ARIZONA'S GROUND-WATER RESOURCES AND THEIR CONSERVATION

(An Informal Summary of Descriptive Information for Elementary-School Teachers)

by

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INTRODUCTION

As Arizona enters the 1980's, we see that population growth, economic expansion, and resource depletion go hand-in-hand. Non-renewable ground-water reserves in Arizona are being extracted at rates that cannot long continue without incurring serious consequences, economic as well as environmental. Growth of irrigated agriculture in the alluvial basins of the state, growth of urban and suburban populations, and growth of industrial pumping, especially for copper mining-milling and for cooling of electric power generation facilities, have incurred a heavy draft on the state's aquifers. The net result of such ground-water withdrawals has been the "mining" of underground water reserves, a continuing overdraft in excess of natural replenishment, and steadily dropping water tables.

This rate of depletion of ground water is generally considered to be the most serious water problem in Arizona. It is by no means the only problem. We must be concerned also with maintenance of water quality in view of existing and potential pollution; administrative systems for equitable and efficient water allocation and use; and the legal and environmental aspects of water acquisition and utilization.

In order to assess present and possible future water conditions in the state relative to growth, water resources will be viewed from the standpoint of (1) water usage, both quantitative and qualitative; (2) conservation of water; (3) availability of water; and (4) projected water needs.

USAGE OF WATER

Statewide Water Use and Trends

For many years, following construction of the major water storage and diversion systems in the state, Arizona water users have diverted more than 2.0 million acre-feet per year (MAF/yr) from streams, and presently the diversion rate exceeds 3.0 MAF/yr. As water requirements grew to quantities greater than the available surface-water supplies, ground-water reserves were gradually exploited as a supplementary source. The trend of increasing ground-water use is indicated in Table 1. The rate of growth in ground-water withdrawals levelled out in the 1950's, and with minor fluctuations the pumpage rate has remained at slightly less than 5.0 MAF/yr.

Table 1

Estimated Annual Ground-Water
Pumpage in Arizona*

Year	Acre-Feet Pumped
1915	123,000
1920	233,000
1925	668,000
1930	854,000
1935	911,000
1940	1,520,000
1945	2,066,000
1950	3,515,000
1955	4,481,000
1960	4,641,000
1965	4,411,000
1970	4,838,000
1975	———

*From Arizona Water Commission, Inventory of Resource and Uses, Arizona State Water Plan, Phase I, July 1975.

This relatively constant rate of pumpage, however, does not indicate a condition of hydrologic balance, because this rate of withdrawal is approximately twice the rate of annual ground-water replenishment. To state it another way, about 2.5 MAF/yr represents "overdraft" or ground-water mining. The direct result is a perennial decline in water levels, as illustrated by the composite water-level hydrographs of wells in the Lower Santa Cruz Basin of Pinal County (Figure 1). Such water-level declines are characteristic of many of the ground-water basins in the state, and are accompanied commonly by deterioration of ground-water quality with depth, the occurrence of earth cracks and land subsidence, and increased pumping costs.

The rate of withdrawal of both surface water and ground water in Arizona by Planning District and County, under normalized 1970 conditions, is shown in Table 2. Yuma County diverts more than one-half the surface water withdrawals in the state, followed by Maricopa County with another one-fourth. Pima and Santa Cruz are the only counties which use no surface water. Pumpage of ground water is greatest in Maricopa County, which accounts for 40 percent of the state total, and Pinal County is next with an additional 20 percent or more.

In terms of water-user sectors, irrigated agriculture is the largest user in Arizona. Irrigated area has been relatively stable during the past 20 years, at an approximate average of 1.2 million acres harvested in crops each year. The rate of water diversion for irrigation is about 6.0 acre-feet per acre or 7.2 million acre-feet per year; allowing for losses or return flows, however, water depletions are about 3.5 acre-feet per acre or 4.2 MAF/yr. This represented about 89 percent of the state's total water depletions for all uses in 1970.[1/] The present trend is for this percentage figure to diminish, for while agricultural use remains rather constant, other uses such as municipal are growing rapidly.

Municipal and industrial water depletions amounted to approximately 328,000 acre-feet per year in 1970, but have grown to a current rate of around 500,000 ac-ft/yr or about 10 percent of total depletions for all uses. Urban growth represents one of the most dynamic elements in Arizona's water-use picture.

Estimates of 1970 water use for agricultural and municipal-industrial purposes, and for the mineral industry (principally copper mining), thermal-electric power generation, and fish and wildlife are shown in Table 3.

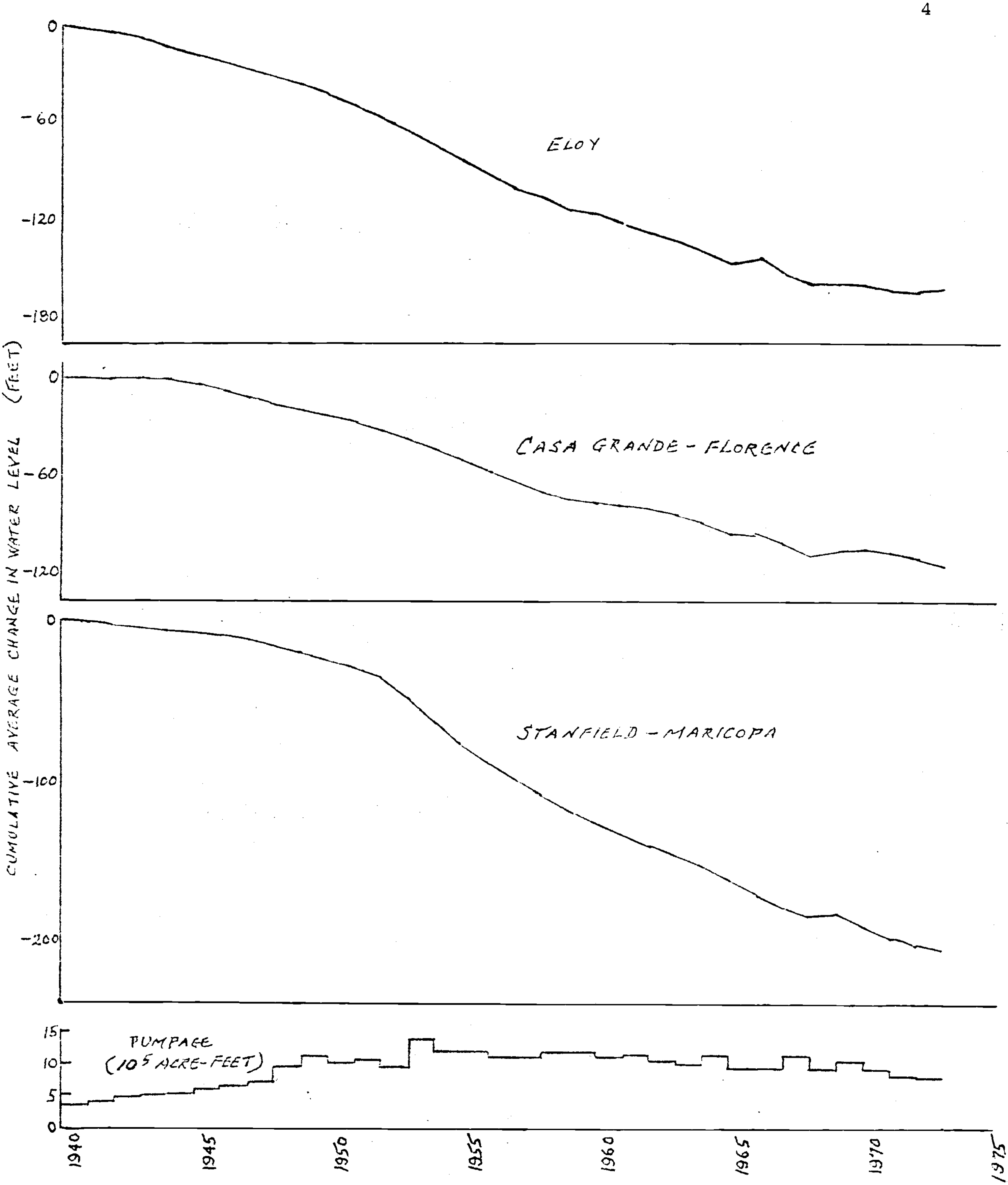

Figure 1. Cumulative Average Change in Water Level and Estimated Annual Pumpage, Lower Santa Cruz Basin.

Source: U.S. Geological Survey

Table 2

Estimated Annual Water Withdrawals by Planning District[1/]
Arizona - Normalized 1970 Conditions

Unit: 1,000 Acre-Feet

Planning District and County	Groundwater Pumpage	Surface Water Diversion	Total Withdrawal
Planning Dist. I			
Maricopa County	2,049	941	2,990
Planning Dist. II			
Pima County	412	0	412
Planning Dist. III			
Apache County	11	13	24
Coconino County	6	15	21
Navajo County	40	16	56
Yavapai County	23	24	47
Total	80	68	148
Planning Dist. IV			
Mohave County	34	52	86
Yuma County[2/]	541	1,878	2,419
Total	575	1,930	2,505
Planning Dist. V			
Gila County	16	5	21
Pinal County	1,115	197	1,312
Total	1,131	202	1,333
Planning Dist. VI			
Cochise County	506	17	523
Graham County	168	113	281
Greenlee County	27	23	50
Santa Cruz County	19	0	19
Total	720	153	873
STATE TOTAL	4,967	3,294	8,261
ROUNDED STATE TOTAL	5,000	3,300	8,300

1/ Values shown are based on the location of the water use. Several imports and exports are involved in getting water to the place of use. Import and export values are indicated in the basin tables.
2/ Groundwater pumpage includes approximately 361,000 acre-feet pumped for drainage purposes only.

Source: Arizona Water Commission, Inventory of Resource and Uses, Arizona State Water Plan - Phase 1, July, 1975.

Table 3

Estimated Annual Water Depletions by Planning District[1/]

Arizona - Normalized 1970 Conditions

Unit: 1,000 Acre-Feet

Planning District and County	Irrigated Agriculture	Municipal & Industrial	Mineral Industry	Steam Electric Power	Fish & Wildlife	Total
Planning Dist. I						
Maricopa	1,681	183	1	8	0	1,873
Planning Dist. II						
Pima County	211	69	53	6	0	339
Planning Dist. III						
Apache County	14	2	1	0	0	17
Coconino County	9	5	0	0	0	14
Navajo County	26	15	0	3	0	44
Yavapai County	24	5	5	0	0	34
Total	73	27	6	3	0	109
Planning Dist. IV						
Mohave County	23	7	4	0	38	72
Yuma County	954	13	0	1	2	970
Total	977	20	4	1	40	1,042
Planning Dist. V						
Gila County	2	3	14	0	0	19
Pinal County	830	12	31	1	0	874
Total	832	15	45	1	0	893
Planning Dist. VI						
Cochise County	335	9	8	1	0	353
Graham County	157	2	0	0	0	159
Greenlee County	17	2	14	0	0	33
Santa Cruz County	11	2	0	0	0	13
Total	520	15	22	1	0	558
STATE TOTAL	4,294	329	131	20	40	4,814

1/ All values rounded to nearest 1,000 acre-feet.

Source: Arizona Water Commission, Inventory of Resource and Uses, Arizona State Water Plan - Phase 1, July, 1975.

Quality Constraints on Water Use

Each use of water carries its specific requirements for water quality. Similarly, each source of water has its inherent or induced quality characteristics. Fortunately, many of Arizona's water supplies are of acceptable quality to meet the uses for which they are needed. But there are important exceptions--and there are instances where poor or marginal water quality is the limiting factor in a water-based activity.

Common water-quality problems in Arizona are locally high fluorides, water "hardness", and water salinity or relatively high concentration of total dissolved solids. Because of high salinity in ground water and in soils, careful irrigation water management practices are essential, particularly in the lower Colorado River region, the Safford Valley, and elsewhere in the Gila and Salt River drainage basins. Public water supplies in the growing cities and towns are derived principally from ground water; in various localities, dissolved salts content exceeds recommended drinking water standards, as do fluoride ion concentrations, and water hardness is a boon to the sale of home water softeners.

To these natural or inherent water quality constituents are being added an array of human-induced contaminants and pollutants, ranging from viruses to pesticide residues to radioactive wastes. Federal legislation and state regulatory measures are at work to preserve water quality, establish standards, and mitigate water pollution, but the achievement of these goals will require a strong effort by all the state's water users and the public at large.

WATER CONSERVATION

Wherever water demand exceeds water supply, it is possible to reduce the imbalance by two general approaches--increasing the supply, and/or reducing the damand. Reduction of demand through water conservation alone may not erase the large and growing water deficit in Arizona, but conservation efforts should be intensified nonetheless; a partial solution is better than none.

In Arizona, the topic of water conservation has been addressed recently by the Arizona Water Commission as a part of the Arizona State Water Plan.[2/] The AWC report describes techniques of water conservation in the urban, agricultural, and industrial sectors, and recommends action programs for implementing water conservation. In the industrial uses (principally mining-milling operations and steam-electric power generation), it was concluded that any substantial water-use reduction will depend upon future technological improvements in process or cooling plant design. In agricultural uses, which account for 89 percent of statewide water depletions, water conservation can be enhanced chiefly by improvements in distribution systems and irrigation water management, and by modifications in application method, crop selection, and water pricing. It is estimated that an intensive program of improvements in irrigation water management and distribution systems would result in a 10 to 15 percent reduction in depletions and would yield a water savings of 430,000 to 640,000 acre-feet per year in Arizona.

In the urban water use sector, residential uses represent the single largest component, and the specific indoor and outdoor use rates (at the 1976 level, statewide) are as shown in Table 4. The outdoor (exterior) water uses account for more than one-half of the total residential use. The seasonal distribution of such uses in an urban center such as Tucson is illustrated in Figure 2. An estimate of possible water savings through conservation in the urban sector is given in Table 5.

An important point is that conservation of energy and capital commonly accompanies conservation of water. The AWC study report included eight recommendations for measures that would conserve energy, capital, and water, and four additional measures that would primarily save energy and capital. For instance, much of the initial cost of producing additional ground water for cities is in the capital cost of wells, pumps and delivery system facilities, and much of the operational cost of producing such water is in the cost of energy for pumping.

This concept is especially applicable in terms of growth, as shown in Tucson's "Beat the Peak" program instituted in summer 1977 which implored residents to do lawn and other watering on alternate days and during non-peak hours of the day, thus reducing peak water delivery requirements. This program has been quite successful, and on a continuing basis, as the City water system expands, it reduces pipe sizing and other design factors and so reduces capital outlay projections in the City's 5-year capital improvement plan. Although the primary purpose of this program was not water conservation,

TABLE 4

ESTIMATED RESIDENTIAL WATER USE

ARIZONA - 1976

Type of Use	gpcd	Percent
Interior		
Toilet	30.0	20
Bath	22.0	15
Laundry and Dishes	14.0	9
Drinking and Cooking	4.0	2
Subtotal	70.0	46
Exterior		
Yard Watering	71.0	47
Evaporative Coolers	6.0	4
Swimming Pools	2.0	2
Other	1.0	1
Subtotal	80.0	54
TOTAL	150.0	100

Source: Arizona Water Commission, Water Conservation, Arizona State Water Plan Phase III - Part 1, June 1978.

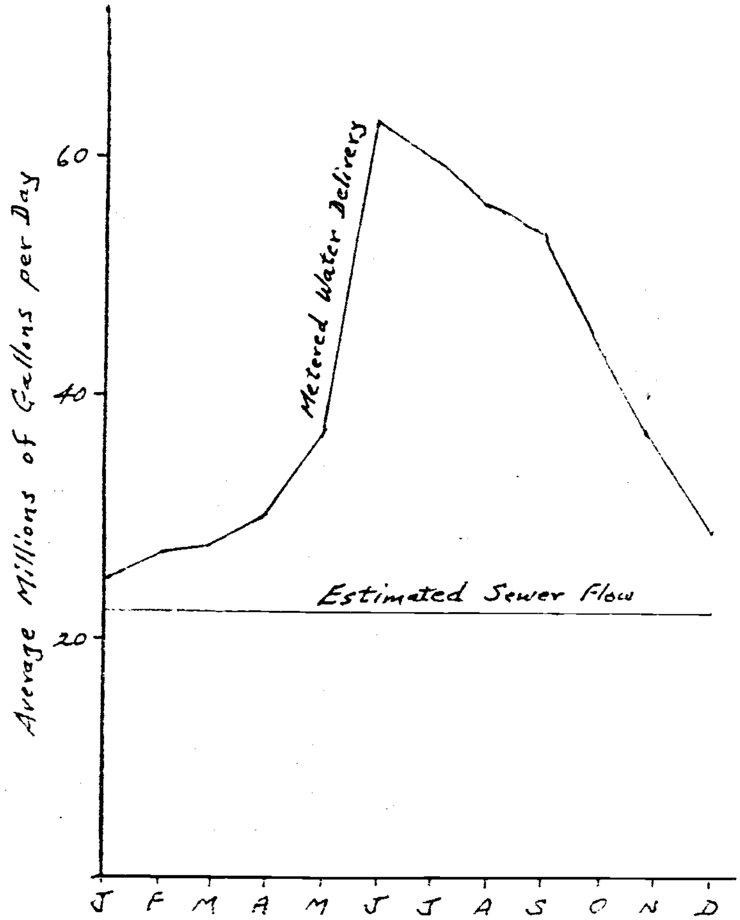

Figure 2. Graph of Average Single-Family Residential Water Use and Sewer Discharge in Tucson, 1975.

Source: De Cook, K.J. and others, Water Conservation for Domestic Users, 1977.

TABLE 5

POTENTIAL URBAN WATER SAVINGS

ARIZONA - 1980

Use	Estimated Withdrawals Without Water Conservation (acre-feet/year)	Assumed Percent Savings With Conservation	Estimated Savings In Withdrawal (acre-feet/year)
Residential			
Interior	212,000	15	32,000
Exterior	250,000	15	38,000
Commercial	142,000	10	14,000
Government	36,000	15	5,000
Industrial	36,000	5	2,000
Losses	36,000	20	7,000
TOTAL	712,000	14	98,000

Source: Arizona Water Commission, Water Conservation, Arizona State Water Plan Phase III - Part 1, June 1978.

a substantial reduction in summer water usage has been observed.

In general, two kinds of incentives for water conservation exist. On either a corporate or an individual level, direct economic incentives are present such as the urban resident's lower monthly water bill or a mining company's potentially lower pumping cost due to water savings. A second kind of incentive is a social awareness of resource depletion and a consequent desire to conserve for the sake of future availability and use of the water resource, as in the case of deep ground-water reserves. In the past, conservation of water for the purpose of direct monetary saving has been a weak incentive, because water commonly has been underpriced or so inexpensive that the user either is unconcerned about water cost or feels that the capital cost of implementing a more water-conserving system would cause a changeover to be not cost-effective. An example may be the cost of changing from a conventional flood irrigation method to a trickle irrigation system.

In recent years, however, the resource conservation ethic has emerged as a factor in public attitudes and national policy, partly because of the environmental movement, the energy crisis, and a growing realization that resources are finite and that the "technological fix" does not always provide a ready solution to shortage, because economic, political, cultural or environmental factors may impede its implementation. Thus public action, both voluntary and coercive, toward conserving water is increasingly evident in the form of tax incentives, zoning and land use ordinances and subdivision restrictions which require low-water-use landscaping and plumbing fixtures, among other measures. But effective changes in attitudes and lifestyles take time, building gradually through public education. This is an essential ingredient, because "...the children of today will face water supply problems more serious than those of today; for them, water conservation will have to be a way of life".[3/]

WATER AVAILABILITY AND COSTS

When water supply is needed, it is necessary not only that it be available in the proper quantity and quality, but at the right time and place. For example, surface-water supplies accumulate in the form of rain and snow in the mountainous terrain of the Salt and Verde watersheds, principally in winter and spring, but are needed for irrigation in the alluvial valleys, principally in the summer. It is this seasonal and geographic displacement that gave birth to the ponderous systems of storage reservoirs and canals on the Salt, Verde, and Gila Rivers, as well as the Colorado.

Ground-water reservoirs, on the other hand, have been provided by Nature, and once we have drilled and tapped them we can turn on the pumps when needed without undue regard for seasonal variations. Geographic dislocations do exist, of course, and it is necessary in places to pump ground water into the canal system, to be commingled and transported with the surface water to the point of use. With judicious conjunctive use of waters in surface and subsurface reservoirs, operational schedules can be devised to handle daily and seasonal variations.

Notwithstanding the rise of prices with time due to inflation, the monetary cost of acquiring, conveying, and utilizing water supplies, from either surface or underground sources, generally increases with growth. Conveyance costs become greater not only because distances for importation become longer, but also because conveyance canals and pipelines have to cross increasingly complex terrains containing denser networks of roads and freeways, more housing and other construction, and higher valued rights-of-way. Non-renewable ground-water sources too become ever more costly to pump, because pumping lifts increase as overdraft pulls down the water table, and the cost of energy represents a large share of total pumping costs.

Environmental costs, whether direct and tangible or indirect and esthetic, also tend to become excessive as water requirements grow. Water conveyance and storage facilities cross or occupy fragile desert vegetative zones; habitats or migration routes of wild animal species, some endangered or threatened; historical and archeological sites; and areas of intrinsic or esthetic beauty. Prolonged pumping of ground water in the alluvial basins results in earth cracks and land subsidence, the effects of which may be irreversible, hazardous, or costly..

In considering water availability, these environmental aspects as well as numerous other factors can be taken summarily into consideration in evaluating all possible sources of water that conceivably could be made available at a given location. Such an evaluation was undertaken recently for the City of Tucson,[4/] excluding the common sources of ground water, wastewater, and Central Arizona Project but including "traditional" water sources such as near and long-distance imports and "exotic" (generally, process-oriented) water sources such as desalinization or cloud seeding. A summary of these sources is shown in Table 6.

PROJECTED WATER NEEDS

The needs of Arizona's water users for the period 1970-2020 have been estimated in planning studies by the Arizona Water Commission, assuming various population projections, along with estimated projections of actual water depletions under selected alternative future conditions. Under all the alternative sets of assumed conditions, perennial water-supply deficiencies are foreseen.

A few figures taken from those studies [5/] may be informative. The 1970-level annual overdraft on water supplies was approximately 2.2 MAF. If it is assumed that the Central Arizona Project is essentially completed by 1987 as scheduled presently, the water imported thereby will reduce the overdraft by possibly two-thirds, to around 800,000 acre-feet per year. By 1990, under "medium" projections, the deficiency will again be rising toward 900,000 ac-ft/yr, and by 2020 will almost double, to about 1.6 MAF/yr. Depletions by sector of use, excluding agriculture, again considering medium growth range, were estimated as in Table 7.

Combining the above data with projected agricultural depletions as per Alternative II (medium) conditions, the summary figures shown in Table 8 are obtained.

The data shown above are illustrative only, pertaining to only one set of assumptions. The nature of the actual water budget in any future year will depend upon actual population growth and other variables which are independent of water management plans or controls. Upon that result will be superposed the effects of whatever management controls are adopted. What these controls will be is not now known, and what their effects will be can only be surmised. In summary, in early 1980 it is extremely difficult to predict what the status of the water resources budget will be from 1980 on.

The reason for this is that the state ground-water code is currently being completely revised. Since ground-water overdraft is the most crucial aspect of the state water budget, and since the revised code will deal principally with management alternatives for groundwater, everything depends

TABLE 6

THE FEASIBILITY OF UTILIZING REMOTE SOURCES OF WATER TO AUGMENT THE NATURAL SUPPLY OF THE TUCSON AREA

The following ranking was prepared for and presented at a public participation meeting of the Tucson Urban Study, August 28, 1979.

SOURCE	RANK+	REMARKS
Evaporation Suppression	1	Especially considering destratification
Altar Valley	2	Proximity but legal/political questions
San Pedro Valley	3	Exchange possibilities: proximity but legal/political/environmental questions
Soil-conditioned Catchments	4	Retired farmland/rural developments: restricted quantities
Cloud Seeding	5	Large potential at low cost: environmental questions
Iceberg Harvesting	6	Technical/environmental feasibility to be demonstrated: institutional questions
Desalinization	7	High cost: legal/environmental questions
Vegetation Management	8	Technical/economic/environmental questions: institutional agreements needed
Salt-Verde-Gila Rivers (exclusive of the Salt River Project)	9	Technical/legal/political questions: surplus floodwaters
Salt River Project	10	Legal/institutional questions: high cost
Columbia River	11	Legal/institutional/environmental questions: Snake-Green diversion
Upper Colorado River (exclusive of the Central Arizona Project)	12	Legal/institutional questions
Other Long Distance Surface Water Transfers	13	Legal/institutional/economic/environmental questions: long time for implementation

+Although the above tabulated sources of water and their ranking are based on technical, economic, environmental and legal aspects of each source, space does not permit a detailed discussion of the rationale for this generalized ranking, which is purely the opinion of the Water Resources Research Center Project Staff.

Table 7

Projected Nonagricultural
Water Depletions*
(1,000 acre-feet)

Use	1970	1990	2020
Urban	329	494	710
Steam Electric Generation	20	139	427
Mineral Production	131	305	622
Fish and Wildlife	40	74	74
TOTAL	520	1,012	1,833
(ROUNDED)	500	1,000	1,800

*From Arizona Water Commission, Alternative Futures, Arizona State Water Plan, Phase II, February 1977.

Table 8

Projected Average Annual Statewide
Depletions and Supplies*
(1,000 acre-feet)

Year	Non-Agric.	Agric.	Total	Dependable Supplies	Water Supply Deficiency	Ratio: Depletion vs. Supply
1970	500	4,300	4,800	2,800	2,000	1.7
1990	1,000	4,300	5,300	4,400	900	1.2
2020	1,800	3,900	5,700	4,100	1,600	1.4

*From Arizona Water Commission, Ibid.

upon which recommended measures are adopted into legislation, if any. The Groundwater Management Study Commission has completed its mandated study and recommendations for water legislation; the political necessity of enacting strong legislation and conserving the ground-water resource has been emphasized by the Governor of Arizona, the Secretary of the Interior, and many others; it remains to be seen how the Arizona Legislature of 1980 responds to this critical need.

REFERENCES CITED

1. Arizona Water Commission, Arizona State Water Plan, Phase I: Inventory of Resource and Uses, Phoenix, July 1975.

2. Arizona Water Commission, Arizona State Water Plan, Phase III, Part I: Water Conservation, Phoenix, June 1978.

3. DeCook, K. J. and others, Water Conservation for Domestic Users, A Handbook Prepared for the City of Tucson by the University of Arizona, 1977.

4. University of Arizona, Feasibility of Utilizing Remote Sources of Water to Augment the Natural Supply of the Tucson Area, Pima County, Arizona, A Report to the U.S. Army Corps of Engineers, Tucson, December 1979.

5. Arizona Water Commission, Arizona State Water Plan, Phase II, Alternative Futures, February 1977.