

# Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 51 • JULY 1959 • NO. 7

## Water Resource Development and Management

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*An address presented on Mar. 11, 1959, at the Illinois Section Meeting, Chicago, Ill., by Luna B. Leopold, Chief Hydraulic Engr., USGS, Washington, D.C.*

**I**N a sandy, riverside location in Wisconsin, my family has a farm, once abandoned by a previous owner because it would not produce much corn. By the time we bought it—for a pittance—only a few remnants of white pine remained from the magnificent stands made famous by the Paul Bunyan legend. In this part of Wisconsin the pines were, even originally, restricted only to patches of the better soil, and the variability of the glacial topography had resulted in an interesting mixture of prairie marsh, swamp woodlot, and sand hill.

We did not acquire this farm because it had a great potential for growing crops. Rather we were interested in the variety of ecologic and topographic types, which, even within the confines of our property, represented a condensed version of the many different types of land in the Wisconsin countryside. The farm also has a very peculiar aesthetic and historical inter-

est. Marquette's canoes once slipped quietly past our favorite fishing hole on the river; passenger pigeons once roosted in our great oaks; and the few remaining white pines silhouetted against the sky-glow of evening made one think of the Round River and the Blue Ox.

After we had acquired the place, the problem arose of what we were to do with it. Its resources were limited and peculiar. They had little economic value—all the more reason that they should be carefully appraised in order that they be fully utilized and appreciated. While we were hammering and sawing the old stable into a usable homestead, we investigated every coulee and covert, every thicket and thatch. By compass and pace we mapped the boundaries, sketched in the topography and vegetation, and made notes on the distribution of soil and the occurrence of water. We counted the various kinds of birds and found

there was a reasonable population of woods species, mostly transients. There were no pheasants, no quail, practically no grouse, and in spring only an occasional woodcock.

With the analysis of what we had to work with we started immediately on the task of development. The techniques were chosen to achieve specific goals. We wanted, over a long period of time, to grow a stand of conifers which would yield both pleasure to the eye and logs to the saw. We could see the possibilities of having quail, pheasants, grouse, and deer, and of extending the stay of some of the migrant species.

We set to work with shovel and axe, wire and nails, and a will to succeed. Trees were lopped so that they formed brush piles. Wild grapes were brought in and planted on the brush piles. We removed grass with a shovel where it was competing with desirable wild flowers, and planted little patches of corn and beans.

Within a few years there were pheasants, grouse, and woodcock to shoot, wildflowers to delight the eye, and the annual increments on the stem of every pine represented increments of future dollars in the bank.

The problems of appraisal, development, and management are essentially the same for all resources. Resources may be renewable or nonrenewable. With renewable resources the problem is to increase, as far as possible, the yield of each increment. With nonrenewable resources the problem is to develop them intelligently and without waste. It is necessary at the earliest possible stage to make an adequate appraisal of the characteristics and distribution of the resource and, on the basis of the facts obtained, to map out a plan of development and manage-

ment. The initial appraisal may be done by pace and compass or with the most modern of scientific instruments. A good appraisal must evaluate all of the important aspects of the resource and not merely one. A resource appraisal is not something that is done once and then forgotten. Because the resource itself is constantly changing, it is necessary to follow up the general study with continuing measurements, usually on a sampling basis.

Resource development and management must be based both on estimates of future needs and on the potentialities of the available resource. On our farm, for example, we had to decide what it was we were trying to achieve. Many of our choices were between economic and aesthetic values, because the aesthetic values, such as scenery or solitude, had to compete dollarwise with other possible uses of the land. It was necessary to decide at the outset which aesthetic values were to be preserved. We had to decide, for example, whether the one fertile part of our prairie should be devoted to growing wildflowers or corn. For us the choice was easy; the spring blush of gray and green, punctuated by the white pergolas of flowering baptisia, was far more important than the few dollars the area could yield in corn.

Though much more complicated, the allowable degree of pollution of our rivers is a matter of choice in which certain aesthetic values may be obtained only at the sacrifice of certain economic values. But in deciding among various possible developments, all alternatives must be considered seriously and carefully.

The period of resource development is characteristically much shorter than the subsequent period of management. It did not take us very long to com-

plete the construction of brush piles, the transplantation of flowers and trees, and the finishing of the rude homestead. Then followed, and continues, the constant culling of undesirable trees from the woodlot, the thinning, the weeding, and the seasonal burning of trash.

### **Management of Water Resources**

The United States has nearly completed the development of its water resources and must now prepare to manage them. That the nation has reached this point is abundantly clear. It is well known that in much of the West the available water resources are nearly fully appropriated. It is now necessary to inspect more carefully the nature of the unused, lost, or wasted portion of the resource to see whether it can be brought under control and managed for productive use.

In a recent paper, Raymond L. Nace (1) compiled a general budget of the total water resource, with the view to identifying those general parts of the resource which offer management opportunities as yet unused. He estimates that in the United States ground water occurring at depths less than 2,500 ft is equivalent to the total of all recharge during the last 160 years. There is, in other words, a sizable reserve which has been accumulating over a long period of time. Nace concluded that at the present time by far the greatest opportunity for new management practices lies in the field of ground water.

### **Need for Appraisals**

There is at this time only an incomplete picture of the water resources of the country. We have certainly not made more than a beginning on a real state-by-state appraisal of the resource,

and a quantitative picture of the water budget, however rough present knowledge would require such a budget to be. Although we in the water resource field talk a lot about water appraisal, it becomes apparent, when our activities are studied in detail, that our effort has placed a disproportionate emphasis on the collection of data. We are not really putting enough measurement data into practical use for management. For example, estimates of ground water resources, including the requisite subsurface geologic information, have been completed only for a few basins. With regard to the surface water resource, the samples represented by stream-gaging data have been obtained at 10,000 sites in the United States. Although this is better coverage than in any other large country in the world, it still is not a large sample of the more than 3,000,000 mi of surface streams in the United States. More of this information on stream-flow must be analyzed, together with ground water information. A water budget must be compiled for each basin, aquifer, or other hydrologic unit, so that the possibilities of management can be evaluated.

Although water resource development is approaching maturity, and in some basins in the West development may be essentially complete, we are hardly beginning to think about the much longer period ahead of us in which the principal water problem will be one of wise management. We still lack many of the essentials for a program of wise management. First, though our store of facts is relatively good, we have yet to translate these facts into adequate appraisals. Second, and more important, our basic understanding of the mechanics and processes in the land portion of the

hydrologic cycle is severely limited. Although many details about the hydrologic cycle are known, in terms of what is necessary for wise and efficient management of the water resource, it is my opinion that our detailed knowledge of hydrologic principles is woefully incomplete.

We lack a third important ingredient in any scheme of resource management. We must make certain generalized decisions concerning what we, as a people, want to be and have. These decisions must be made on the basis of aesthetic values as well as economic ones. As a people, we must decide what we want in the way of clean streams, of natural scenery, recreation, and beauty—all of which compete with the economic possibilities of resource development.

#### **Engineer's Responsibility**

The engineer has a peculiar responsibility in this field of water development—which responsibility, in my opinion, is too often inadequately discharged. It is up to the engineering specialists not only to analyze and appraise the magnitude and characteristics of the resource but also to present this information to the public in such a way that a philosophy about management and use can gradually emerge. Before we transmit the facts to the public, however, there is a need for the delineation of general concepts. We in the engineering profession must ourselves analyze water problems and water facts in sufficiently broad terms that we can develop generalizations on which we may base a professional point of view. I suggest here one such generalization: America is now entering a period in which water management rather than water development will be the major engi-

neering task. If we accept this generalization as true, the nature and scope of necessary data, management techniques, and appraisal studies must be reframed in managerial terms.

#### **Meaning of Management**

Let us clarify what is meant by management. The intelligent management of money consists of making sound investments that give a satisfactory balance between risk of loss and financial return. The management of water might be considered in an analogous way. To make a sound investment of water resources would be to apply water to fitting and reasonable uses—that is, uses that are consonant with the quantity, variability, and quality of the supply. The “risks” in the field of water investment might be defined as undue depletion or unnecessary degradation of the quality. Return on the investment might be the number of times a given supply is used and the social benefits accruing from these uses.

Probably the most obvious type of water management is reservoir storage, in which flow that occurs during periods of high runoff is stored and released later during periods of low flow. A higher type of management is the release of reservoir storage for developing hydroelectric power and meeting other needs, such as irrigation, at the same time. Reservoir operation involving more than a single use of stored water is often complicated by the fact that power demands have quite a different time schedule from other demands. To generate the maximum amount of power while simultaneously meeting irrigation or municipal supply demands requires considerable skill. Also, scheduling reservoir releases for such multiple use

becomes increasingly efficient with increased skill in forecasting not only the timing and volume of demands, but the volume of expected runoff. Add to these considerations the relation of evaporation losses to the area of exposed water surface—a factor of importance in semiarid or arid areas—and reservoir operation becomes an art requiring great skill.

In large river basins a system of reservoirs presents even more complicated problems. The need for unfilled reservoir capacity for flood control is sometimes a factor, although in most reservoir systems, flood control capacity is generally kept separate and additive to capacity for holdover storage.

Reservoir operation is only one form of water management in widespread use today, however, and in the present discussion I wish to consider management in a larger context. Consider, for example, the much more complicated system of water relations in a drainage basin, and let storage include reservoir storage, ground or aquifer storage, and soil moisture; let water use include municipal, industrial, agricultural (both dry-farmed and irrigated), and recreational uses; and let availability mean the amount of water at a given place at a given time. Availability, of course, is interrelated with utility of water—that is, the applicability of a given quality to a particular use.

If storage is to include the use of aquifers as underground water reservoirs, much additional knowledge is needed. Some of the advantages of underground storage are quite obvious. Evaporation losses would be minimized. Underground storage eliminates the gradual replacement of usable storage capacity by sedimentation, which is a disadvantage of surface res-

ervoirs. At present, however, the techniques for getting surface water into an aquifer efficiently and in sufficiently large volumes are inadequately developed. Only in a few exceptionally favorable geologic, topographic, and hydrologic situations is artificial recharge practiced at present. Infiltration by surface ponding involves difficulties in the maintenance of sufficiently high permeability. Well injection is hampered by a tendency for clogging of pores by chemical precipitation, air bubble locking, sediment, or organic substances. Induced infiltration by manipulation of ground water levels and by operation of surface storage reservoirs is still in its infancy.

Management, in this broader context, requires foresight in identifying both possibilities and difficulties, and the initiation of investigations of ways to overcome the difficulties.

Appraisal, from the standpoint of management, is not merely the collection of records. To record history is neither appraisal nor management. Records are used to evaluate the characteristics of the resource. The function of management is to project these characteristics into the future, forecast the results of alternative actions, and develop plans utilizing these forecasted results to attain desirable results.

Because forecasts usually require additional knowledge and experience, part of the task of appraisal is to identify the nature of such needed knowledge and experience and to arrange for obtaining it. Thus management can mean both advance planning and day-to-day operation.

### **Problems in Management**

Once an appraisal has been made that is sufficiently complete to allow some reasonable generalizations to be

made about the amounts, variability, and quality of water in various districts or areal units within a basin, if a particular industry wished to know possible places with certain amounts of water available, the proper governing body would inquire first concerning the minimum quality characteristics necessary for that industry and then about the amount and types of waste products that would be discharged. The appraisal information would reveal those areas where the water would satisfy the minimum quality requirements. An industry requiring water only for cooling might use a water with a higher concentration of salts than would be fit for municipal use, and would be urged to use the lowest quality water that would meet the needs. The areas that might supply such water would then be considered in terms of the effects of the pollutants to be discharged by the industry. One area might have enough flow during the entire year that satisfactory dilution would render the effect of industrial pollutants unimportant. In another area, any permit to use water might include a provision that the industrial user undertake a specified treatment of wastes before discharging them into a stream. Good management requires recognition that such choices will have to be made. Particular kinds of information and data must be available; such information must be used in advising industry and making decisions concerning the issuance of water use permits.

If a municipality foresaw a need for additional water, it could, from the appraisal data, determine upon various physical alternatives. Analysis of the data, coupled with the experience of water users in the area, might point to several alternatives, which might

include both ground and surface sources. Let us assume that if a surface supply were developed it would compete with certain recreational and wildlife needs. A cheaper solution could be the development of wells to tap a ground supply, provided that the aquifer were not already fully utilized for supplementary irrigation.

### **Water Rights**

It is not sufficient to say that municipal use has a higher priority than agricultural use. Although this may be sound as a broad generalization, it is not a criterion which could by itself lead to a decision unless life or health were an issue. Moreover, legal doctrine does not necessarily lead to a single, clear-cut answer. In the field of ground water, particularly, it is difficult even under optimum conditions to define what water belongs to whom. Much depends on the hydrologic relation of the recharge area to the point of use, the relation of surface streams to recharge, and the effects of the location and amount of withdrawal on the rate and source of recharge. In other words, although a legal doctrine may be quite clear, its application in any given instance depends heavily on hydrologic facts and physical interrelations.

The administrative machinery of commissions, boards, committees, or executive directors, however powerful or well coordinated, can neither prevent nor solve water problems *ex cathedra*. Two things are vitally necessary for such officers or groups to be effective: [1] an understanding of the hydrologic environment within which their authority is exercised, and [2] an informed public whose aspirations and needs are known. The public must be made aware of both the

hydrologic environment and the broad social needs of community and state. It is not enough to consider local and financial aspects. It is obvious that these requirements can only be met if there is sufficient understanding of the water resource and the physical relations that affect it.

Some areas and some groups are entering the phase of water management which I have tried to picture. One of the most significant examples was a recent action by the state engineer of New Mexico, S. E. Reynolds. Recognizing the hydrologic fact that surface streamflow is intimately interconnected with ground water in the permeable valley deposits of the Middle Rio Grande Valley, Reynolds declared that withdrawals of ground water in that valley amount to diversions from the river, and are therefore subject to the same rules of appropriation. This decision is outstanding because it exemplifies so clearly that hydrologic considerations can and must eventually become one of the bases for administrative action.

Water problems do not usually arise until competition develops, but as resource development progresses, and particularly during periods of less than normal supply, competition for the water intensifies. It is my opinion that no law, series of permit regulations, or priority rating between municipal, industrial, and agricultural use can automatically solve such problems. I do not believe that an appropriation rather than a riparian doctrine would

necessarily prevent water rights problems from arising, or, indeed, that any one doctrine would necessarily, by itself, make the problems more amenable to solution. It is for this reason that I have stressed the concept of water management rather than to recommend specific kinds of legislative doctrine, rules of priority among uses, or administrative procedures.

### Conclusion

No matter what type of resource is under consideration, sound management principles should accompany development from the very beginning. Development and management, in turn, depend on an adequate system of continuing appraisal. We, the engineers and other scientific personnel who consider ourselves experts in the field of water, are trying to operate the complex mechanism of modern water resource development with an outmoded tool kit for water appraisal.

Management means the intelligent application of data and knowledge in a framework that allows flexibility of action. Management implies the liberal use of horse sense rather than legal horsepower. Horse sense can be used to good advantage only when there is enough knowledge to permit choices to be framed in some sort of rational terms.

### Reference

1. NACE, RAYMOND L. Water Management: Agriculture and Ground Water Supplies. USGS, Washington, D.C. (*in press*).