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WATER RESOURCES OF THE UNITED STATES[1]

By

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The concern that has grown gradually in recent years over the future of our water supplies has been forcefully dramatized by the water shortage that New York City is now experiencing. This shortage is not the first that has affected an American community and it is not the most serious. Ample sources of additional water are known to exist in Upstate New York and construction that will bring this water to the city is being pushed as rapidly as possible. Nevertheless, the fact that our largest city, the center of our business life, has a water shortage, even though it is temporary, causes even the layman to realize something of the importance that water has in our national life and our national economy. In nearly every State in the Union, one or more communities now has or has had water problems as serious as or more serious than that which faces New York City. These problems are springing up in increasing numbers and it is high time that serious consideration be given to the question of the adequacy of our water supplies. If the crisis in New York serves to bring this fact into national focus, New York's misfortune may in the long run be a blessing in disguise.

The discussion and comments on the water problem that have appeared in the press and on radio and television during the past few months have ranged all the way from the alarmist view that we are running out of water on a national scale to the

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complacent view that all that is needed to cure the trouble is some particular type of conservation or construction which the particular writer favors. Actually, the truth lies somewhere between these extremes. It is hoped that this discussion may lead to a better and more rational approach to the subject.

Throughout the period of record the available water resources, except for local and temporary variations due to droughts, have remained essentially constant. I know of no evidence in either precipitation, stream-flow, or ground-water data that controverts this statement. During the past 40 to 65 years, stream runoff in many places, as shown by carefully selected records of the U. S. Geological Survey, showed a downward trend which reached its lowest point in the decade from 1930 to 1940, but most records show an upward trend since 1940. The Geological Survey note that precipitation data of the U. S. Weather Bureau show no definite trend toward long-term declines. Records of water levels in nearly 15,000 observation wells maintained by the Geological Survey and its cooperating agencies show no over-all trend toward decline. There are many areas where water levels have declined because of pumping or other activities of man and, of course, water levels have temporarily declined as a result of severe droughts. Even the great drought of the thirties was subsequently offset by above-average precipitation which fully restored stream flow and ground-water levels to predrought stages.

On the other hand, our use of water has increased by leaps and bounds. A century ago the per-capita use of water was probably not more than a few gallons per day. It is estimated on the basis of very meager data that at present our per-capita use of water amounts to at least 700 gallons per day, exclusive of water used for hydroelectric power generation. Although this figure may be substantially in error, the order of magnitude is believed to be correct. Of this amount, some appreciable percentage is actually consumed. The remainder is discharged into the ground or into streams, more or less altered by its use. Much of it may be reused several times. During the past century the population has increased about 600 percent. It follows therefore that the use of water has increased by several thousand percent. Municipal, industrial, and agricultural uses have shared about equally in this increase. The number of municipal supplies has increased many times. Modern plumbing, higher standards of living, sanitation and fire protection, and the growth of industries receiving their water from municipal systems have all required great quantities of water. The rapid growth of industry and technological advances, the introduction of new industries such as the chemical industry, and the introduction of air conditioning and temperature-control processes in industry have made enormous demands on water resources. The irrigated acreage has increased from a few thousand acres a century ago to 21,000,000 acres in 1939 and is perhaps 25,000,000 acres at present. Dairy farming alone, requires large amounts of water. The introduction of automatic pumps and farm distribution systems has substantially increased water consumption on the farm.

There appears to be no prospect that this trend toward increased use of water will be halted or reversed in the near future. Each new industry will require water and some of them, such as the application of nuclear fission as a source of energy, and the hydrogenation of coal and oil shale, will require enormous amounts. No figures are available for the probable use of water in harnessing atomic energy, but fragmentary information shows that it may be very large. The quantity of water needed for producing 10,000 barrels of oil per day by hydrogenation of coal is estimated at 5.5 to 6.5 million gallons per day, depending on the process used 1/. Of this amount about 80 percent is consumed. This is the requirement for the operation of the plant only. To this figure must be added the amount that will be

1/ See references at end of paper.

needed for the municipalities that will spring up to house the employees of the plant and for the associated service industries. Plans are going forward for large additional developments of irrigation in the West. In the East, especially on Long Island (2), supplemental irrigation to provide optimum moisture conditions for optimum growth of crops has spread very rapidly in the last few years. Inasmuch as the increased productivity that results from supplemental irrigation frequently makes it possible to finance the cost of the installation out of the first year's profits, it is to be expected that this activity will spread rapidly throughout the humid parts of the country and that eventually supplemental irrigation of suitable crops will be practiced wherever local sources of irrigation water are available.

It has been stated frequently that our water supplies as a whole are entirely adequate for all present needs. This statement is doubtless correct if proper and adequate methods of water conservation are adopted. However, it does not follow that our present water resources are adequate for an indefinite length of time in the future. As a matter of cold fact we do not know what our water-resource potential is nor do we know accurately what our present use of water is. The hydrologic data available to date have been collected very largely for specific purposes. They have proved to be of inestimable value not only for planning and constructing specific projects but also for drawing broad generalizations. However, the appraisal of the over-all water resources or of the ultimate total use of water has been scarcely begun.

By far the largest part (perhaps more than four-fifths) of our water supplies are derived from surface sources and many developments of surface water are still being planned. Nevertheless, it is believed that much of the readily available surface water of good quality is already allocated for various uses. Thus it would appear that more extensive use will have to be made of ground water and of ground-water reservoirs. Although we do not know how much ground water is available or the exact boundaries of our major ground-water reservoirs, rough calculations indicate that the amount of ground water in storage in ground-water reservoirs may be several times the amount of surface water that can be stored, even including the Great Lakes, the water of which would cover the entire United States to a depth of about 10 feet. The annual rate of replenishment is believed to be considerably greater than the present use. Therefore it is of utmost importance to the Nation that these resources be located and utilized to the fullest possible extent. In the early part of the century many ground-water developments proved unreliable because the principles of ground-water occurrence were not recognized. Thus ground water came to have a bad reputation among engineers. In the twenties, however, the use of ground water began to increase and by 1935 it is estimated to have been 10 billion gallons a day. By 1945 the total use had doubled (3) and at the present time it may be in the neighborhood of 25 billion gallons a day (4). Much of the reestablished confidence in the reliability of ground water has resulted from the work of the Geological Survey and its numerous cooperating State agencies. The welfare of the Nation demands that this confidence not be impaired, for we must develop our remaining untapped supplies fully yet wisely. Although the water table has declined substantially in areas of heavy pumping, this fact does not mean that the water table is dropping throughout the country. In many cases it means that water is being taken out faster than it is being replenished, but in many others it merely means that the ground-water reservoir is adjusting itself to the hydraulics of ground-water movement under pumping conditions. To secure maximum ground-water development it is necessary to determine, for each reservoir, the rate at which replenishment occurs.

In part, the increasing amounts of ground water are used to provide for new developments, as for irrigation on the High Plains of Texas, where present pumpage exceeds the annual replenishment by many times (5) In central Arizona, where the principal use of water is for irrigation, the initial developments were made from surface-water sources. Ground water was pumped initially as a means of lowering the water table, which had risen as a result of irrigation. Gradually the amount of ground-water pumpage was increased and by 1945 ground water provided about half the 4,000 acre-feet of water used. (An acre foot = 1 foot of water over an acre, or about 325,000 gal.) By 1948 the use of water had increased to about 4,330,000 acre-feet, of which ground water provided 71 percent or 3,075,000 acre-feet (6). A part of this increase in ground-water use has resulted from the need to supplement surface-water supplies that were dwindling because of drought, but a substantial amount has resulted from irrigation of new land outside the area served by surface water.

Even this sort of increase, however, has its limitations, for in the last analysis, even though many of our ground-water reservoirs are enormous, the quantity of water that may be drawn perennially from a ground-water reservoir is limited by the economic and natural factors that involve recharge and pumping lifts. Perhaps we could afford to draw on ground-water storage and reduce water levels over a long period of time if we were sure that eventually the climatic cycle would swing to a period of wet years that would provide enough recharge to restore the water level. From the long-range viewpoint, however, such withdrawals would be unwise unless we were sure of substantial replenishment.

The increasing number of water problems in all parts of the country has been cited. They are nearly all local and they range widely in seriousness. Some of them result from overdevelopment of the immediately available water resources and can be corrected only by finding additional sources of supply. For example, in the area southwest of Los Angeles, Calif., the overdevelopment of the ground-water basin has lowered the water levels to such an extent that sea water is moving inland through the formations at a rate of as much as 250 feet a year (7). It is impossible to reverse this movement without raising the water level near the coast either by artificial recharge of imported water or by a substantial reduction in pumpage. In several interior basins, as in the San Joaquin Valley (8) and in central Arizona (9), in the El Paso area (10), and many other places in the interior, salt-water contamination threatens the ground-water supply. In the San Joaquin Valley and in the El Paso area the salty water comes from certain saline formations. In the central Arizona area the ground water is becoming more mineralized largely owing to consumptive use of the water and the resulting concentration of the initial salt. Adequate provision for flushing out the concentrated water would correct this situation.

Some water problems result from local overdevelopment and can be corrected by spreading ground-water pumpage over a larger area, or, for surface water, by raising the dam so as to store more water in the reservoir. Some are brought on by attempts to manage or control water. A good example of this type is the drainage of the Florida Everglades in order to provide rich farm lands for agriculture (11). This lowered the water table over a wide area and disturbed the fresh water-salt water balance so that pumping of ground water for municipal supplies along the coast began to draw in salt water and several well fields had to be abandoned. Moreover, the canals constructed for drainage provided easy access for sea water. During dry periods sea water moved inland along the canals and seeped into the aquifers and thus threatened other well fields, including the main well field of Miami. Similarly the reclamation of swamp lands by drainage in the Middle West encouraged rapid runoff of storm water and increased the flood hazard downstream.

At the present time, under present rates of use, it appears that adequate supplies can be obtained in most places by the expenditure of a sufficient sum of money. It would seem that use of water is likely to continue to increase until, in areas of shortage, it will no longer be feasible economically to increase the water supply further. Then it will be necessary to decentralize populations and industries and perhaps agriculture.

Before this state of affairs becomes general there are certain steps that should be taken in the interest of protecting the future economy. These are suggested as primary steps, but by no means a complete list of the possibilities.

1. A complete inventory of the present and potential water uses should be assembled city by city, section by section, and State by State; also by type of use. This inventory, of course, should be set up to differentiate between consumptive use and nonconsumptive use.

2. A careful appraisal of all our water resources, both in ground water and in surface water, should be made. This is a difficult and time-consuming task and it should be undertaken immediately if it is to be completed in time to be of substantial use.

3. On the basis of the above, it should be possible to delineate those areas where water is now in excess of the beneficial use to which it is put.

4. Adequate research on the hydrologic cycle should be programmed and carried out to determine the major factors that affect the net amount of water available for beneficial use. This research would include the effects of water-shed management, the determination of the areas and quantities involved in wasteful evapo-transpiration, etc.

5. Areas where brines, natural or artificial, enter streams should be located and studies should be made of possible methods of preventing such entrance where it is demonstrated to be detrimental.

6. Flood-control and drainage practice should be extended to include consideration of potential artificial recharge to ground-water reservoirs that have been depleted.

7. In the planning of water developments, of either surface or ground water, sufficient investigation should be carried out to enable adequate appraisal of the effects of the proposed projects on the over-all water supply rather than limiting such appraisal to one possible objective.

8. It should be realized that the control and development of water involve competitive features that are not now adequately appreciated. Agricultural, industrial, and municipal uses are in competition; flood control, hydroelectric power, drainage, wildlife, and water supply require management and controls of different kinds and objectives. There is serious need for a national water policy that will provide effectively for the needs of each of these interests.

The serious consideration that is being given to the water problem is shown by the introduction during the last session of Congress of a bill (H. R. 6257) which envisions broad attack on the existing deficiency in hydrologic data, and by the establishment by the President of the Water Policy Commission, which should serve to evaluate further our present situation with respect to water.

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