an altitude of 2,400 feet. Average rainfall, at 12 inches per year, is similar to that of Santiago, Chile. Tucson's rainfall tends to arrive during two rainy seasons whereas that of Santiago tends to fall mostly in the winter months. Tucson's winter temperatures are rather temperate, but summer high temperatures often exceed 100 degrees Fahrenheit.

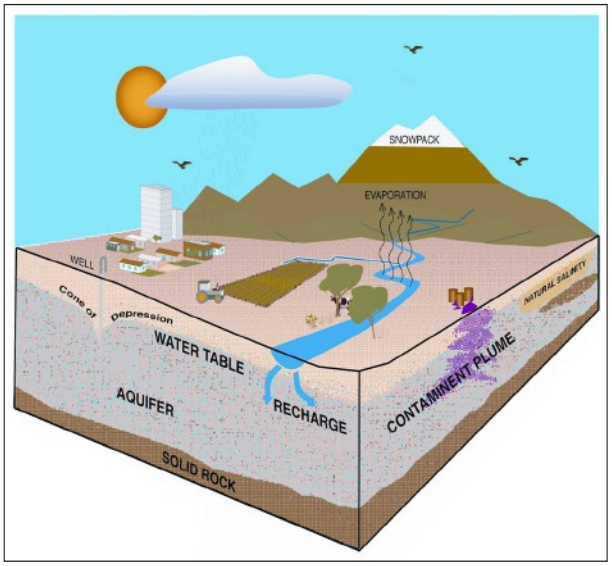

Figure 4 - Natural water cycle

Tucson region's use of groundwater

Tucson has relied on groundwater to supply its water needs. Figure 4 shows the workings of the natural water cycle. Over time, the pumping associated with residential, agricultural and industrial water use has outstripped nature's ability to replenish the underground aquifers. As a result, river beds are dry (Figure 5) except during rain events or when river washes contain mountain run-

Figure 5 - Dry riverbed

off or wastewater flows. (Figure 5) Although a sufficient quantity of groundwater exists to meet needs for many years, supplies are finite, and groundwater levels have been declining. The consequences of declining water tables include higher pumping costs, reduced water quality, and possible land subsidence, which in turn can damage structures of many types. (Figure 7)

In order to reduce the overdraft of groundwater in the Tucson region and four other areas of Arizona, the state legislature enacted in 1980 the Groundwater Management Act. The Act established regions, called Active Management Areas, where comprehensive groundwater management was required. (Figure 8) Active Management Areas' boundaries are largely determined by hydrological considerations and are not the same as city or county boundaries. Not surprisingly, they included the two major urban areas of Arizona, Phoenix and Tucson, and a major agricultural center in Pinal County. For the Active Management Areas, regulations limiting the use of groundwater and requiring more stringent water conservation programs over time were key components of the legislation. In addition, the Act created a few irrigation non-expansion areas, also shown on Figure 8. These are areas where groundwater use is largely unregulated but irrigation cannot expand. Amendments to the law provided the framework for artificial recharge (underground storage) of water for future recovery and use.

Figure 6 - Runoff flowing in riverbed

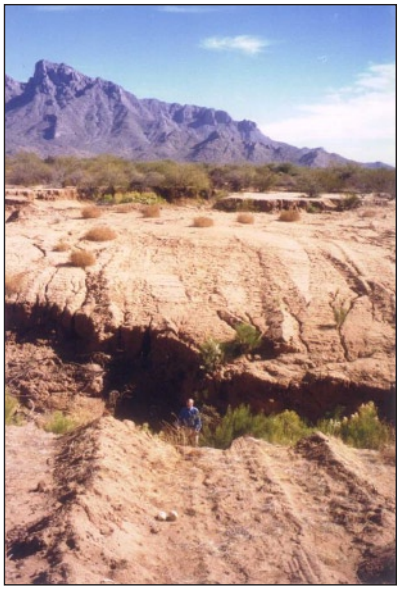

Figure 7 - Effects of subsidence

The Tucson metropolitan region constitutes the major population center of the Tucson Active Management Area. The Groundwater Management Act established safe yield as the groundwater management goal for this area. The goal is to achieve by the year 2025 — and thereafter maintain — a long-term balance between the annual amount of groundwater withdrawn in an Active Management Area and the annual amount of natural and artificial recharge occurring in the area.

Although the state has established, and also enforces, the legal framework for groundwater regulation, local entities supply water for residential, industrial and agricultural needs. Water may be provided by publicly or privately owned systems. In the Tucson area, the largest water provider is Tucson Water, a city owned and operated utility. It provides water to most, but not all, City of Tucson residents as well as many who live outside the city limits. Other water providers, some privately owned and operated, also provide water to parts of the Tucson region. In addition, agricultural users, some industrial users, and some individuals own and operate their own wells. The decisions regarding how to meet water use regulations are made by the water user/supplier. Increasingly, these decisions involve using water supplies other than groundwater.

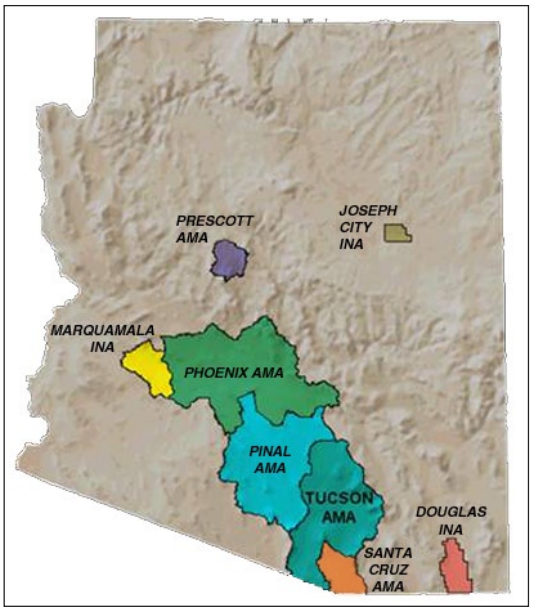

Figure 8 - Map of Arizona showing Active Management Areas

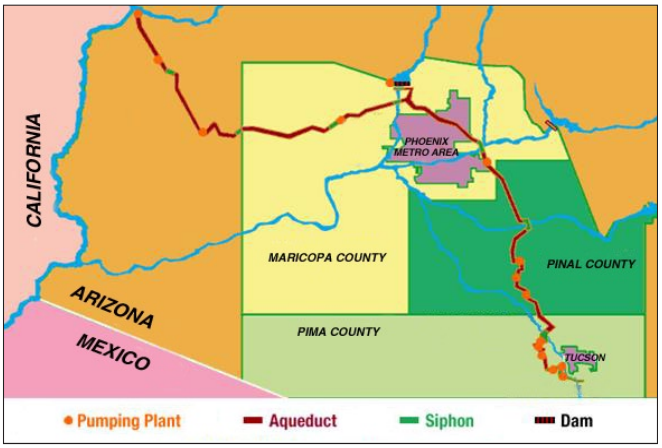

Figure 9 - CAP canal from beginning to end

Availability of renewable water supplies

In order to achieve safe yield, assured water supply rules have been implemented that require most new residential and some new industrial water demands to be satisfied with renewable water supplies rather than groundwater. The renewable water supplies available to the Tucson Active Management Area are Colorado River water, which is delivered through the Central Arizona Project, and treated wastewater or effluent. These rules are resulting in a gradual move to more reliance on renewable water supplies in the region.

In Arizona and the western United States, water use is measured in acre feet. An acre foot of water is the amount of water it takes to cover one acre, one foot deep. An acre foot of water is 325,900 gallons or 1,233 cubic meters. In the year 2000, over 300,000 acre feet of water was delivered to water users in the Tucson Active Management Area. Approximately half of that was delivered through municipal systems. Another approximately 90,000 acre feet was used by agriculture, with the remainder used by large industrial operations. The majority of that water use was groundwater. Over time, however, due to the assured water supply rules, the use of renewable water supplies is expected to increase substantially. Agricultural activity in the Tucson area is expected to decline as agricultural land is developed for urban uses. The future use of groundwater by the copper mining industry in the Tucson Active Management Area, which has used significant quantities of groundwater per year, will depend on the international market for copper as well as the extent to which CAP water is utilized by the mines.

Figure 10 - CAP canal across desert

The Central Arizona Project is a constructed open canal that takes water from the Colorado River and pumps it southeast and over 2,500 feet uphill to the Tucson region. Figure 9 shows the path of the canal in red as well as the many pumping stations along its reach. Completed in 1993, it extends 336 miles and cost $3.6 billion to build. The CAP was designed to deliver 1.5 million acre feet of water annually to central Arizona. It provided the region with a new source of water and has been an important factor in allowing the region to grow. As Figures 10 and 11 show, the canal's imprint on the Arizona desert is remarkable.

Figure 11- CAP canal east of Phoenix

Entities in the Tucson region, including Indian Tribes, currently have contracted for about 215,000 acre feet of the 1.5 million acre feet of CAP water available. Most but not all of the CAP water is under contract, with a considerable amount going to Native American communities and water providers in the Phoenix metropolitan area northwest of Tucson. The CAP system includes a large lake for storage in the Phoenix area, but there is no large reservoir for storage of CAP water in the Tucson area.

How the Tucson region has used CAP water has left significant imprints as well. The Tucson area has considerably more CAP water available than it is currently using. The City

of Tucson has contracted for just under 140,000 acre feet of CAP water, which is more than Tucson Water's current annual deliveries. Surface water, such as CAP water, requires treatment if it is to be delivered directly to customers' homes and business. In the early 1990s, Tucson attempted to integrate CAP water into its delivery system. But this effort failed. Customers had problems because of the difference between the chemical nature of the groundwater that had been used and the treated river water. An $80 million treatment plant that operated during that aborted effort to directly deliver CAP water is no longer in use.

Figure 12 - Clearwater Recharge Facility

Figure 13 - Water flows into excavated basins

Although Tucson itself decided to curtail use of CAP water, the citizens of Tucson in 1995 approved a ballot initiative restricting the manner in which the city could utilitize CAP water. As a result, Tucson abandoned its plan to treat CAP water to drinking water standards prior to delivery and instead adopted a program of indirect use of CAP water through underground storage and recovery. Although the voter-approved restrictions were later modified, Tucson continues to implement a large-scale program of recharge and recovery. Other Tucson Active Management Area water providers have adopted similar programs.

Figure 14 - Recovery well pumps

Figure 12 is a picturesque view of one basin of the Tucson Clearwater Facility, which serves as the foundation for Tucson's recharge and recovery efforts. The Clearwater Facility includes recharge basins that cover many acres of otherwise unused land. It is permitted by the Arizona Department of Water Resources to store 60,000 acre feet annually. Water is delivered to excavated basins, as shown in Figure 13, and allowed to infiltrate to the underground aquifer. The City of Tucson's Clearwater Facility is located northwest of Tucson, outside the city limits. A series of nearby pumps, going as deep as 1,000 feet and shown in Figure 14, recover water from the aquifer and deliver it through an 11-mile pipeline to an entry point into the water distribution system.

Figure 16 - Lower Santa Cruz Replenishment Project

Figure 15 - Pima Mine Road Recharge Project

Figures 15 and 16 show other CAP water storage projects located in the Tucson Active Management Area. Figure 15 shows the Pima Mine Road Recharge Project, a project south of Tucson located near orchards of pecan trees. It is jointly owned by the City of Tucson and the public agency that operates the CAP. It is permitted to store up to 30,000 acre feet of water annually. Figure 16 shows the Lower Santa Cruz Replenishment Project, a storage facility built northwest of Tucson in the Town of Marana. Also located near farm land, the project was built in conjunction with the construction of a flood control levee. The materials removed when excavating the basins were used as material for the flood control structure. While the basins shown were expected to be the first phase of a two-phase project covering 80 acres, the three basins included in the first phase of the project, which cover just over 30 acres, have experienced very high water infiltration rates. Consequently, the three basins can accept more than the 30,000 acre foot annual permitted storage volume, and there are no plans to construct additional basins.

Currently, these CAP recharge projects are for the primary purpose of storing water. There are no associated recreational uses or environmental restoration components to them. Yet, as the photos show, the recharge basins add water features to an otherwise dry landscape.

In addition to CAP water and groundwater, the other major water source in the Tucson region is effluent or treated wastewater. Currently, large amounts of effluent are discharged from two major treatment plants into the Santa Cruz River. Figure 17 shows the point of discharge for one of the plants, with Figure 18 showing the riparian growth the discharge supports. Effluent has been used to irrigate crop land and, if treated sufficiently, can be used to irrigate open access (unfenced) ball fields and golf courses. The City of Tucson operates an extensive reclaimed water system, which delivers via pipeline over 10,000 acre feet of effluent for turf irrigation purposes. The reclaimed water system is being expanded to reach additional areas in the Tucson metropolitan region.

Figure 17 - Treated discharge from treatment plant

Figure 18 - Riparian growth from treated discharge

Effluent also recharges the aquifer, either through the natural infiltration that occurs in the riverbed or through basin recharge. Figure 19 shows the Sweetwater Wetlands facility, which is operated by the City of Tucson. Built in 1996 and located inside the city limits, this facility receives backwater from the wastewater treatment plant, which is naturally treated as it infiltrates the soil. Its wetlands habitat is a welcome addition to the surrounding landscape and also is used as an educational setting to teach the workings of a watershed.

Figure 19 - Sweetwater Wetlands

There are many other examples of projects in the Tucson area that have water storage as a primary purpose. In addition, there are some projects, many still in development, that have riparian enhancement or restoration as a primary element. Discussion of them is beyond the scope of this paper.

Concluding Remarks

Since enactment of the Groundwater Management Act, the Tucson area has reduced its reliance on groundwater. Colorado River water has been imported to supplement existing water sources. Use of this resource will increase over time. Likewise, effluent utilization will increase. Usage of these resources have left their imprint on the desert. As the region grows, efforts to better manage and utilize water resources will continue. "The frog does not drink up the pond in which he lives" is an American Indian Proverb. It is important that all in the region follow the practice of this small amphibian and not over-pump groundwater.

*The author thanks the Central Arizona Project, Tucson Water, the Town of Marana, Pima County, the Pima County Flood Control District, the Arizona Department of Water Resources, and Terry Sprouse for providing figures and information directly or through their web sites. Gabe Colbaugh assisted in preparing the presentation made in Santiago, Chile. Joe Gelt and Gabriel Leake did the layout of the paper.