THE NATIONAL WATER SITUATION AS DEVELOPED BY THE SELECT COMMITTEE ON NATIONAL WATER RESOURCES

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The Senate Select Committee on National Water Resources was created in 1959 to study the national water problem and recommend policies to be followed by the Senate in enacting federal legislation. The Committee had some 90 studies made, held hearings over the country, and published the results in the form of hearing transcripts, committee prints, and a committee report. Upon publication of its report the Committee's work was completed and its staff discharged.

My talk will deal with the data on the supply of and demand for water developed for the Committee. My participation in this study was occasioned by the fact that prior to the Senate's creation of the Select Committee, Resources for the Future had already decided to embark on a study of water supply and demand. The Select Committee's staff, knowing of RFF's interest in the subject, proposed a partnership. In exchange for facilities provided by the Select Committee in acquiring data, RFF would supply the Select Committee with a preliminary report of its own study. The partnership was a happy arrangement for, I believe, both parties. I can speak for my side of the bargain, at least. With the Select Committee's help it was possible to acquire much more data than would otherwise have been available. RFF and I are deeply indebted to Senator Kerr, Chairman of the Committee, and to Theodore M. Schad, its Staff Director, for their support of the research task that was involved. The contribution of federal agencies in the man-hours of scientific work performed directly for the committee, let alone in the back-log of data accumulated in the files, cannot even be estimated. It is, in any case, a large multiple of the $100,000 which the Committee spent.

Method of Study

The study of the supply of and demand for water that served as the basis of the Committee's report was "preliminary" in two respects. It was preliminary in the sense that a final study incorporating essentially the same data, but reviewed and expanded, was still to be published. Under a grant from Resources for the Future to the University of New Mexico the review and expansion has proceeded, and I shall give you some of the additional results. It was also "preliminary" in the sense that incompatibilities between projected uses of water and the available supply had not been eliminated by some plan that either revised national projections or

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redistributed output among regions.

The study began by selecting an appropriate regional division of the United States. The Bureau of the Census Water Use Regions of the United States were adopted, modified by dividing the Missouri into an upper and lower region, separating the Upper AWR from the Lower, separating the Rio Grande and Pecos from the lower Rio Grande and the remainder of Western Gulf streams, and, finally, by separating the southern seven counties of California from the rest of the state. By making these changes, we attained greater homogeneity of each region in terms of water supply, facilitating any generalizations that we would be able to make.

Next we adopted national projections of population, gross national product, farm production, electric power production, and industrial output for 1980 and 2000. These projections were made for low, high, and middle paths of growth. So far only water use requirements based upon the middle projections have been published. The final report will deal with lows and highs as well.

The next task was to distribute national aggregates among the twenty-two regions. Population projections for each region were based upon dampened trends of ratios of regional population to U.S. population. Agricultural output, power production, minerals and major water-using manufactured goods were distributed by various federal agencies. The Department of Agriculture and the Bureau of Reclamation dealt with agriculture; the Federal Power Commission with electric power - both steam and hydro; the Bureau of Mines with mining and the refining of petroleum; and the Business and Defense Services Administration of the Department of Commerce with the manufacturing of food, pulp and paper, chemicals and primary metals. Public Health Service estimated municipal water requirements; Fish and Wildlife Service estimated water requirements for fish and wildlife habitat; the Soil Conservation Service estimated water required by soil and moisture conservation programs; the Corps of Engineers estimated navigation requirements.

The model of water use that was adopted for the study was designed to reveal determinate relationships between the available supply of water and the amount of water required to meet the levels of output projected for each region. We wanted to be able to say that if a designated level of output was projected for a given region the water supply would or would not be adequate. This meant that water "requirements" had to be framed in a manner that would avoid the indeterminacy inherent in measures of gross intake, since such a measure ignores the possibility of recirculation of water within a river basin. We defined water "requirements" as the sum of two elements: one, the amount of water lost to the atmosphere by evaporation and transpiration resulting from man's use. (This measure excludes wild or natural evaporation and transpiration, hence the losses we are concerned with are charged against runoff, rather than against precipitation.) A corollary of this measure is the stipulation that water quality is maintained at a level that allows recirculation within the basin and permits all uses to be met. Industrial wastes and municipal sewage can be treated, but even treated water will not be satisfactory for many uses unless mixed with high quality fresh water. This need for waste dilution is the second element of our requirement. The amount of waste dilution required depends upon three things: (1) the level of waste generated, which is a function of the level of output of waste generating products; (2) the level of treatment given to the waste effluent; (3) the quality of water desired after treatment and mixture of high quality water.

In estimating waste dilution requirements it was assumed that dissolved oxygen would serve as an index of the intensity of other pollutants. Given a designated level of treatment, if adequate dilution water were provided to assure an average of 4 milligrams per litre of dissolved oxygen, it was assumed that other pollutants would be adequately diluted. Although waste treatment levels up to 97½% removal of organic matter was assumed, no radically new technology was implied.

The relationship between waste dilution flows and level of treatment would be inversely linear were it not for the fact that at higher levels of treatment the conversion of organic matter into nitrogen and phosphorous fertilizes the receiving waters, stimulates the growth of algae, and creates a need for dilution water to offset the unfavorable effects of algal growth. Hence, as the level of waste treatment increases up to a certain point the need for waste dilution water decreases; but beyond that point, waste dilution requirements increase. The level of treatment at which this critical reversal takes place depends upon stream characteristics such as turbidity, velocity, depth, volume, length of reach, exposure to sunlight, and reaeration factors that vary from stream to stream and region to region. Based on findings that are still tentative, minimum required flows are found in the neighborhood of 90% to 95% treatment. In a few regions minimum flows are found at somewhat lower rates of BOD (biological oxygen demand) removal.

For a given level of economic output and population it is possible to estimate the loss of water to the atmosphere plus the amount of high quality water that must be flowing in the streams in order to mix with the effluent from treated waste. This sum is what is meant by "water requirements" or "water demand." The required flows are stipulated for the time of year in which waste assimilation is poorest, namely, the latter part of the summer for most regions. In other words, the requirement is the minimum amount of water that must be flowing in the stream during the period of low flow. This is a quantity that is not only free of ambiguity, but is framed in terms that make it directly comparable with available measures of supply.

Our measure of supply is a flow-frequency table for each region that indicates the flow equalled or exceeded 95% of the time, 90%, 80%, 70%, and 50% of the time, and the average flow. We know that by constructing enough storage, we can regulate a river so that its minimum flow approaches the level of average flow, measured at a designated point. Data on flow and storage were supplied by the U.S. Geological Survey. Average flows were adjusted to take into account increased losses from evaporation as a result of adding surface storage.

From the point of view of requirements we were able to stipulate the size of minimum flows that had to be provided, given the level of water-related economic activity and given the level of waste treatment. From the point of view of supply we had measurements of minimum flows under present regulation, and by how much minimum flows could be raised provided additional storage were constructed. With these two sets of figures at hand we could determine whether or not a region could meet its water requirements, and how much, if any, would be the deficit or surplus. We could also as shown later, estimate the costs of changing minimum flows and the costs of achieving designated levels of quality.

It is apparent that ground water did not figure explicitly into our measures of supply. We adopted the convention that our measure of supply was limited to the annual crop of water. Accordingly, it was assumed that ground and surface flows were inter-related, and that our measures of surface runoff indicated the annual water crop, after accounting for surface evaporation and interception by wild vegetation. By this assumption we ignore the supplies of water underground that are discharged into the oceans or that escape the United States across Canadian and Mexican borders. How large a quantity is involved for any border region is unknown. By measuring supply in terms of annual crop we also ignore the once-and-for-all withdrawal of water from underground reservoirs. Regions for which shortages of water are projected by 1980 may, in fact, be able to support indicated levels of activity by drawing down the water table. Such solution is, of course, temporary but may conceivably bridge a shift in water technology.

Measures of water use are restricted by two qualifications that may result in error of estimation of future water requirements. First of all, we did not take into account what effect higher costs of water would have on the quantity of water consumed. Second, our estimates of changes in water use per unit of output, based on technological improvement, were only crude guesses. A much more deliberate attempt was made in estimates for agriculture than for industry to account for the spread of knowledge as well as its discovery. The results, however, are scarcely more than intuitive extrapolations.

Our findings fall into two categories:

(1) the relationships between supplies and projected requirements in the twenty-two regions;

(2) the costs of alternative programs designed to yield water of designated qualities.

Supplies and Projected Requirements

The results of our estimates, for medium projections, can be summarized as follows:

In 1980 projected evapo-transpiration losses alone exceed average daily surface runoff in the southwestern part of the country and in the Upper Missouri (67 BGD (billion gallons per day) and 54 BGD, respectively). If we add the flows required for quality maintenance, aggregate required minimum flow in the Upper Missouri, Rio Grande-Pecos, Colorado, Great Basin, and South Pacific, amounts to 83 BGD, compared with an average daily flow of 54 BGD. Indicated requirements exceed maximum supply by 50%. By the year 2000, based upon the medium path of growth, total requirements are 113 BGD, compared with maximum supply of 54 BGD. By 2000, Western Great Lakes joins the original five as a water short region, largely because of the need for large waste dilution flows: 59 BGD required, 40 BGD available.

A word about the rate of growth implied in the medium projections. They assume that population and gross national product will grow at the average rate experienced over the last three decades. Senators Engle, Hart, McGee and Moss, in a supplemental statement in the committee report, objected to the fact that the projections used for Committee Print #32 were at these historical rates when in fact "water resource programs...must be paced to match demands generated by an economy growing at the rate of 4 to 5 percent rather than at the current rate of half that much."1/

If we project on the basis of a population growth that follows the path of the Bureau of the Census Series I, modified by increasing the amount of immigration from 150,000 yearly to 300,000 and if we allow GNP to grow at a rate of about 5% yearly, we have the high projections used for our study. As a result, by the year 2000:

(1) ten of the country's twenty-two regions are deficit areas;

(2) required flows in the original five regions amount to 181 BGD, compared with 54 BGD maximum supply. In addition to these five, western regions that are now deficit areas are the Upper AWR and the Western Gulf;

(3) the aggregate of deficits in all deficit regions is approximately equal to the aggregate of surpluses in all surplus

1/ Report, p. 137

regions. This implies that we should be able to meet 2000, high, national outputs with proper regional reallocation of economic activity.

Costs of Water

I would like now to indicate briefly some of the estimates of the costs of water.[1/] The costs I am talking about are restricted to those designed to provide minimum flows and waste treatment. Costs incurred to meet specific needs such as irrigation distribution systems, hydroelectric power plants, navigation locks, and water treatment plants have not been included.

We can construct cost curves for water on the basis of data we have. When we speak of supply, therefore, we can attach the economist's usual meaning to the word--a schedule of quantities related to costs. We do not have, as I have already indicated, equivalent information about demand. Until we know the elasticity of demand for water in terms of size of flow, variability of flow, and quality for each use, we cannot construct equivalent curves. The best we can do is estimate the physical requirements for a specified pattern of use on the basis of known technical relationships.

Neither representations of supplies nor demands are, properly speaking, curves, but multi-dimensioned schedules. Water provides an example of the difficulties created for the economist as a result of interdependence between supply and demand. A supply curve for water cannot be constructed until we first know the uses to which the water will be put, since use determines both loss and quality change, and these, in turn, determine the level of flow and level of treatment that are needed in order to assure water of a designated quality after use and treatment. If there is an elasticity of demand greater than zero--i.e., if price paid for water affects the uses to which it is put and the quantities of these uses--we must solve simultaneously the equations that describe the supply and demand functions. At present we do not have the necessary information for reaching such solutions. Furthermore, since such solutions are normally derived from static relationships, whereas the world that generates the observable measures is a dynamic one, we can never directly observe the proper values for our equations unless we use dynamic models on the one hand or achieve a static world on the other. Our conclusions whether they are relationships between flows required and flows available, or between type of program and costs of program, are based upon holding a number of variables constant and drawing our inferences from a restricted set of conditions.

1/ These figures are still tentative, as well as the estimates of flow requirements.

To meet medium projected requirements between now and 2000 we shall have to raise treatment levels to between 90% and 97½% BOD removal in most regions. At present there are many points at which raw, untreated sewage is being dumped directly into receiving waters.

We shall have to increase our reservoir capacity by an amount that will more than double present capacity. In some eastern regions we shall need as much as 40 times the capacity we now have.

Annual costs of treatment and storage to provide water of adequate quality will be between $4 and $5 billion at 1960 prices by the year 2000. Cumulative capital costs by 2000 will be about $100 billion. Actual costs will depend upon the programs we adopt. For example, if we emphasize waste dilution rather than waste treatment, the capital costs of storage needed to assure the dilution will be about $45 billion. If we emphasize treatment rather than storage, the costs of storage will only be about $14 billion. Treatment costs will vary in the opposite manner. If we emphasize storage, capital costs of treatment facilities, will be about $74 billion. If we emphasize treatment rather than storage, capital costs of treatment will be about $93 billion.

Since the costs of treatment and storage do not vary by an inversely proportional relationship, the program that minimizes the costs of treatment and storage taken together will emphasize treatment. For such program the capital costs of storage are about $18 billion and the capital costs of treatment are about $82 billion, for a total of $100 billion. By comparison, the program that emphasizes storage and minimizes treatment would cost about $18 billion more.

These are not forecasts but are, instead, estimates of what will happen if we make certain choices. The estimates themselves are subject to modification if we develop new technologies of water use and waste treatment, or if we grow at a different rate from that postulated, or if we shift our consumption from the projected pattern of goods and services to others that use and pollute either more or less water. Finally, our estimates would be subject to revision upward if we choose a higher standard of water quality, or downward if we choose a lower standard.

We need to know more about many things before we can speak with assurance about the various estimates that emerged from the Select Committee's research effort. A few examples will illustrate these needs.

(a) the inter-action between ground and surface water movement, and the possible substitution of ground storage for surface storage.

(b) the effect of recirculation on the rate of water loss and quality of waste discharge.

(c) the effects of rising costs of water on the demand for water.

(d) the effects of stabilizing flows on the output of hydroelectric power and the place of hydro in the total energy picture.

(e) the effects of waste discharge and waste dilution flows on estuarine waters and the productivity of commercial fisheries.

Need for a well conceived national water resource program based upon adequate information can hardly be overstressed. Its urgency is indicated by the results that are yielded by the high projections for the year 2000, which imply that by that year our water supply will be fully utilized and under full regulation. Since the high projection leads the medium projection by about one generation, we do not have much spare time even if growth follows the medium path. At the lower rate of growth we will be at the same point of full use by the year 2035.