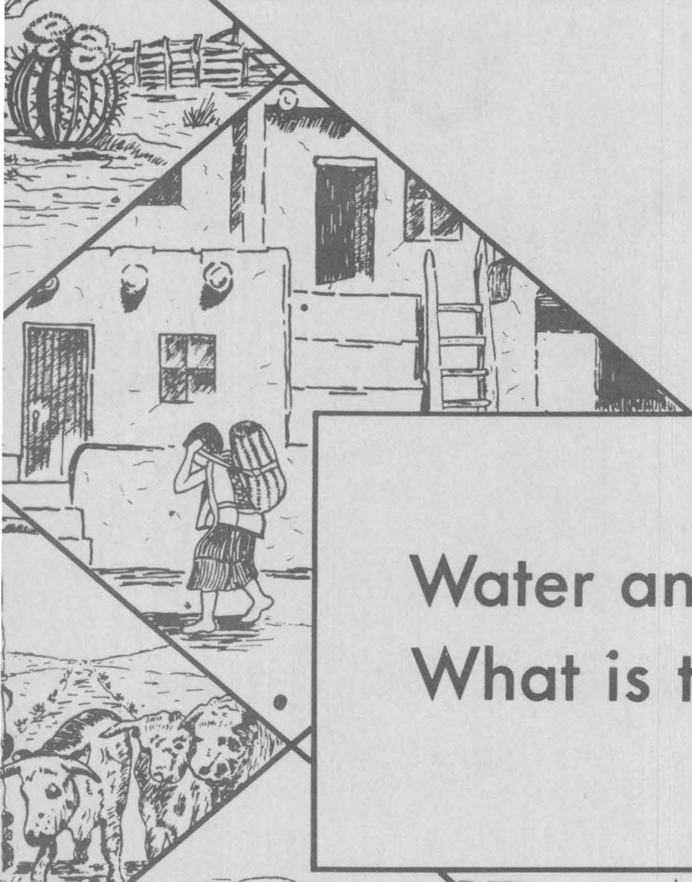
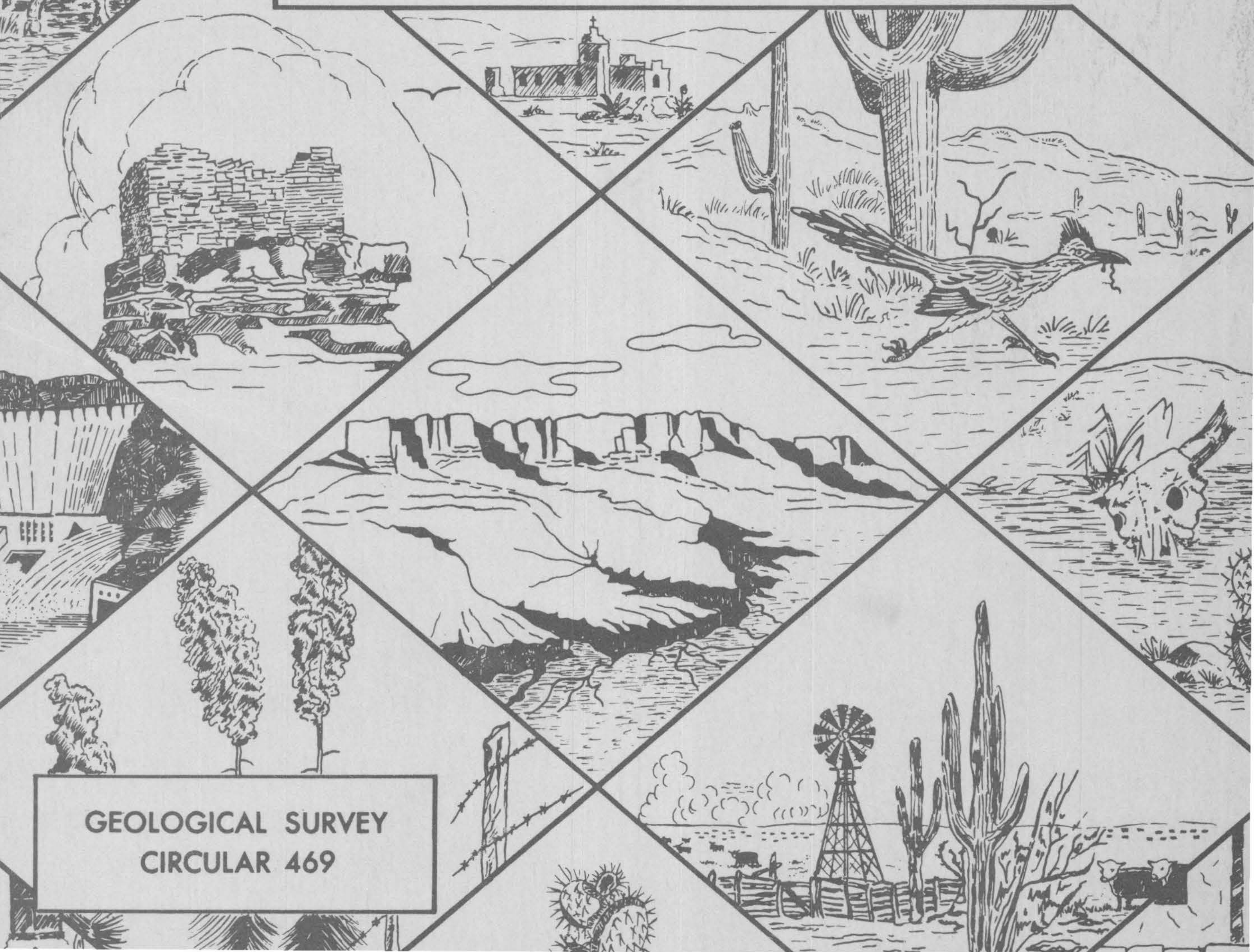


Water and the Southwest—What is the future?



GEOLOGICAL SURVEY CIRCULAR 469

Water and the Southwest—What is the future?

By H. E. Thomas

Geological Survey Circular 469

Washington
1962

United States Department of the Interior
STEWART L. UDALL, SECRETARY

Geological Survey
THOMAS B. NOLAN, DIRECTOR

Free on application to the U.S. Geological Survey, Washington 25, D. C.

CONTENTS

ILLUSTRATIONS

Water and the Southwest—What is the future?

By H. E. Thomas

INTRODUCTION

As a Nation we are in a better position than ever before to take stock of what we have, peer into the future, and plan to make the best of it. Partly this is because of the studies of water resources activities made for the Senate Select Committee which during the past 2 years has published 32 reports (or prints) in 3 volumes of 600 to 700 pages each. Doubtless many of you have seen some of these prints, and several may have contributed to them. They are new to me, however, and at the risk of repeating what may already be well known to you, I should like to offer a brief review.

REVIEW OF SENATE SELECT COMMITTEE PRINTS

The first volume, on background, includes a number of prints, one of which gives a history of water resources during the past 50 years, another incorporates the views and comments of the States, and a third provides projections of population and economic activity to 1980 and 2000. Three prints by the U. S. Geological Survey summarize the physical data and problems concerning water: a resource that is derived from precipitation which varies from place to place and fluctuates from season to season and year to year but which is a perennial supply whose long-term average evidently approaches a constant. (See fig. 1.) Of this average precipitation, 70 percent returns to the atmosphere. The part remaining as surface water or replenishable ground water is about 1,200 billion gallons per day (bgd), which eventually runs off to the oceans. We are currently withdrawing a quarter of this--or 300 bgd--for municipal (24 bgd), irrigation (138 bgd), and industrial (138 bgd) uses (fig. 2), but only about 90 bgd is consumed in these uses, and more than 200 bgd rejoins streams, so that runoff is still 1,100 bgd. Most of this unconsumed 200 bgd has been used for cooling in industry (fig. 3), but the rest may carry chemical or organic residues that impair its quality. Projection of trends in water use, as shown in figure 4, indicates that the withdrawals by 1980 will be about 600 bgd--double that at present--but most of the increase will be in the eastern half of the country, where nonconsumptive uses are dominant. Thus even by 1980 the average runoff to the oceans will be close to 1,000 bgd. This is the national average.

The variations from this average can be shown in many ways. Precipitation divides the country into a humid East and an arid West, which has abundant precipitation only on mountain ranges and along the north Pacific coast. (See fig. 5.) Runoff reflects this same general pattern (fig. 6). The quality of water ranges widely and is generally best in the regions of greatest precipitation and runoff (fig. 7). In each stream, and at each point on the stream, the runoff is likely to fluctuate seasonally and annually; in some regions we find alternating droughts and wetter periods, each of several years' duration (fig. 8). As a result of these variations, the Nation has a considerable variety of water problems (fig. 9). Here in the Southwest, we have nearly all the problems, although pollution and floods are less troublesome than in some other parts of the country.

The second volume, on future needs, includes prints prepared by Federal agencies. These prints give estimates on the future requirements for all contemplated uses, including municipal, industrial, pollution abatement, electric power, navigation, soil conservation, agricultural, reclamation, flood control, recreation, fish, and wildlife. In places of short supply, obviously, some of these uses are competitive for the available water.

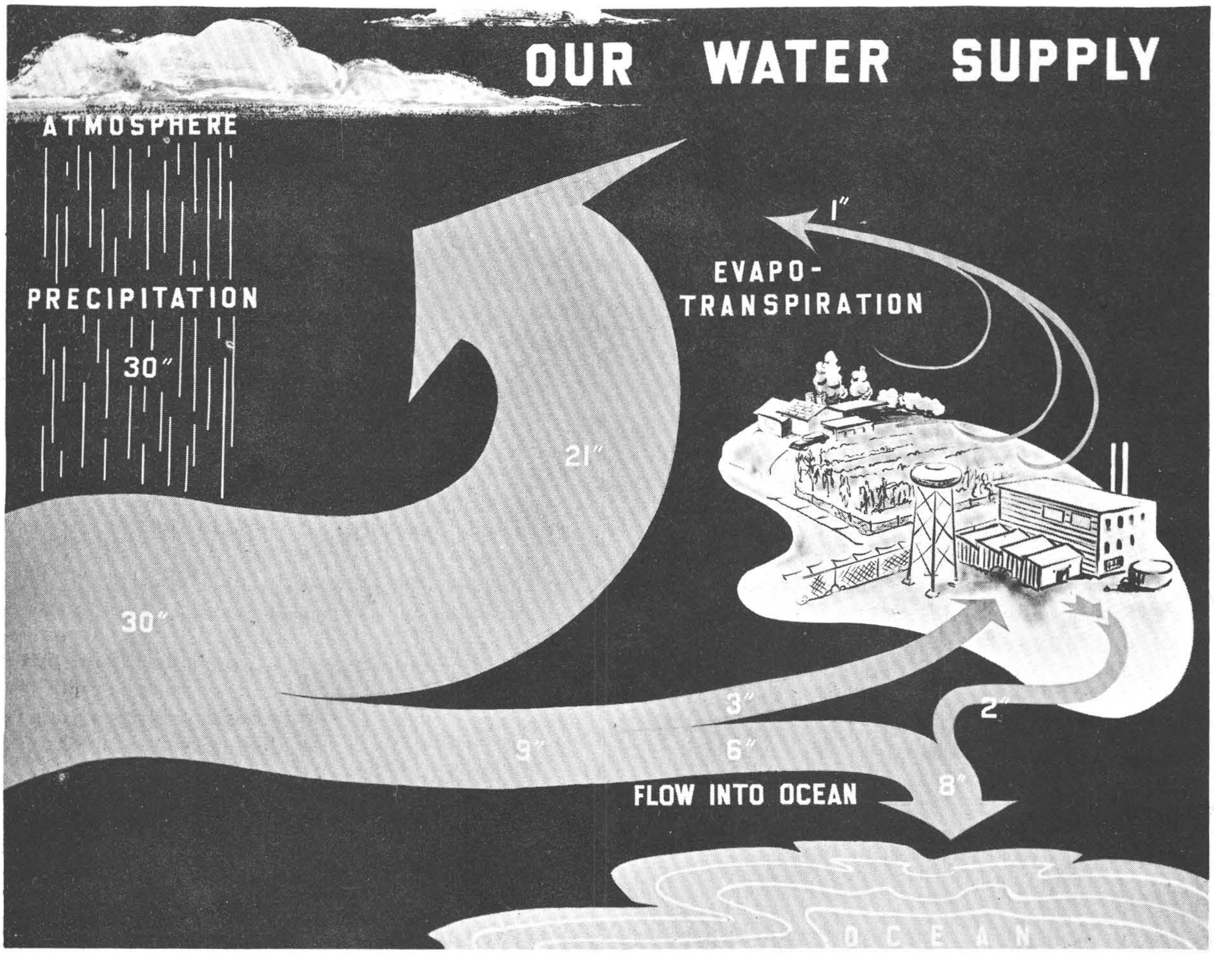


FIGURE 1.

The third volume, on meeting needs, includes prints on subjects ranging from reuse of water to desalination and weather modification, and I would like first to summarize the last and longest of these, one prepared by the Resources for the Future entitled "Water Supply and Demand." Dr. Nathaniel Wollman here relates the natural variation in water supply to the estimates of future population, level of economic activity, use of water, and maintenance of satisfactory quality, as of 1980 and 2000. As to supply, he does not include ground water, except as it contributes to surface runoff. For future requirements he uses the estimates contained in the second volume. For the streams of the Nation he points out two broad essentials for meeting these requirements: storage for regulation of the variable flow and treatment of wastes to minimize the dilution required for maintenance of satisfactory water quality. His medium estimate for 1980 is that 525 bgd (75 percent more than at present) will be required for a population of 240 million (33 percent more than at present). Wollman's "minimum cost" program to assure this quantity of usable water would require a capital investment of $2 billion annually and annual operating costs of about $2.4 billion. The GNP (gross national product) is projected to double by 1980--to an estimated $1,060 billion. Thus this "minimum cost" program would require about 1 percent of the projected increase in GNP. An encouraging note is that, if the GNP doubles while population is increasing only 33 percent, this program can be paid for by money that we don't even receive today.

This national picture is an aggregate derived from separate analyses for each of 22 reasonably homogeneous water-resource regions. Four of these regions are in the Southwest: the Colorado Basin, the Great Basin, the South Pacific (southern California), and the Central Pacific (the rest of California and southern Oregon). In these four regions the population by 1980 is predicted to be 60 to 80 percent greater than in 1960--a rate of increase that will approach twice the national average. The Central Pacific region has sufficient water to meet the increased needs in 1980 and even in 2000, provided maximum storage is developed for regulation. But according to Wollman, the other three regions of the Southwest have water supplies that will fall short of meeting projected needs. On the basis of his medium projections of population and economic activity, he predicts that consumptive use of water in 1980 will exceed the maximum total capable of being developed by maximum storage and by complete (97 percent) treatment of wastes in each of the three regions. He concludes that if the Southwest (I will use this term henceforth for his three regions--Colorado Basin, Great Basin, and South Pacific) is to share in projected population and economic growth one or more of the following adjustments in the projections for 1980 must take place:

1. An increase in water supply by increase in precipitation, increase in runoff, importation, or desalination.
2. An increase in efficiency of water use beyond that which is anticipated.
3. A reduction in heavy water-depleting uses in order to allow fulfillment of other uses.

CRITIQUE

My first reaction to these conclusions was to wonder whether the prospects are really so serious in the Southwest and to look more closely at the estimates pertaining to some of the items I know best--ground water for instance. Wollman did not consider ground water separately, and remarked that our knowledge of ground water is not sufficient to permit a satisfactory integration of ground and

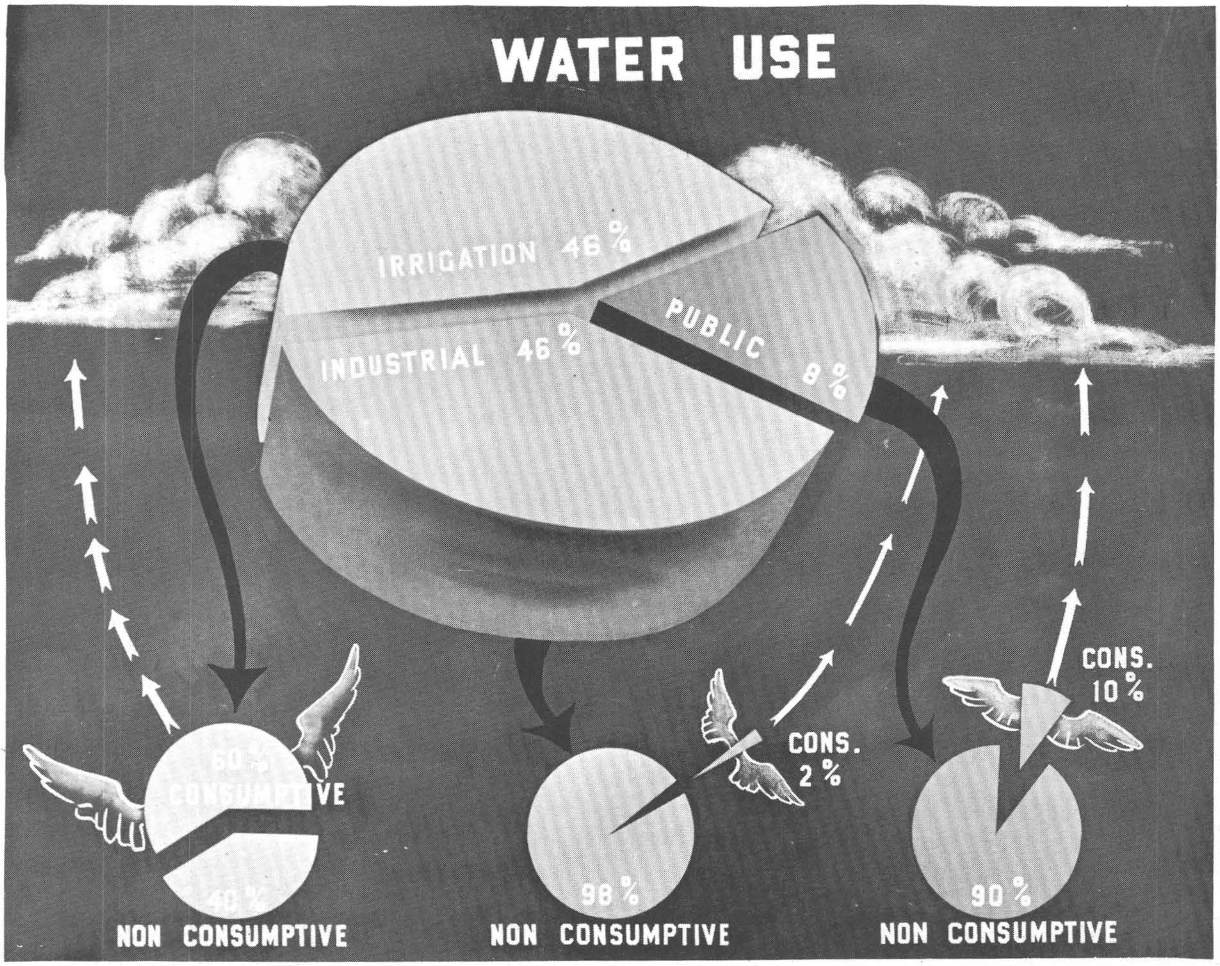


FIGURE 2.

surface supplies. (See fig. 10.) But his tabulations of present withdrawals for use include ground-water pumpage that has not reduced streamflow and will not be replaced by streamflow. As a result in the Colorado Basin, for instance, although the natural average runoff is only 13 bgd, irrigation alone can consume 14 bgd and yet leave an available supply of 3 bgd of streamflow. The apparent discrepancy is accounted for by pumping depletions from ground-water storage, especially in Arizona. Ground water is mined (fig. 11) in several places in the Southwest. At each place there may be sufficient water still in storage to last for many years, but such a supply is not perennial. If these current requirements must be met from the stream system eventually, they will add to the seriousness of the situation.

A second item is Wollman's estimates of surface runoff. The calculation of total supply in the regions of the Southwest has complications that do not arise in humid regions, where one can measure the quantity and quality of the water pouring into the ocean and see rather quickly what he has to work with and what he must do to get the optimum use of the resource. By contrast, no water flows to the sea from the Great Basin. Streams gain in some reaches, chiefly in their headwaters, and then lose by seepage to ground water, by diversions, and by evaporation. In the Southwest there are hundreds of closed basins where water may accumulate in the lowest part, either above or below ground, but where eventually all the water that falls as precipitation returns to the atmosphere (fig. 12). Significant natural losses are characteristic also of the Colorado River and its tributaries. Here ground water may be a significant but unmeasured part of the perennial supply, and thus a plus in our reckoning. However, it may be necessary to mine a large volume from ground-water storage in order to salvage the perennial yield now lost by natural discharge.

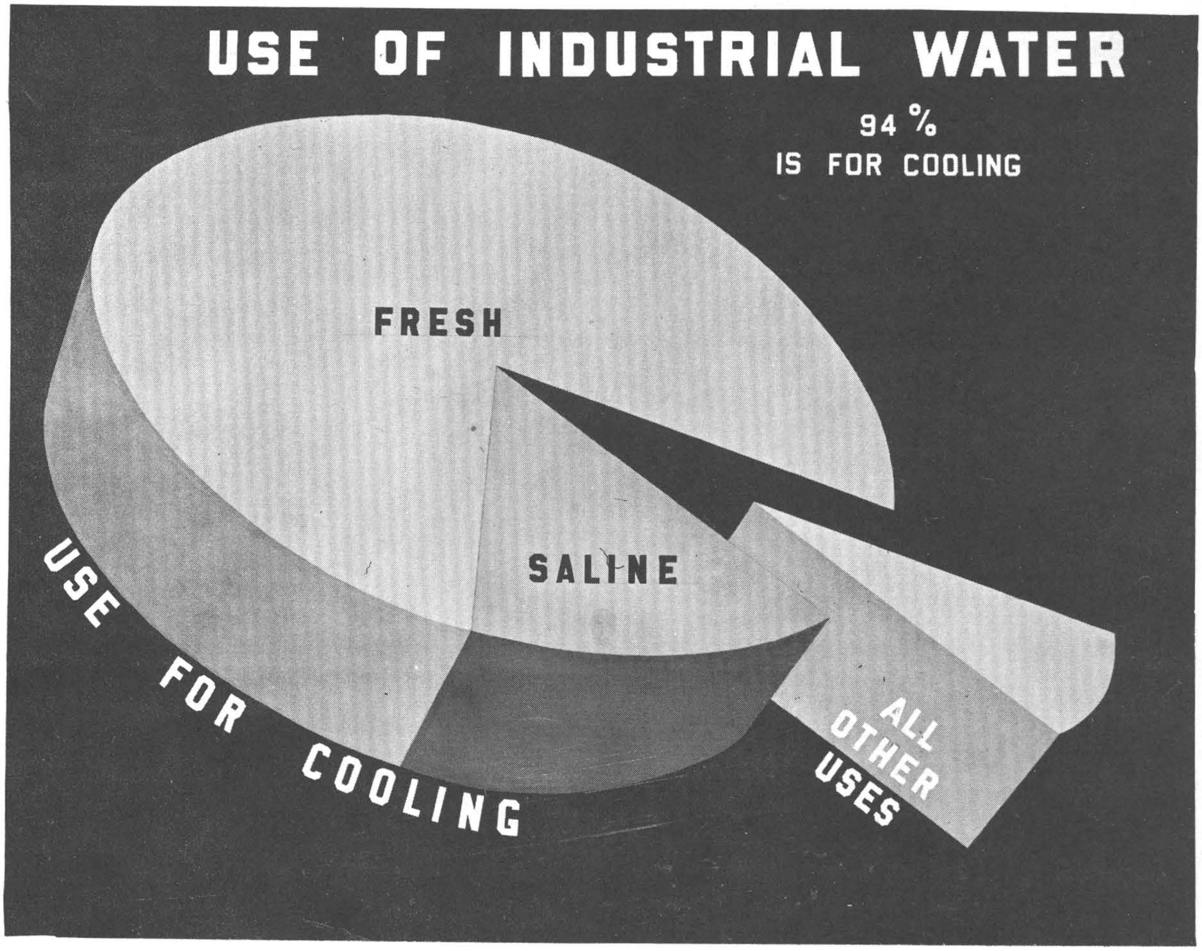


FIGURE 3.

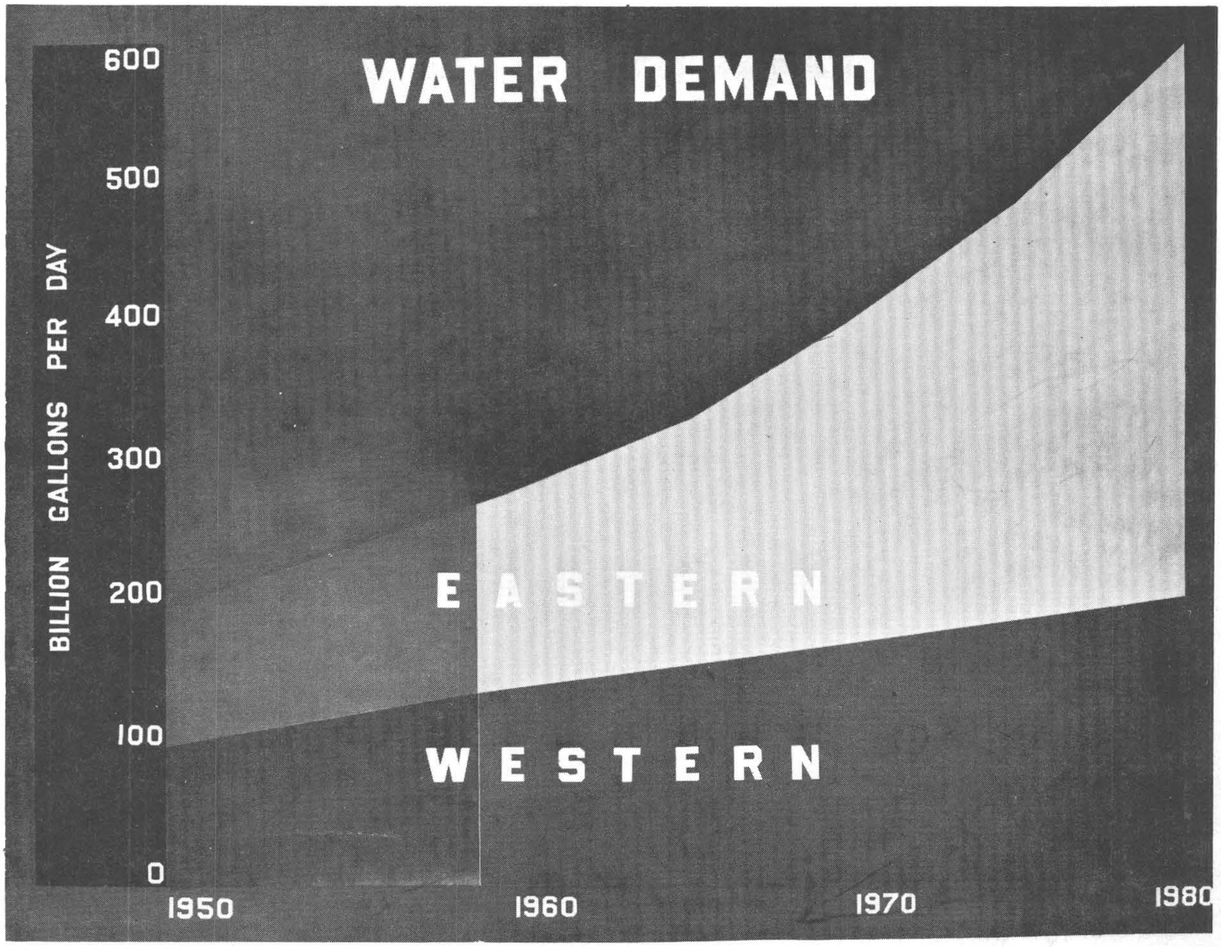


FIGURE 4.

If we were to recalculate the water supplies of the Southwest with full recognition of ground water and the salvageable natural losses, we would doubtless arrive at totals that are appreciably different from those used by Wollman. Such differences are to be expected and serve to point up Wollman's observation that there are inconsistencies and gaps in our existing knowledge and his recommendation for an expanded research program in all phases of water occurrence, behavior, and use. Basically we are confronted by the mathematical certainty that with a constant supply and an expanding demand created both by an increasing population and an increasing per capita use, eventual shortage is certain. By comparison with the rest of the country, we have in the Southwest a combination of least supply and most rapidly increasing population which gives us good reason for greater concern.

We can also agree with Wollman that if the population and economy are going to expand as projected, something must give. We must either increase the supply beyond that which nature provides or we must allocate the available water to certain approved uses and users and deny it to others. Or we must increase the efficiency of water use beyond that which is anticipated. The increased efficiency anticipated by Wollman is to be achieved by maximum storage (in surface reservoirs, resulting in increased losses by evaporation as water is held over until used) and by "complete" treatment (involving primary and secondary treatment of sewage, followed by sufficient dilution to make the mixture tolerable for further use). The Southwest has adapted these practices to a greater extent than many other parts of the country, because it has always had a more restricted water supply. But these standard operations of storage and treatment, advanced though they are in comparison with primitive practices, give us only a low order of efficiency in water use. The simplest proof of this statement is in the fact that the specter of water shortage has been seen in localities in practically all States, yet nearly 95 percent of the

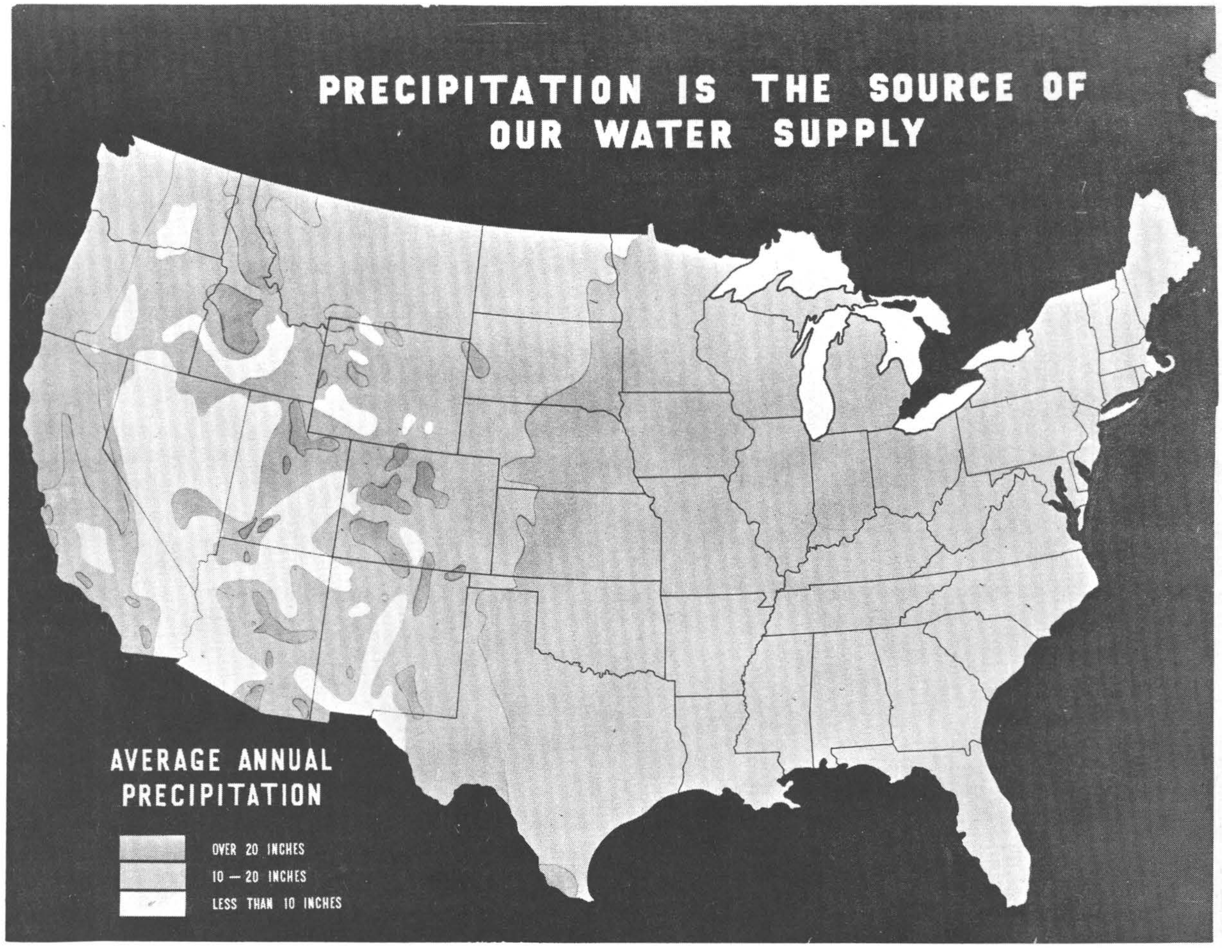


FIGURE 5.

natural runoff is still flowing to the sea. In other words, our standard bag of tricks is not enough; we will need more, and perhaps much more in the Southwest.

PERSPECTIVE

Let us pause now for a little perspective. Start with that of Colonel Glenn a few weeks ago, from an altitude of slightly more than a hundred miles. Most of his circuit around the earth was over water: oceans that have a total volume of 300 million cubic miles. Continents and islands were partly hidden from his view by water in the atmosphere--and these clouds generally give up only 5 to 15 percent of their water when they are yielding precipitation to the land surface. Certainly no one not earthbound would suspect that earthlings could be short of water. The earthling knows, of course, that the water in the oceans is not "usable" until it is purified and that water in the atmosphere is not "usable" until it gets down to earth.

Of our mineral resources other than water, we find very few ready for our use in the native state: gold nuggets, native copper, gem minerals, and a few others. The rest we must sort, grind, float, smelt, boil, condense, or otherwise refine and purify to make them usable. A large part of the cost of the usable products of these mineral resources is in this processing. If that cost for any specific product becomes exorbitant, we may be able to use a substitute that will serve our purpose at less cost. Thus our "requirement" for a specific resource is not necessarily unalterable.

What can we substitute for water? Here we are spoiled by the fact that nature is continually processing and purifying water in quantities that are very small in comparison with the total resource but large in comparison with our past needs. And this is done at no cost to us. Inevitably we have all been habituated to expect a lot for practically nothing. Within a month after I arrived in California, I received a bill for $ 6.75 for water I had used during February, a winter month and the wettest in years. This is twice as much as I pay per month for garbage removal. But the water bill was for 1,800 cubic feet, or more than 50 tons. Per ton the water, which I consider essential to my existence, cost me less than one-hundredth as much as the garbage which is nonessential. Nevertheless, the cost of the water was at the rate of $160 per acre-foot, and you know how unreasonable that sounds to our principal water users.

As another perspective, 99.44 percent has been a well-advertised standard of purity for one industry. But not for water: raw sewage is generally that pure. "Water fit to drink," according to U.S. Public Health Service standards, should be at least 99.95 percent pure, and the impurities must be harmless to health. Water meeting these minimum standards is considered to be of poor quality in many parts of the country, and indeed it would be unsuitable for many uses. Thus, although water is an abundant resource, our high standards eliminate from consideration all but an infinitesimal fraction of the total.

In perspective, then, "water shortage" is a frame of mind. Water is abundant enough that even today most of us pay only for its warehousing and delivery to the specific point where we want to use it. Thus we are conditioned to a cost so low that it is hopeless to find any substitute, except other water. Our standards for "usable" water are so high that there is an impressive total of "other" water. This "other" water can be made usable for any purpose by processes that might make the cost considerably greater than the water provided by nature; and it is usable in its present state for some purposes, of which a prime example is cooling, but we would face the additional cost of dual distribution systems for the pure water and the "other" water. The "shortage" is actually in our willingness to pay any more for water than we have become accustomed to.

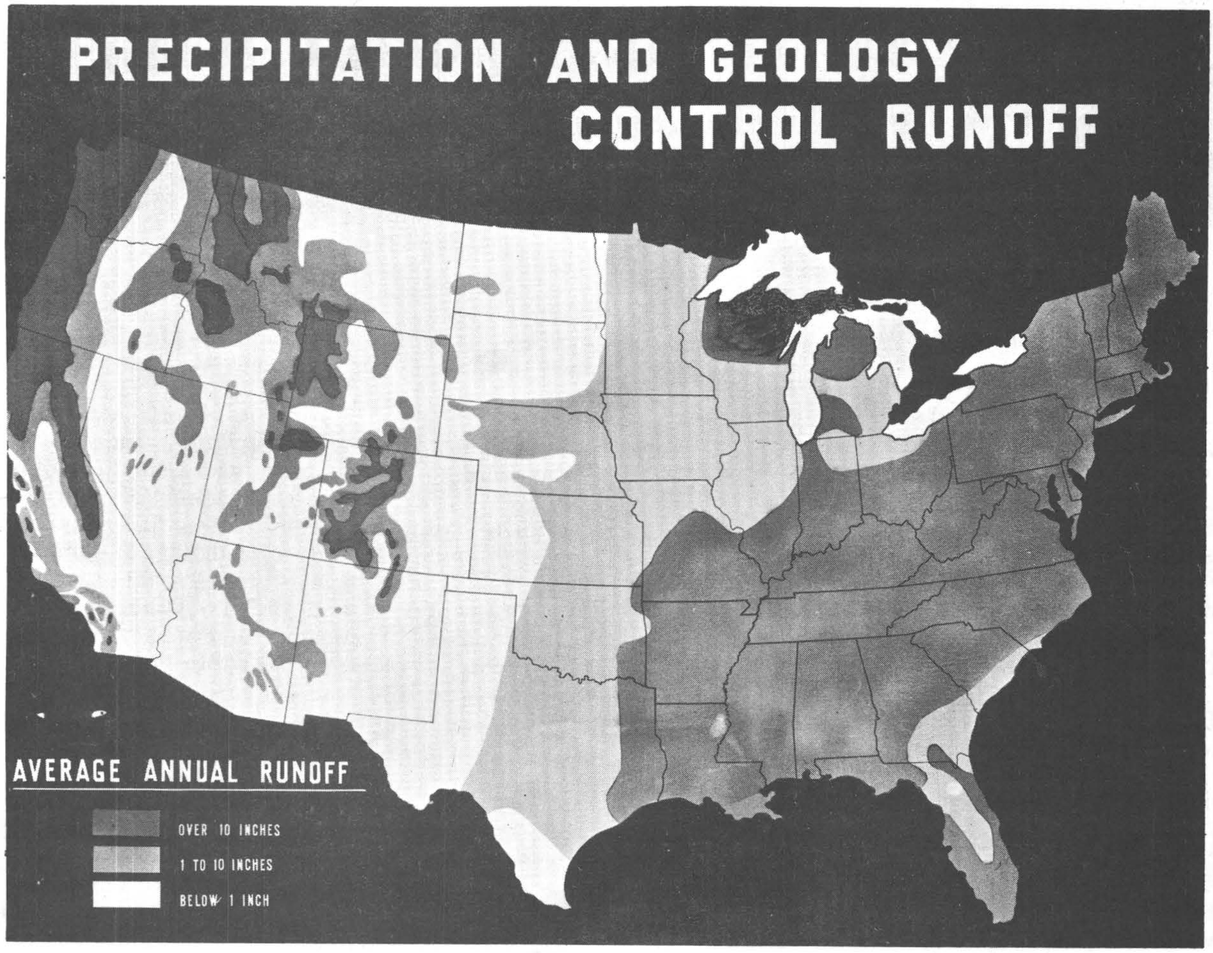


FIGURE 6.

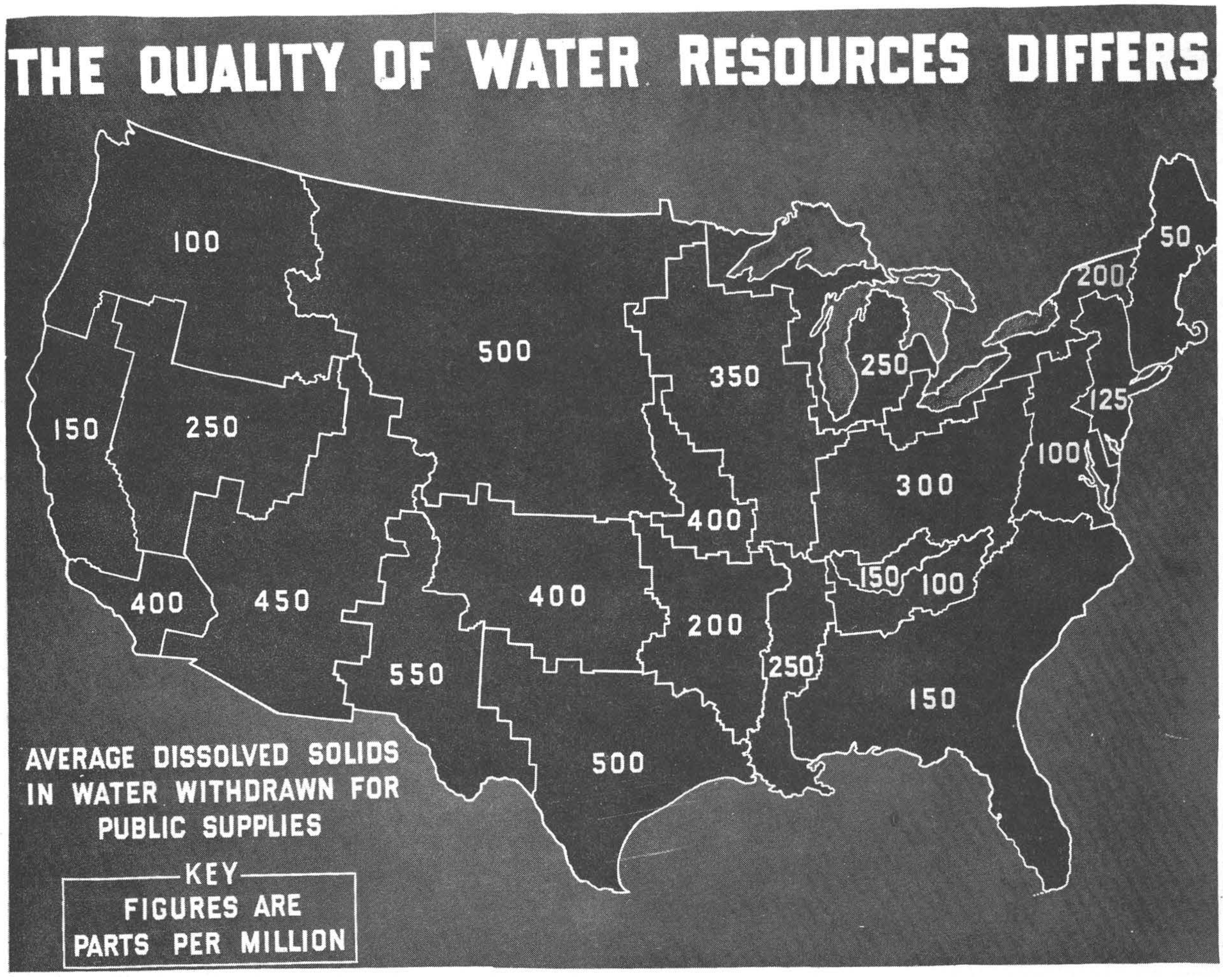


FIGURE 7.

SEEKING A BALANCE

The projected "shortage" of water in the Southwest could be avoided by restricting the population and economic growth. Los Angeles attempted to turn back an advancing wave of population in 1934, but Los Angeleans were not as numerous then as now, and they lost the battle. Since then we have found that there is much profit in subdividing the desert, and limitation of population or of economic growth or of immigration to the Southwest will probably be attempted only as a last resort.

Increasing the efficiency of water use is a more attractive objective for it would permit release of some of our existing supplies to new uses and users. Currently the principal use of water throughout the Southwest is for irrigation, and we all know that the present efficiency could be increased. Wollman anticipates widespread adoption of water-saving techniques by 1980, so that even though the irrigated acreage remains about the same as today, his projections presume that the irrigation water consumed in the Southwest will be about 3½ bgd less than the present rate.

According to Wollman's tabulations, the item representing the greatest increase--about 6 bgd--in consumptive use in the Southwest by 1980 is the requirement for fish and wildlife habitat. To some extent this requirement may be met by water that we are unable to salvage and use fully before it accumulates in saline lakes and playas. Otherwise the maintenance of swamps and wetlands, in an environment more unfavorable than any other in the country, should rate a low priority among the numerous competing requirements for water in the Southwest.

We anticipate a considerable increase in requirements for municipal and industrial use by 1980, but those uses are chiefly nonconsumptive. For the Southwest, Wollman's estimates indicate that the water to be consumed by these uses will be 1 to 1½ bgd. This increase is less than half the projected decrease in use for irrigation. We see the changeover from rural to urban lands in all our metropolitan areas, generally with only slight change in water requirement per acre.

The most challenging field for increasing the efficiency of water use in the Southwest is in the salvaging of water lost from our surface and subsurface reservoirs by evapotranspiration. The Southwest doubtless accounts for more than a quarter of the total 43 million acre-feet (40 bgd) thus lost in the 17 Western States (fig. 12). Lake Mead loses a million acre-feet (0.9 bgd) by evaporation in years of moderately high stage, and almost another million acre-feet is lost to phreatophytes in the lower basin below Lake Mead. **These losses alone take the equivalent of our** commitment to Mexico for Colorado River water. Add to this the evaporation losses from other reservoirs, and the losses to phreatophytes along other streams, and you can see that you have--or rather you don't have--a large quantity of water that could be salvaged.

The natural losses from the interior basins pose another type of salvage problem. The principal source of water is precipitation upon the mountainous rims of these basins, and the water diminishes in quantity and deteriorates in quality as it moves toward the lowest part of the basin, which is generally an area of natural discharge and probably an area of saline water and saline soils. Present users intercept the water en route, by means of dams, canals, and wells. The natural loss will continue, however, until the water level in the lowest part of the basin is lowered beyond the reach of phreatophytes. This generally requires mining of a large volume of water in order to salvage a relatively small quantity.

For each of the 22 regions of the Nation, Wollman calculates the flow needed for dilution of wastes (that have been treated to the minimum required level) so that the water

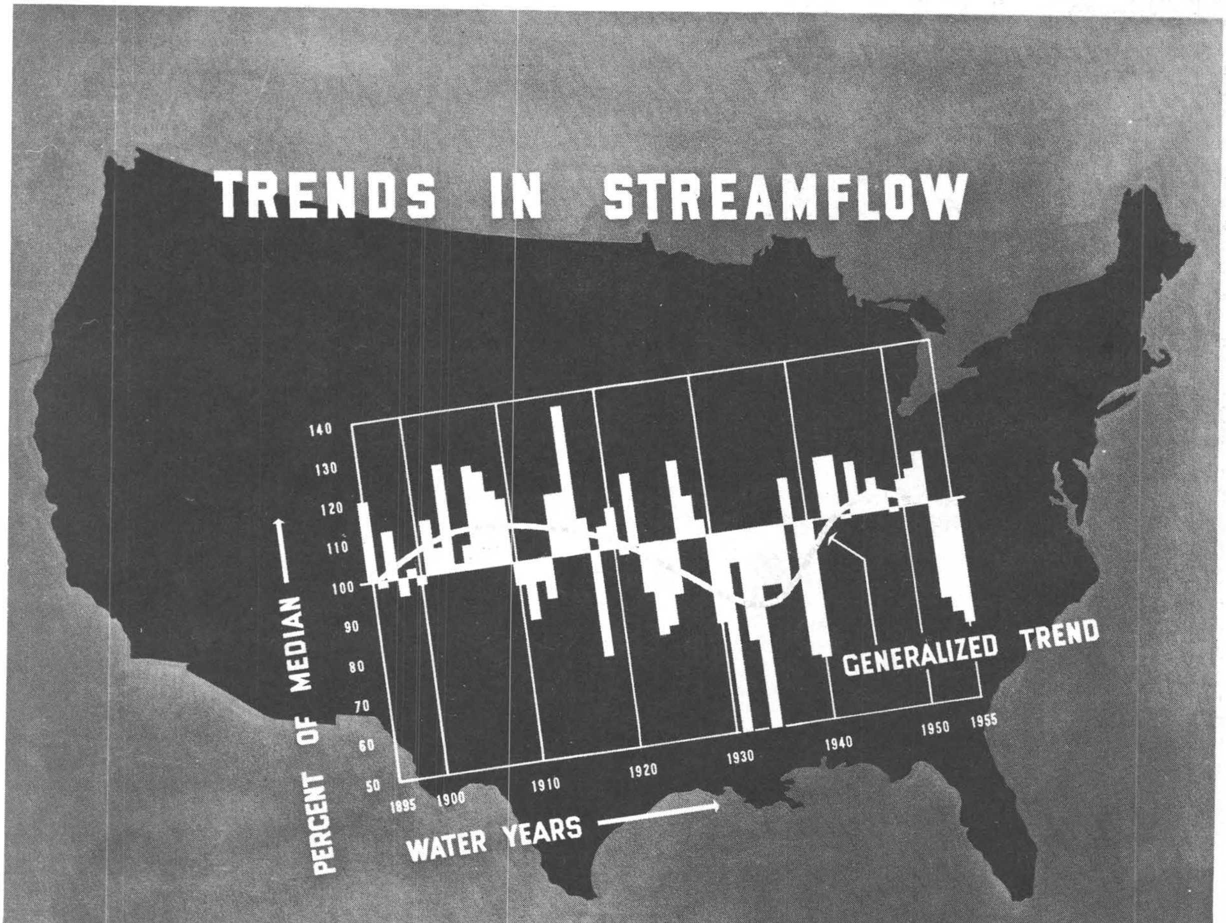


FIGURE 8.

will be usable downstream. In the three regions of the Southwest he estimates that flows of about 10 bgd would be required for dilution even after all wastes had received "maximum" treatment. However, he points out that by 1980 the projected consumptive uses alone, without taking waste dilution into account, would exceed the maximum sustained flow capable of being developed from the present supply. In several of our basins there is no problem of dilution of the waste waters: Imperial Valley is an example where the water draining the salts from the irrigated area goes to Salton Sea where no further use is made of it. A different problem arises in the lower Gila basin, where maintenance of suitable salt balance also requires removal of salts from irrigated lands. Here a separate pipeline for waste waters, discharging to the gulf or to a desert basin, may pay for itself by reducing the amount of dilution flow rerequired in the Colorado River downstream.

INCREASING THE SUPPLY

Importation of water from regions of surplus to regions of deficiency is merely an extension of a basic concept of Western civilization: live in the dry valleys and enjoy the sunshine, and use the water from the mountains which have snow and rain and are less comfortable for living. Southern California thrives on imported water, and the California Plan is essentially one of moving water from areas of present surplus in the north to areas of deficiency in the south. Even in 1980 a surplus of water is forecast in the Pacific regions north of Mount Shasta. However, one must anticipate greater use within the areas of surplus, greater resistance to exporting water from those areas, and greater costs of pipelines and transport of water that may be imported into the Southwest. In any case importation does not increase the Nation's supply but merely redistributes it.

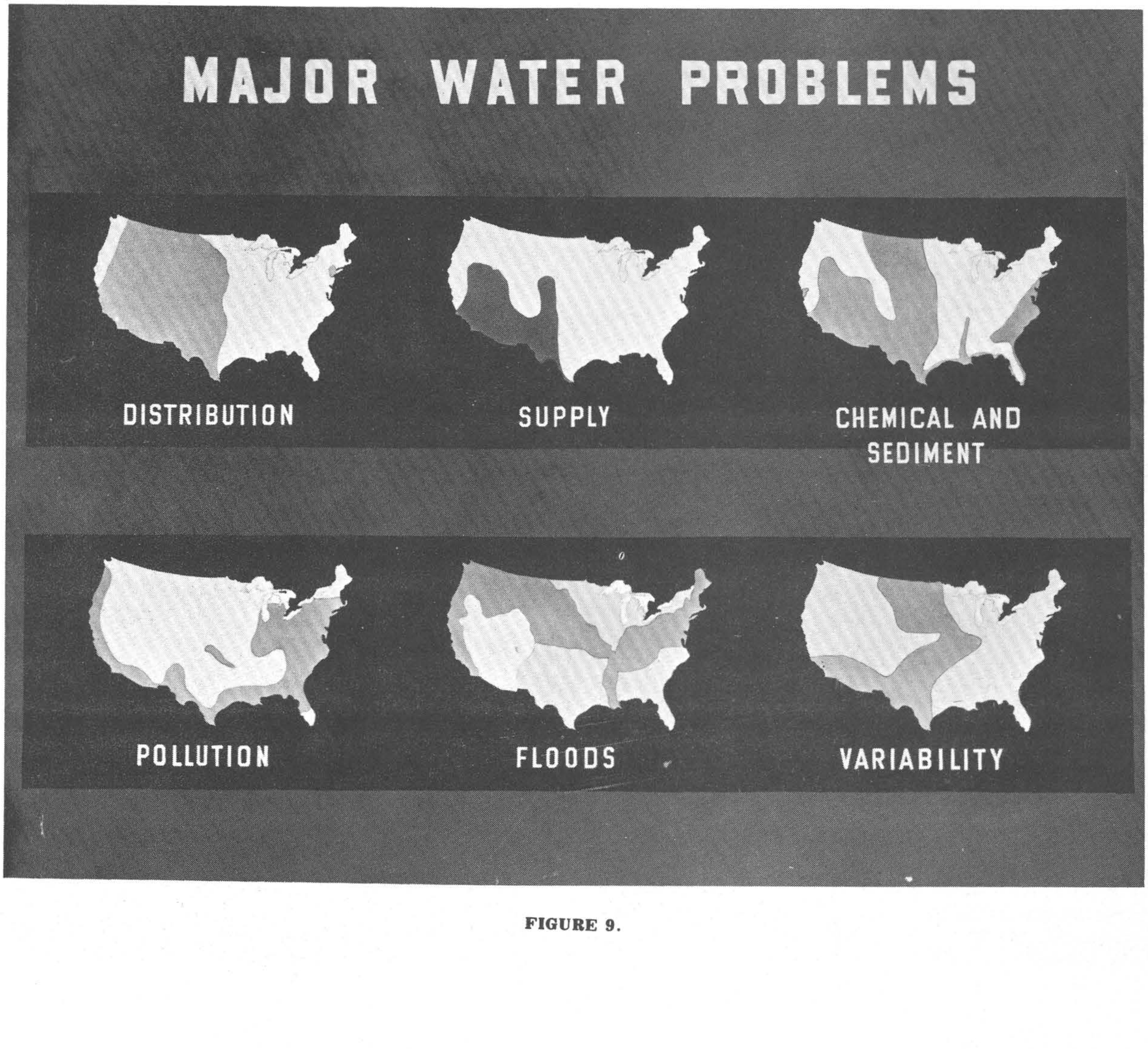


FIGURE 9.

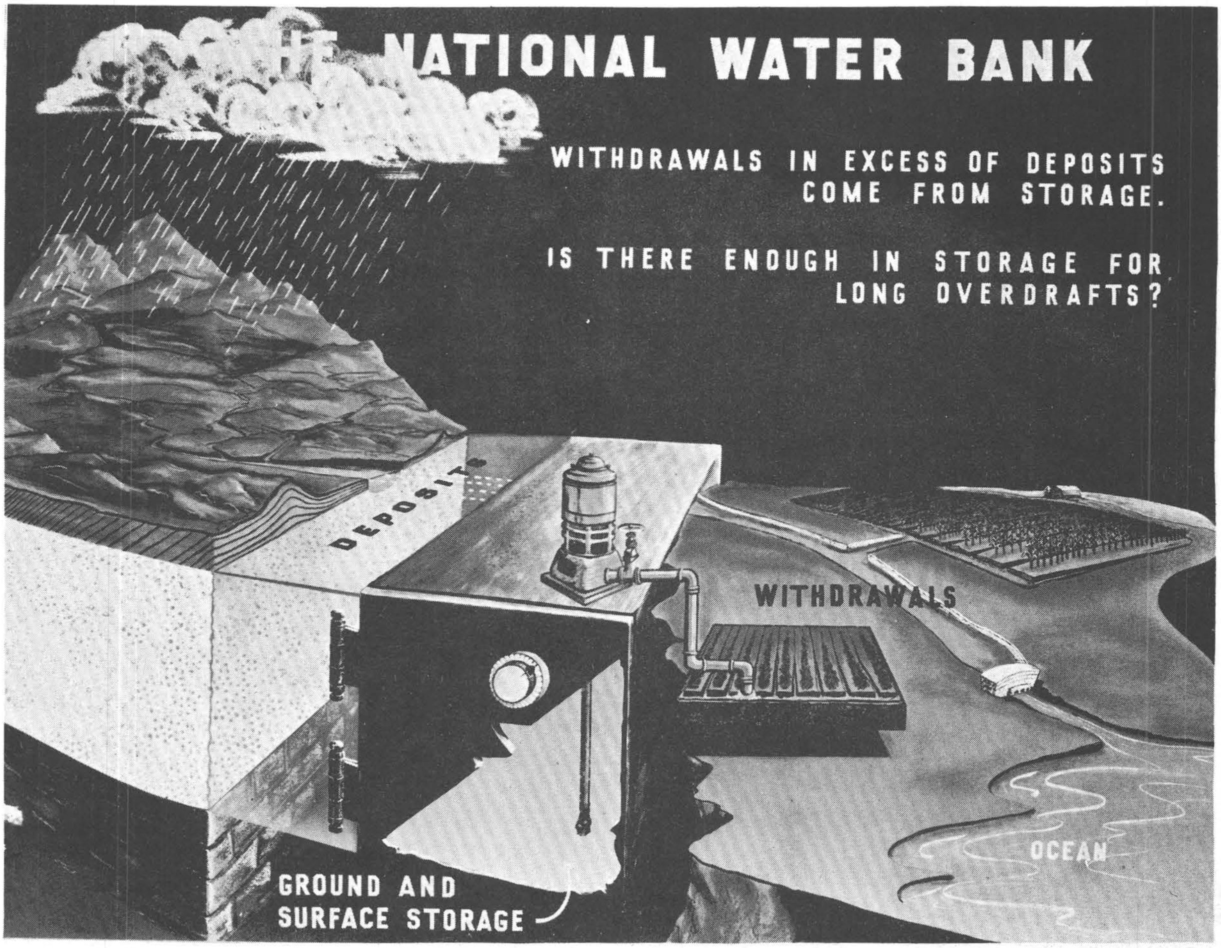


FIGURE 10.

The net water supply of surface water and ground water would be increased by any reduction of that 70 percent of the precipitation that now returns to the atmosphere. Some opportunities have already been mentioned: suppression of evaporation from reservoirs; eradication of phreatophytes along streams, thereby increasing streamflow; and pumping from wells to salvage water now lost from basins of interior drainage. Among others that might be mentioned are: modification of land cover or control of snowmelt, either to increase runoff or to induce ground-water recharge; artificial recharge of ground water when surplus surface water is available; and storage underground rather than in surface reservoirs where there is opportunity.

For increase in total precipitation, there is "cloud seeding" or weather modification, and our success to date is still controversial, as shown in the divergent views expressed in the Senate Select Committee's prints. All are agreed that there is need for further fundamental research and controlled experimentation. To date the best proof of benefit has been from seeding of winter-type storm clouds in mountainous areas of the West, and the increase has been perhaps 10 to 15 percent above what would have precipitated naturally. Thus we appear to have the environment most favorable for success in weather modification. Also, in the cloudless skies of extended droughts we have the most unfavorable conditions.

Desalination represents a substitute for the atmospheric part of the hydrologic cycle, from evaporation to precipitation. Many processes have been developed, using distillation, freezing, electrodialysis, and solvent extraction, and several of these have reached the demonstration-plant stage. However, to quote from the introduction to the Senate Select Committee print "Saline Water Conversion": "Low-cost saline water conversion is a problem which has not been satisfactorily solved to date."

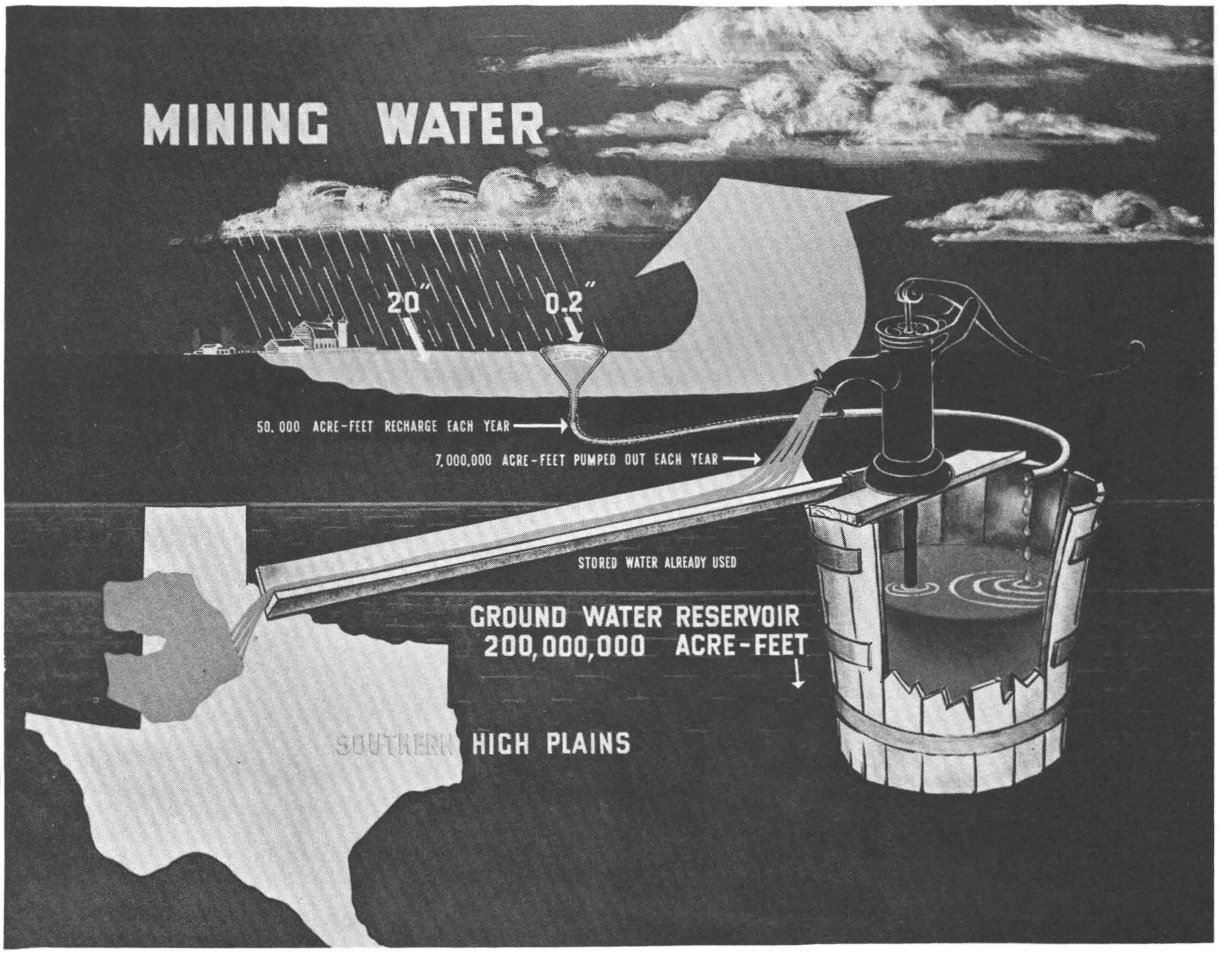


FIGURE 11.

Is there any doubt in your minds that saline-water conversion will eventually provide an important part of our fresh-water supplies? Plants producing millions of gallons per day have been operating for several years at Kuwait, Aruba, and Curacao, which are woefully short of conventional fresh-water supplies, and the cost is generally greater than $1.75 per 1,000 gallons. At the new Point Loma plant at San Diego it is hoped that the cost of distillation can be reduced to less than $1.00 per 1,000 gallons. Intensive research is seeking new processes that require less energy or new forms of energy that will reduce the cost of desalination even further. Meanwhile, we can be assured that the costs of conventional water supplies to meet increasing demands of the future will be greater than the costs of water to us today, whether that additional water comes from more reservoirs, longer pipelines, deeper wells, or various salvaging and treatment techniques.

Even now the cities along the coast may find it economical, as their requirements increase toward the limit of existing supplies, to supplement their supply by sea-water conversion and distribute the cost among all their consumers, rather than enlarge their supplies by conventional methods. Eventually it may also be profitable to separate and market some of the salts that are extracted from the water. Inland, if water users wish to tap the unlimited source offered by the ocean, they must bear the costs of pipelines and pumping lifts in addition to those of the desalination process. Alternatively they may tap continental sources of brackish water, or even brines, subject to the limitation that these sources, like the continental fresh-water sources, will not be "inexhaustible."

In some places desalination may be economically feasible on the basis that it results in far more usable water than the quantity actually processed. A saline spring discharging into a river, for instance, may require dilution by 50 units of river water in order to make the spring water usable--that is, the spring yields a small quantity of water to the river, but in doing so takes 50 times that amount of river water down to the borderline of usability. Here the benefits of desalination would extend beyond the amount of water actually processed.

This short summary of the opportunities for more effective use of the present supply and for increasing the supply of fresh water may seem to exude optimism for the future. The sober side is that these are not merely opportunities, but prerequisites, to the future welfare of the people of the West. And they require greater knowledge and greater effort than we have achieved to date, and a greater expenditure of funds than has been allocated to water up to now.

If the future is to be as rosy as we hope, the science of hydrology must play an increasingly important role. Our knowledge of water, and our objectives in obtaining data, have expanded with the increasing development and use of water. Like the early settlers starting with one well or spring or diversion point on a river, the earliest data were concerned with immediate and local problems. With increasing demands upon a limited resource, it has been necessary to widen our horizons to entire streams and ground-water basins and, then, to major regions, and in the course of this evolution we are developing the broad natural interrelations of the water resources and of the modifications made by man. Projecting our present knowledge into the future we can see that catastrophe can result from ignorance of these potential effects and also that knowledge can be the basis for successful management and use of water to meet our needs. We don't yet have all the knowledge we need.

Economics and, its unregimented relative, politics, will be the determining factors in the proportion of the GNP allocated to water development and use, and in the choice of specific projects for making, storing, purifying, salvaging, or efficiently using water. Hydrology can assist in these choices by assessing the regional or long-range benefits and costs which may be obscured by, and in

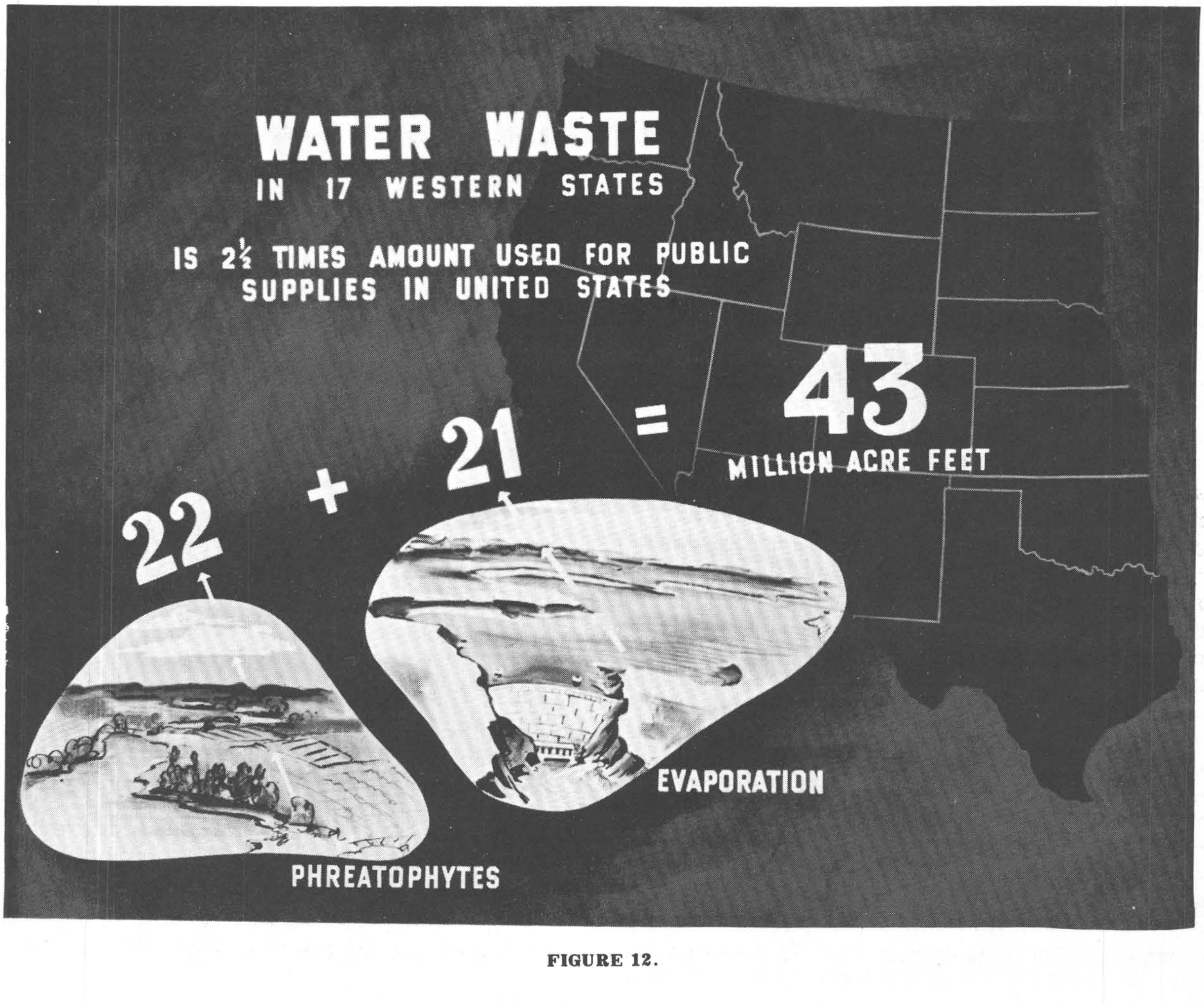


FIGURE 12.

conflict with, the local and immediate benefits of specific projects. A major difficulty here is that our existing developments, existing patterns of use, and existing patterns of thinking tend to create a rigidity that hinders change for the better.

FEASIBILITY AND DEFEASIBILITY

Feasibility has become an important word in the vocabulary of all those concerned with water-resource activities. It represents their best judgment of the overall worth of a project, generally on the basis of a cost-benefit ratio or similar yardstick. This best judgment is achieved through the combined talents of the water users, hydrologists, economists, financiers, lawyers, and elected representatives of the public. But we know that standards have changed through the years with advancing technology. Today we are doing many things that would have been classed as unfeasible a few years ago, and we now seriously question proposals that may be well within the range of feasibility by 1980.

In this gradual evolution it is far easier to accept the new than to put off the old. Lot's wife became famous, and saline, for her inability to break off sharply with the past, and we all have that trait to some degree. Here I should like to bring in a word that is very little used, except by lawyers: defeasibility, the capability of being undone or annulled. The word may be applied to ideas and concepts that are relics of the evolutionary process, now outmoded and hampering our progress. In a sense, "feasible" has two opposites: "infeasible"--not capable of being done; and "defeasible"--capable of being undone.

In my own field of ground water, I believe "safe yield" deserves consideration as a defeasible concept. Defined several decades ago as the rate at which water can be withdrawn from an aquifer without depleting the supply to such an extent that withdrawal at that rate is no longer economically feasible, it would appear to offer a means of insuring perennial ground-water supplies, and several States have laws restricting development to the safe yield. Such laws may provide satisfactory solutions to problems restricted to a single aquifer or to short-range economics. But in the broad view, if the water does not come from storage within the aquifer it must deplete the supply somewhere else in the integrated hydrologic system; on the other hand, wholesale depletion may be economically feasible in the long-range view if it results in building up an economy that can afford to pay for water from a more expensive source.

My prime candidates for defeasibility are some of the time-honored concepts concerning property rights in water, a touchy subject to bring up in a group concerned with land, mortgages, and the property rights that may be an essential part of the security for these mortgages. These water-rights concepts have been developed by tremendous effort extending over many decades, even more than a century, but chiefly with an objective that amounts to fitting a round peg into a square hole: the round peg symbolic of the drop of water--fluid, dynamic, moving from place to place, variable in quantity and quality; the square hole symbolic of land parcels--solid, static, rigid, unmoving. In the process we have created a pseudohydrology that is awe-inspiring but unacceptable to the scientist. For example, I would not dare use the term "percolating water" now that it has been worked over and rolled out into a monomolecular film covering everything, and yet is defined so negatively that it would seem to be the embodiment of the mathematical $\sqrt{-1}$.

I would not suggest anything so drastic as abolishing water rights, which are essential to the orderliness with which we can distribute the variable supplies of water and which could not be overthrown without the danger of overthrowing also the Government and the Constitution on which it is based. But there is need to adapt our concepts of water rights to the dynamics of the flow systems that characterize our water resources. Flexibility will become increasingly important in the future, to adapt to regional variations--greatest natural water loss in the Southwest deserts, greatest surplus in the Pacific Northwest, most economical places for sea-water conversion along the California coast and the lower Colorado basin. "Adapt" is a word that is easily said, but we all know that no one holding a valid water right would accept any change unless he had advantages at least as great as those afforded by his present right.

A major attribute of a water right is security in the use of water. There is little concern over water rights when the supply exceeds the needs of all potential users, but water deficiency or even the threat of insufficient supplies can make water rights a prime concern. Judging by the attitude of most urbanites who are served by an efficient municipal water system, people do not have an instinctive interest in water rights as such, and are quite willing to delegate their worries to the waterworks, if they have assurance of water when and where they want it. It can safely be predicted, however, that if the increasing use of water continues without a concurrent program that will give assurance to the users of a perennial supply, the competition for water will make water rights of dominant concern.

Water rights also confer upon certain users tremendous advantages in water costs. Recently the San Francisco Chronical reported in its column "100 Years Ago Today" that floods along the Sacramento River had caused so much loss in livestock that the price of beef had gone up to 12 cents a pound. Do you know anyone who buys steaks at that price today on the strength of a right established in 1862? But some of our contemporaries obtain water at very low cost based on rights developed in that year. Because of differences in rights, some people may pay several times as much for water as do others obtaining water from the same source. Water rights by their relation to water cost can thus be an obstacle to comprehensive water-resource management of broad regions, although this obstacle has been overcome in many places and can be generally overcome by bargaining, compromise, and eventual agreement on pooling of rights.

Where water rights protect and sustain gross inefficiencies in water use, the community may have the power to tax or charge for the water wasted. The definition of "beneficial use" can be progressively tightened so that losses now considered "unavoidable" can be increasingly charged as a responsibility of the right holder. Thus a water right may eventually carry not only the assurance of a share of the water but also a share of the responsibility for such items as evaporation from reservoirs, phreatophytes along ditches and canals and along streams, and contaminants and pollutants in nonconsumptively used water. Where pumping from wells causes a progressive depletion of storage--and the implication that eventually someone must provide a substitute water supply or absorb the population that cannot subsist after the present supply is exhausted--a possible solution may be a severance tax on the water (rather than a tax benefit based on a depletion allowance to the "owners" of the water, as has been proposed in some regions).

Within a month after I came to California, the electric company had me on its mailing list. My bill for electricity amounted to about 2½ cents per kwhr. I know that others are on different rate schedules, and some may pay more, whereas others are charged a far lower rate. I also received an envelope full of literature, from which I learned that the four private utilities in California are closely integrated for power interchange. Of all the kilowatts I use, I haven't the least idea where any originates, and I don't care. To me, the essential feature is that electricity is there when I need it or want it--and I appreciate that more fully after 2 years in Africa. I would like to see water similarly served to the people to meet their needs, according to fair rate schedules that would doubtless vary according to the use. Then the property rights in water could diminish in significance.

CONCLUSION

In conclusion as to the future, we can be sure that water supply in the West will continue to present many problems, undoubtedly of increasing complexity. We can be sure also that our water supplies will become increasingly expensive. If we do nothing constructive, we will pay heavily for controversies over division of the limited supplies that nature will provide. If we continue the present trend of modest development and improvement, we will still not have enough for our foreseeable requirements in 1980. And if we do meet those foreseeable requirements, we must have more knowledge, more effort, and more enlightened attitude of the public. Water, H_2O, is sufficiently abundant that we may have several alternative means or combinations of means of providing a specified quantity at a desired standard of purity. Our choice then becomes one of greatest benefit at least cost from the viewpoint of the public as well as the individual. Necessarily in effective economic planning for the future, planning of water use will be an inseparable component.

REFERENCE

U.S. Congress, Senate Select Committee on National Water Resources, 1959-60, Water resources activities in the United States--Committee prints 1-32: U.S. 86th Cong., 1st and 2d sess., pursuant to Senate Res. 48. [Prints are independently paged.]

INT.DUP.,D.C.62- 16670