Management Alternatives for Santa Cruz Basin Groundwater

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MANAGEMENT ALTERNATIVES FOR SANTA CRUZ BASIN GROUNDWATER

By

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ABSTRACT

Combined urban, agricultural, industrial and mining groundwater withdrawal from the Santa Cruz River Basin exceeds natural aquifer replenishment by 74,000 acre-feet annually. Four ameliorative water management alternatives are presented singly and in combination with one another. These alternatives are importing Colorado River water, exchanging treated effluent with mining and agricultural interests for groundwater, interbasin water transfer, and retiring farmlands for groundwater rights. These management philosophies are applicable to most economically emergent urban areas in arid and semiarid regions.

INTRODUCTION

Abundant sunshine and water scarcity are two factors common to all of Arizona. During an average year Arizona receives about 80 million acre-feet of water from rain and snow, of which some 2.3 million acre-feet are captured in surface water reservoirs or as aquifer recharge. It is estimated that people in Arizona use about 4.8 million acre-feet of water per year. Thus, the approximate two million acre-feet received through precipitation each year must be augmented by pumping about 2.5 million acre-feet of water from groundwater reservoirs which, in essence, constitute finite supply sources.

THE SETTING

The Santa Cruz River Basin (Figure 1) has several groundwater districts, and the total drainage area contains about 2,240 square miles. Structurally, the Santa Cruz Valley is a typical example of the Basin and Range physiographic province of the Southwest United States. Northward trending mountain ranges border the broad,flat alluvium-filled Valley (Figure 2).

NATURAL RECHARGE

Matlock and Davis (1972) calculated annual aquifer recharge in the Tucson-Sahuarita districts to be about 55,000 acre-feet during 1960-1969. The Arizona Water Commission (1975) estimated natural recharge in the Upper Santa Cruz Basin to be 65,000 acre-feet per year (AFY). The Tucson Comprehensive Plan (1975) places recharge rates in the Basin at 65,000 AFY, the figure which will be used in this paper.

CURRENT WATER USE

Agriculture. Matlock and Davis (1972) estimated the average agricultural consumptive water use on approximately 15,000 irrigated acres in the Santa Cruz Basin, excluding the Cortaro District, to be 46,000 AFY in 1972. Mining company demand for water is leading to retirement of agricultural land, however, for water rights. Since 1970, over 8,000 acres (Armstrong, 1977) in the Santa Cruz Valley have been retired from production through mining company purchases. Less than 1,800 acres of irrigated cropland remain in the Basin adjacent to the City. South of Tucson along the Santa Cruz River only about 6,800 acres of cropland remain, principally in pecan trees. Water use in the Basin today for agriculture is estimated to be 30,000 AFY, assuming a consumptive water use of 3.5 acre-feet per year.

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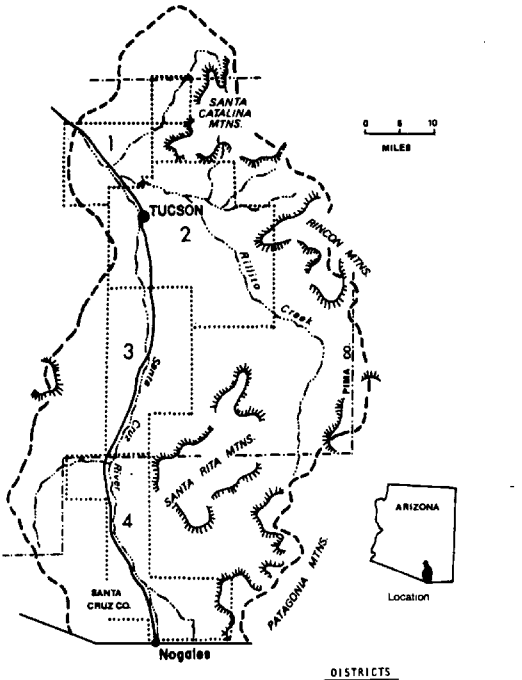

FIGURE 1

SANTA CRUZ BASIN

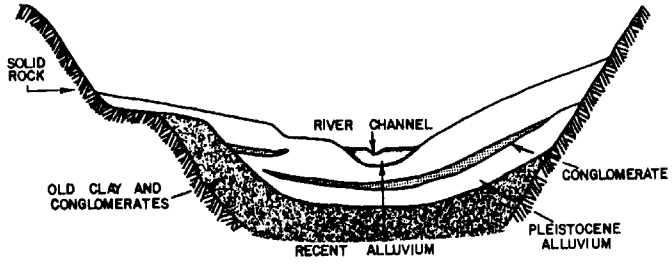

FIGURE 2

CROSS SECTION OF TYPICAL ARIZONA VALLEY

(FROM SCHWALEN AND SHAW, 1957)

Mining. The Santa Cruz Basin contains five major open-pit copper mines plus a sixth mine under development. It is estimated that 400,000 tons are mined daily in the Valley under full production. Approximately 200,000 tons of sulfide-copper ore are processed through the mills (Jett, 1973). The remainder is either overburden (150,000 tons assumed) or stockpiled for oxide-copper ore leaching (50,000 tons assumed). The ores have copper content of about 0.5 percent or 10 pounds of copper per ton of ore.

Water use by mining activities was estimated in 1975 to be 45,000,000 gallons per day (Tucson Citizen, 6 August 1975). An estimated 210 gallons of water per ton of ore are consumed in mining and flotation concentrating processes. Ore grades now mined average about 0.5 percent copper as compared to 1.0 percent in 1960. Assuming a copper content of 0.5 percent, 20 gallons of water per pound of copper are consumed. An increase in water consumption in 1977 is attributed to greater water use for mine dust control and the need to mine more tonnage because of lower grade ore. On daily and annual bases, average water consumption amounts to 139 acre-feet per day or 50,735 AFY, assuming 200,000 tons of mined ore per day. These water consumption figures are based on the assumption that no aquifer recharge occurs through tailing ponds.

Municipal, private, industrial. The Water Resources Division of the Tucson Water and Sewers Department estimates current urban and recreation groundwater withdrawal to be 80,000 AFY (Brooks, 1977). The Tucson metropolitan area obtains approximately 60,000 AFY of water from the Santa Cruz River Basin and 20,000 AFY from Avra Valley. Of this amount, 43,000 AFY are consumptively used and 37,000 AFY are returned to the sewage plant for treatment. The treated water is discharged into the Santa Cruz River and eventually recharges the aquifer; however, most of this recharge occurs outside the City's pumping influence and does not constitute significant abatement of local water level declines. The 80,000 AFY thus are considered to be depleted in this paper.

SANTA CRUZ RIVER BASIN WATER BALANCE

The Santa Cruz River Basin water balance is a function of inflow (natural recharge plus underflow) and outflow (pumping plus underflow).

Inflow. Inflow into the Basin consists of two components: natural recharge and underflow into the Basin from the Santa Cruz River.

Values for these components are estimated to be as follows.

1. Natural recharge		65,000 AFY
2. Underflow		2,000 AFY
	TOTAL	67,000 AFY

Outflow. Inflow is assumed to equal outflow; thus current depletion from pumping is by agricultural, mining, and municipal sectors in the Santa Cruz Basin and is estimated to be as follows:

1. Agriculture		30,000 AFY
2. Mining		51,000 AFY
3. Municipal		60,000 AFY
	TOTAL	141,000 AFY

THE DILEMMA

Current water use is exceeding natural recharge to the aquifer by 74,000 AFY. As a result, groundwater levels in the Tucson and Sahuarita-Continental districts have fallen significantly. During 1947-1965, water levels in the Tucson District have fallen more than 100 feet in some areas. The maximum decline at one site was 172 feet. During 1947-1969 wells in the Sahuarita-Continental District declined one-to-three feet per year. For the six-year period (1969-1975) average annual declines of six-to-twelve feet are common. Total water-use requirements in the Basin will reach 195,000 AFY by 1985 and 265,000 AFY by 2000.

MANAGEMENT ALTERNATIVES

Various water resources management alternatives to reduce groundwater level declines in the Santa Cruz Basin have been discussed by several researchers and governmental agencies during the past 20 years. Among alternatives most frequently discussed are: 1) importing water from the Colorado River; 2) exchanging municipal sewage effluent with mines or farms for their fresh water rights; 3) interbasin transfers of

water; 4) retiring farmlands for water rights; and 5) implementing a combination of alternatives.

ALTERNATIVE 1: IMPORTING WATER FROM THE COLORADO RIVER

Projections are that 100,000 AFY of CAP water will be available to the Tucson area by 1985. Plans call for the City of Tucson to receive 50,000 AFY, leaving 50,000 AFY to be divided between the mines and farms.

By 1985 water use in the Santa Cruz River Basin will total 195,000 AFY; the groundwater overdraft will exceed natural recharge by 130,000 AFY. The 100,000 AFY of CAP water will almost alleviate the overdraft if all CAP water were kept within the Basin. This may not be the case, however, because some agricultural water will be diverted to agricultural users outside the Basin, thus leaving a deficit. By 2000, water use in the Santa Cruz River Basin is expected to increase, and CAP deliveries will decline, leaving a larger deficit.

ALTERNATIVE 2: EXCHANGING MUNICIPAL SEWAGE EFFLUENT WITH MINES OR FARMS FOR THEIR FRESH WATER RIGHTS

Mines. Some 37,000 AFY of Tucson's groundwater pumpage recharges aquifers after passing through primary and secondary sewage treatment. This recharge is projected to reach 65,000 AFY by 2000. Historic reuse of effluent has been agricultural interests north of Tucson out of the portion of the Basin from which Tucson withdraws water.

A possible alternative would be to pipe the effluent to the mines for use in partially meeting their milling process needs. Thus, the mines would reduce pumping from the Basin aquifers. Tucson, in turn, could withdraw that amount not pumped by the mines in meeting its needs, and there would result a net reduction of groundwater pumping by the City.

Farms. Most Pima County agricultural areas are west of Tucson in Avra Valley, a separate groundwater basin.

Cluff and DeCook (1974) suggested establishing a metropolitan-operated district to provide waste water to irrigate farmland in the Avra-Marana area (Figure 3). Exchanging City waste water for groundwater would be a viable alternative to Tucson's present practice of purchasing farmland and retiring it to acquire groundwater rights. By 2000, the City could pump up to 65,000 AFY of groundwater in Avra Valley if the farms used the effluent and reduced their pumping by a similar amount.

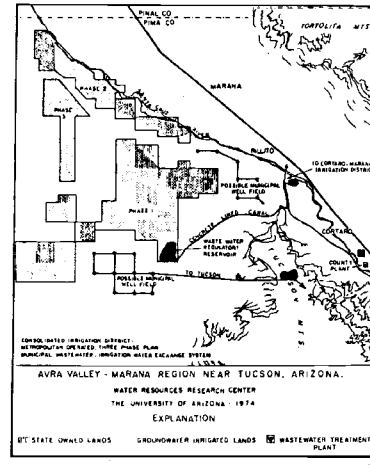

FIGURE 3

WASTE WATER FOR IRRIGATION OF FARMLAND

ALTERNATIVE 3: INTERBASIN TRANSFER OF WATER

Since the early 1970s the City of Tucson and the mines have purchased and retired more than 18,000 acres of irrigated farmland. About 10,000 acres of this land are in Avra Valley, west of Tucson. Once purchased, the City of Tucson established a well field and now transfers about 20,000 AFY, about 25 percent of Tucson's annual demand. Plans call for Tucson to pump up to 40,000 AFY from Avra Valley by 1985 which would reduce groundwater withdrawals in the Santa Cruz Basin.

Farms within Avra Valley are using 120,000 AFY to meet water-use requirements, and as a result, water levels also are declining in this area because of insufficient recharge.

ALTERNATIVE 4: RETIRING FARMLANDS FOR WATER RIGHTS

The present policy of the City of Tucson and the mines is to purchase and retire farmland to obtain its water rights. This policy has been in effect a number of years. About 10,000 acres of farmland in Avra Valley have been retired by Tucson. Mining interests also have been purchasing farmlands for water rights, especially south of Tucson in the Santa Cruz River Basin. About 8,000 acres of farmland have been retired by mine purchases.

The Arizona Supreme Court restricted City pumping to an average of 2.4 acre-feet of groundwater per acre of farmland retired. Assuming this to be an average groundwater pumping amount for the mines as well, almost 43,000 AFY are being diverted from agricultural use by the City and mines.

In 1973, 41,000 acres were still under cultivation in the Santa Cruz and Avra valleys. Assuming retirement of all but 6,000 acres of this acreage during a 10-year period, an additional 84,000 AFY of groundwater could be diverted for City and mining use by 1985.

SYNTHESIS OF ALTERNATIVES

Possible inputs and transfers to the Basin, are listed below.

Source	Alternative	1985 Amount (AFY)	2000 Amount (AFY)
Natural recharge	-	65,000	65,000
CAP import	1	75,000	40,000
City effluent exchange	2	50,000	65,000
Interbasin transfer	3	40,000	40,000
Farmland retirement	4	84,000	84,000
	TOTAL	314,000	294,000

Estimated Basin demands are listed below.

Sector	1985 Demand (AFY)	2000 Demand (AFY)
City of Tucson	100,000	170,000
Mines	75,000	75,000
Farms	20,000	20,000
TOTAL	195,000	265,000

DISCUSSION

Water distribution within the Santa Cruz River Basin never has had the benefit of a long-range plan. Ironically the City of Tucson was sited near the Santa Cruz River because in the late 1800s it was a perennial stream and served as the local water supply.

Combined water uses clearly are exceeding the natural recharge rate. Unless some combination of the four alternatives is implemented groundwater levels will continue to fall.

The CAP, discussed in Alternative 1, is under construction. The possibility of Colorado River water being diverted to central Arizona becomes ever-increasing. It appears that by 1985, however, Alternatives 2 and 4 may not be implemented totally, thus retired Avra Valley farmland will supply only the 40,000 AFY described in Alternative 3. If this happens 1985 demands for 195,000 AFY cannot be met with CAP, inter-

basin transfer and natural recharge waters. These sources total 180,000 AFY, 15,000 AFY short of a balance.

As demand for groundwater increases by 2000, some water-use trade-offs must occur. At this time it appears that the trend to purchase farmland for water rights may lead to widespread farm retirement as discussed in Alternative 4. This Alternative would permit diverting the entire CAP allotment into the Basin for non-agricultural users. Should this occur, Alternatives 1, 3, and 4 plus natural recharge would provide 229,000 AFY by 2000.

Waste water use by the mines by 2000 (Alternative 2) may become a reality as new techniques are found to minimize copper and molybdenum losses. This Alternative also would provide for an effective use of the effluent within an area where Tucson and the mines have extensive well-field development.

It should be noted that the outcome of Indian water rights litigation could produce considerable impact on striking a groundwater use balance in the Santa Cruz Basin. The Papago Indian Tribe irrigated 800 acres in its San Xavier District during 1975. Applying the 3.5 acre-feet-per-acre consumptive use figure for irrigated agriculture to the 800 acres shows that an additional 2,800 AFY are being consumed. If litigation restores and protects the Tribe's water rights in the Santa Cruz Basin, the Papagos could elect to put another 9,000 acres of arable land under irrigated cultivation. Employing current practices to irrigate this additional acreage would demand 31,500 AFY of groundwater, slightly more than all agricultural groundwater use in the Basin today.

CONCLUSIONS

No simplistic approach can be used to formulate sound water management policies. Instead, the economic, political and physical aspects of developing water resources must be considered thoroughly. Water policy based upon an efficient approach is possible in the physical and economic realms, but much additional definition will be needed to apply the same concept to the political realm. Probably the most important variable contributing to the success of any water management policy is characterizing social well-being; yet this is precisely the variable that appears to be the least understood.

The tendency to "do something" quickly in response to preceived water management problems without a serious consideration of the entire water supply-demand system must be resisted. However, the need for making short-term policy decisions in arid environments is self-evident; those decisions were made in the past initially for self-preservation and later for economic returns.

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