



The Challenge of Water Management

**GEOLOGICAL SURVEY
CIRCULAR 414-B**

Part B
**The Challenge of
Water Management**

By Luna B. Leopold

CONSERVATION AND WATER MANAGEMENT

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PART B

The Challenge of Water Management

By Luna B. Leopold

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In 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 Paul Bunyan. The variability of the glacial topography had resulted in an interesting mixture of prairie marsh, swamp woodlot, and sandhill.

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 many different types of land in the Wisconsin countryside. It has also a very peculiar esthetic and historical interest. Marquette's canoes slipped quietly past our favorite fishing hole on the river. Passenger pigeons had once roosted in our great oaks. The few remaining white pines silhouetted against the sky-glow of evening made one think of the Round River and the Blue Ox.

All right, we had acquired this place. What were we to do with it. Its resources were narrowly limited and peculiar. They had little economic value. All the more reason that they should be appraised in order that they be fully utilized and appreciated. So, while we were

hammering and sawing the old stable into a useable homestead, we walked, sat, dug, and pruned in every coulee and covert, in every thicket and thatch. By compass and pace we mapped the boundaries, the vegetation, and sketched in the topography with 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 pheasant, no quail, practically no grouse, and in spring only an occasional woodcock.

In conjunction with the analysis of what we had to work with we started immediately on the task of development. The techniques were chosen with an eye to 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.

So 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. Grass was removed with a shovel where it was competing with desirable wild flowers. Little patches of corn and beans were planted to provide proper combinations of food and cover.

Within few years we had pheasants, grouse, and woodcock to shoot, wild flowers to delight the eye and the nose, and the annual increments on the stem of every pine were future increments of dollars in the bank.

The problem of appraisal, development, and management are similar, whatever the nature of the resource. Resources may be renewable or nonrenewable. With renewable resources our problem is to increase, insofar as possible, the take from each increment. With nonrenewable resources the problem is to develop in an orderly manner without waste.

As in other resource problems, it is necessary at the earliest possible stage to make an adequate appraisal, to estimate the characteristics and distribution of the resource, and, on the basis of the facts obtained, to map out a plan of development and management. The initial appraisal may be done by pace and compass or it may be done with the most modern scientific instruments. The appraisal, however complete, must be designed in such a way as to evaluate the various aspects of the resource and not merely one part of it.

A resource appraisal is not something that you do once and then forget, because the resource itself is constantly changing. It is therefore necessary to follow up the general study with continuing measurements, generally on a sampling basis.

There is another characteristic which is common to all resource problems. The resource appraisal, its development and management, must be based on an estimate of future needs in due relation to the potentialities of the available resource. On our farm we had to decide what it was we were trying to achieve. Many of our choices were between economic and esthetic values, because the esthetic values, such as scenery or solitude, could not compete dollar-wise against other possible uses of the land. An initial decision had to be made concerning

the esthetic values which were to be preserved. We had to decide, for example, whether the one fertile part of our prairie should be devoted to growing wild flowers or corn. For us this choice was an easy one. The spring blush of gray and green, punctuated by the white pergolas of flowing baptisia, was far more important than the few dollars which the same area could yield in corn.

Though much more complex, the choice of the American people concerning the degree of pollution of our rivers is a matter of choice in which certain esthetic values may be obtained only at a certain economic price. But in choosing among various possible developments, these choices must be faced squarely.

In a resource problem the period of development is characteristically much shorter than the subsequent period of management. It did not take us very long to complete the construction of brush piles, the transplantation of flowers and trees, and the finishing of our 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.

In the field of water, the United States has nearly completed the homestead and must now prepare with shovel and pruning shears to manage the developed resource. That we have reached this stage is abundantly clear in the recent realization that in much of the West the available water resource is nearly fully appropriated and being used. 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 compiled a general budget of the total water resource of the world with special emphasis on the United States. He was concerned with identifying those general parts of the resource which are

most susceptible to unused management opportunities. He estimates that in the United States ground water occurring at depths less than 2,500 feet 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.

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 appraisal of the resource, State by State, with a quantitative picture of the water budget, however rough present knowledge would require such a budget to be. We in the water-resource field talk a lot about water appraisal, but when our activities are studied in detail it becomes apparent that our effort has been overbalanced, with disproportionate emphasis on the collection of data. We are not really translating enough measurement data in the manner that would be most helpful for true management. For example, estimates of ground-water resources, including the requisite subsurface geologic information, have been completed for only a few drainage basins in the United States. 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 3-million odd miles of surface streams which exist in this country. More of this information on streamflow must be analyzed, together with ground-water information, to compile a water budget for each basin, aquifer, or other hydrologic unit, so that the possibilities of management might be evaluated.

Though the period of development approaches maturity, and in some drainage basins in the

West development may be almost 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 elements essential for a program of wise management. First, though our store of facts is relatively good, we are deficient in translating these facts into adequate appraisals. More importantly, our basic knowledge of the mechanics and processes in the land portion of the hydrologic cycle is severely limited. Yes, we know many details about the hydrologic cycle, but in terms of the kind of knowledge necessary for wise and efficient management of the water resource it is my opinion that our detailed knowledge of hydrologic principles is woefully short.

We lack a third important ingredient to any scheme of resource management. There must be certain generalized decisions concerning what we want to be and want to have as a people. These decisions can stem only from a philosophy which extends into the field of esthetic values as well as economic ones. As a people, we must decide what we want in the way of clean streams, of natural scenery and wilderness, and of other values for recreation and beauty which compete with the economic possibilities of resource development. The engineer has a peculiar responsibility in this field, which in my opinion is not now being adequately discharged. It is up to the engineering specialists in the field of water 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. But even before we transmit our knowledge and facts to the public there is a need for the delineation of general concepts.

We in the engineering profession must ourselves analyze water problems and water facts

in terms sufficiently broad for us to develop generalizations on which we may base a professional point of view. I suggest here one such generalization: America is now entering a period when water management rather than water development is the major engineering task confronting us

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

Let us clarify what we mean by management. By the management of money we think of making sound investments which give a satisfactory balance between risk of loss and financial return. Management of water might be considered to have analogous elements. To make a sound investment of water would be to apply water to uses which are fitting and reasonable; that is, uses which are in consonance with the supply, the variability that is characteristic of the supply, and with the quality. Risk of loss in the field of water might be defined as undue depletion or unnecessary degradation of the quality. The analogy to financial return might be to the number of times a given supply is used and the social values accruing from these uses.

To be more specific, let us consider some examples of water management, both theoretic and actual.

Probably the most obvious type of water management is by reservoir storage, impounding flow which occurs during periods of high runoff, and later releasing this stored water to supply needs during periods of low flow. A higher type of management is that concerned with releases from a reservoir when hydroelectric power is to be developed as well as, say, irrigation needs are to be met. Reservoir operation involving more than a single use of stored water is often specialized and complex.

Power demands have quite a different time schedule from irrigation demands. To generate the maximum amount of power while simultaneously meeting irrigation or municipal-water demands requires considerable skill. Also, scheduling reservoir releases for such multiple use becomes increasingly efficient with increased skill in forecasting, not only forecasting the timing and volume of demands, but forecasting the volume of expected runoff. Add to these considerations the relation of evaporation losses to area of exposed water-surface area, 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, though in most reservoir systems, flood-control capacity is generally kept separate and additive to capacity for holdover storage. In some places there is pressure to use flood-control storage capacity for municipal holdover storage. Where the engineer must do this, forecasting becomes imperative.

Reservoir operation is a form of water management in widespread use today. But, in the present discussion I wish to consider management in a larger context. Consider the much more complicated system of water relations in a drainage basin. Let storage be considered to include reservoir storage, ground or aquifer storage, and storage as soil moisture. Let water use include municipal, industrial, agricultural (both dry-farmed and irrigated), and recreational. Let water availability mean how much water is at a given place at a given time, but availability is interrelated to utility of water—that is, the applicability of a given quality to a particular use.

If storage is to include the possibility of using 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 sediment, a long-term disadvantage of surface reservoirs. But at present the techniques for getting surface water into an aquifer efficiently and in sufficiently large volume 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 maintaining sufficiently high permeability. Well injection is hampered by tendency for clogging of pores by chemical precipitation, air bubble locking, by sediment or organic clogging. 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, then, implies foresight in identifying both possibilities and difficulties, and the initiation of investigations aimed at overcoming the difficulties.

Appraisal from the standpoint of management is not merely the collection or records. To record history is neither appraisal nor management. History must be used to evaluate the characteristics of the resource which is appraised. Management is the projection of these characteristics and of this history into the future to forecast the results of various alternative actions and to develop plans which utilize these forecasted results to attain desirable or profitable results.

Such forecasts usually require additional or new 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. Now in this setting, consider how management might mean both advance planning, and day to day operation.

Assume that an appraisal has been made which is sufficiently complete to allow some reasonable generalization to be made about the amounts, variability, and quality of water in various districts or areal units within the basin.

Industry is increasing. A particular industry wishes to know the possible places where certain amounts of water would be 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 which would be discharged. An inspection of the appraisal information would show areas where water exists which would satisfy the minimum quality requirements. An industry requiring water only for cooling might use a water higher in salts than would be needed for municipal use. The industry would be urged to use the lowest quality water which would meet the needs.

The areas which might supply such water would then be considered in terms of the effects of the pollutants to be discharged. One area might have sufficient flow during drought periods to dilute industrial pollutants enough to make treatment unnecessary. Another area under consideration may not be so blessed. For use of the latter, any permit to use water would include a provision that the industrial user undertake a specified type and degree of treatment of wastes before they are liberated into a stream.

Management implies foresight that such choices will have to be made. It requires particular kinds of information and data, and the utilization of such information for advising the industry and for the decisions concerning the issuance of water-use permit.

A municipality foresees the need for additional water. From the appraisal data, various physical alternatives could be visualized. Analysis of these data, coupled with experience of water

users in the area, might point to such alternatives as new surface reservoirs or a well field to develop ground water for the new supply. Let us assume that a surface supply might be developed, but would compete with certain recreational and wildlife needs. A financially cheaper solution could be the development of wells tapping a ground supply. But assume that the aquifer is already fully utilized for supplementary irrigation.

It is not sufficient to say that municipal use has a higher priority than agricultural use. Though this may be sound as a broad generalization, it is not a criterion which by itself can lead to a decision in a case like the one cited, because life and health are not at issue.

Legal doctrine similarly would not necessarily lead inexorably 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 recharge area to point of use, on the relation of surface streams to recharge, on the effects of withdrawal location and amounts to the rate and source of recharge. In other words, a legal doctrine may be quite clear, but its meaning and application in any given instance depends greatly on hydrologic facts and physical interrelations.

Nor does the administrative machinery of boards, committees, or executive directors, however powerful or well coordinated, either prevent or solve water problems. Two things are vitally necessary for such officers or groups to be effective. First is an understanding of the hydrologic environment within which their authority is exercised. Second is a social environment, meaning an informed public, whose aspirations and needs are known. These aspirations must be voiced with at least some attention to both the hydrologic environment and the broad social needs of community and State, rather than merely to local and financial

aspects. It is obvious that both of these requirements demand both facts and knowledge about the water resources and the physical relations affecting the resource.

There are some outstanding examples indicating that some areas and some groups are entering the phase of water management which I am trying to picture. One of the most significant and far-sighted is indicated by 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, the State Engineer declared that withdrawals of ground water in that valley would be considered to be the same as diverting water from the river and, therefore, subject to the same rules of appropriation. This decision is outstanding because it exemplifies so clearly that hydrologic principles can and must eventually become one of the bases for administrative action.

Water problems do not arise until competition develops. As long as the supply is adequate, problems are minimal. But as development of water supply progresses, and particularly during periods of less than normal supply, competition intensifies.

It is my opinion that no law, no series of permit regulations, no priority-ordering among municipal, industrial, and agricultural use will automatically solve such problems. Nor do I believe that an appropriation rather than a riparian doctrine would necessarily prevent the problems from arising. In fact it is open to question whether one kind of doctrine rather than another would necessarily, by itself, make the problems more amenable to solution.

It is exactly in this sense that I stress the idea of water management rather than recommend specific kinds of legislative doctrine, rules of priority among uses, or administrative pro-

cedures. Management connotes the application of data and knowledge in a framework of flexibility of action. Management implies the use of liberal *horsesense* rather than *horsepower*. But *horsesense* can be used to good advantage only when there is sufficient knowledge to permit choices to be framed in some sort of rational and logical terms. Pure guesswork is not the same as the use of *horsesense*.

Thus, no matter what type of resource use is under consideration, whether a farmstead, a

river basin, or a State the boundaries of which include many kinds of natural resources, management should accompany development. But development and management 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 still trying to run a mechanized complex of water development with a tool kit for water appraisal limited to a screwdriver and a pipe wrench.

