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THE ROLE OF ECONOMIC EVALUATION IN PLANNING FOR WATER RESOURCE DEVELOPMENT

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Economic planning and evaluation of water development projects is currently a popular subject in the field of resource economics. This has not always been so. Economic evaluation has always been employed on Federal resource development projects but initial evaluation procedures were informal in nature and their implications were not studied in detail. Prior to the past decade, the role of economics in water resources planning was limited primarily to calculation of costs and benefits after the project had been formulated. Within the last few years, however, economists have begun to participate actively in the survey and planning stages of efforts that seek optimal multipurpose resource development of whole river systems.

Although the economist's participation in several phases of the planning process is now more or less taken for granted, incomplete understanding still remains as to what his function should be. Many leading economists have contributed to the development of theories, precepts, and principles necessary for the planning and economic evaluation of water resource development projects. Economists engaged in water resource development and planning activities, however, have seldom communicated adequately with those who supply them with conceptual and methodological tools. Nor have economists made clear their point of view and the character of problems with which they deal to non-economist members of the water resources planning team—the engineers, hydrologists, demographers, politicians, public administrators, and the man in the street. For these reasons, the coordinate position of economics, with engineering and the political process, has not been widely understood.

In this paper we indicate the character of a number of the problems of economic-social choice encountered in planning for water resources development and the role of economic reasoning in dealing with them. In doing this, we are not primarily concerned with description or criticism of the current planning and evaluation procedures of resources agencies. Some of the characteristics of water which differentiate it from other natural resources are outlined initially. Thereafter, the broad relationship of the political process to water resource development is described. Subsequent sections of the paper are devoted to an exposition of the place of economic reasoning and methodology in system planning, a

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discussion of some difficult and incompletely answered questions of social valuation, and some remarks concerning the implications of economic analysis for determining suitable administrative structures for water resource development. While water resources planning necessarily takes place in a regional context, the emphasis of this article is from the broad public viewpoint rather than from the viewpoint of sectional interests.

Unique Characteristics of Water

The broad-based study of the nation's water resources recently completed by the Senate Select Committee on National Water Resources has focused widespread attention on this highly important natural resource. Out of the vast store of collected data a number of important conclusions have been drawn that already have served as an impetus for special studies aimed at meeting emerging problems constructively. The overriding conclusion to be gleaned from this study can perhaps best be expressed in the words of Dr. Nathaniel Wollman in the introduction of his report to the Senate Select Committee. He states:

> "The report indicates that the status of water in our economic system is rapidly changing. Once water could be regarded as a free good—only pipes, pumps, and treatment plants cost money; water was free for the taking. This view seems destined to disappear from the Eastern scene as it did from the West some time ago . . . And while the country is in no imminent danger of running out of water, no longer is it in the enviable position of having enough water at all times for all conceivable uses. In other words, water is quickly moving into the realm of economic goods."[1]

The relegation of water into the realm of economic goods places it in the same company with most other natural resources—soil, minerals, timber, and the like. This will lead many to assume that the principles of planning and evaluation applicable to our other natural resources can be applied without modification to water. Such is not the case. Water possesses a number of characteristics which present special problems and make unusual demands upon the tools and skills of analysis in all professions concerned with its development and use. Among these characteristics of water are:

1. It is highly mobile and subject to wide variations in quantity and quality in both time and space. Physical and economic results of its planned control and use can be forecast only in probabilistic rather than determinate terms.
2. The major movements of water are dominated by the forces of nature and, therefore, it is not subject to political boundary restraints unless physically controlled by man-made devices.

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[1] Wollman, *Water Supply and Demand,* Senate Select Committee on National Water Resources, Water Resources Activities in the United States, 86th Cong., 2d Sess. (Comm. Print 1960).

3. Given quantities of water at specific locations have great inherent potentials for simultaneous and sequential multipurpose use. In addition, it has a greater reuse potential within short periods of time than any other natural resource.
4. Water can quickly change from an economic (beneficial) good to a disutility by a change in either quality or quantity, or both; excess pollution and floods are prime examples.
5. The people who are adversely affected by water development and control, or by upstream water use, usually are spatially separated from those who benefit.
6. Water in major watercourses is most often, at least nominally, held in public ownership, in part because of the difficulty of unambiguously defining private property rights to it.
7. Water is a part of the land complex (if we define land as the surface, subsurface, and suprasurface of the earth), which makes it difficult, sometimes impossible, to isolate for independent analysis or investigation.

Public Goals of Water Resource Development

Because of the characteristics of water mentioned above, public rather than private agencies are usually called upon to arrange for its development. Once a decision is made to develop the water resources of a given area (say a river basin) by public means, some form of public objective overrides specific private objectives.[2] It is useful to differentiate between two kinds of public goals—the general and the specific. Under present practice general goals tend to be broad and conceptual in nature, for example, "optimum development of water resources." Specific goals are more concrete and specific, such as a proposal to build River Bend Reservoir on the Potomac River in order to supply Washington, D.C. with an expanded water supply.

Public goals usually arise out of citizen action which has become sufficiently organized and oriented to promote legislative action.[3] Because public goals are a result of competition of the specific goals of economic groups, resulting legislation is spelled out primarily in general terms. Specific goals may be mentioned but usually public consideration of specific projects awaits completion of a planning study authorized by the legislation.

The plan of work for the Corps of Engineers Potomac River Basin Survey, now nearing completion, will serve to demonstrate how specific goals of diverse

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[2] Historically, several different goals have tended to dominate public water resources development at different times. For an interesting discussion, see Fox & Caulfield, *Getting the Most Out of Water Resources,* Resources for the Future, Inc. (Wash. D. C. 1961).

[3] The term "public" in this sense is based on the concept developed by Dewey, Intelligence in the Modern World 365-70 (1939).

economic groups are comprehended in the over-all or general goals of the survey. The objectives and scope of the survey are stated as follows:

> "The corps of Engineers has been authorized to prepare a comprehensive plan for the control of floods and the development of water and related resources in the Potomac River Basin.
>
> "The plan will present specific recommended projects to be undertaken before the year 1980, and probable needs based on anticipated trends and projections to the year 2010. The plan will not attempt to delineate agency responsibility for installation, but will list desirable projects whether these are expected to be installed by Federal, State, local, or private agencies.
>
> "The survey will be comprehensive and will be concerned with problems of maintenance of navigable channels, flood control, water supply, pollution abatement, irrigation, recreation, fish and wildlife, hydroelectric power, salinity intrusion, and general beneficial uses of water."[4]

The over-all goal (or goals) thus is meant to orient the specified water development planning effort in a general way. Specific goals, however, are developed as an end product of such surveys, stipulated in a water development plan, brought to the attention of the general public through a process of open hearings, and eventually accepted or rejected by means of the political process. However, the specific goals or project components identified at the planning stage ideally should be part of an optimum plan of development in the "public" interest.

"In practice, legislatures are probably as efficient in allocating resources in accord with public demands, as markets are in reflecting consumer demands."[5] To this should be added: neither the legislative process nor the market place can possibly do a good job of resolving conflict of goals, however, unless rather extensive knowledge of the relevant physical and economic effects of specific developments exists. Moreover, political decisions and planning efforts in the "public" interest require that some reasonable view concerning the meaning of these terms is arrived at and embodied in the planning process. These are the keys to the role of economic reasoning and economic evaluation in river basin planning efforts carried out prior to legislation authorizing the construction phase of water development projects. The function of economics is in part that of helping to provide relevant information. More fundamentally, however, its function is to bring to bear a system of analysis which explicitly introduces the values of the public into the process of system planning and design and allows estimation of the degree to which alternative systems fulfill those values.

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[4] USDA Potomac Field Advisory Committee, Plan of Work, (Mimeograph Report) U.S. Dep't of Agriculture Participation in the Potomac River Basin Survey (1958).

[5] Sargent, *The Political and Economic Framework of Water Resources Development Research,* 15 J. Soil & Water Conservation 156 (1960).

We must hasten to add that reality is sufficiently complex, and our understanding of economic and social values is sufficiently circumscribed, so that the process of planning and evaluation can never be adequately carried out by mechanically following a set of defined rules. The economists' major contributions are to offer a simple but well developed conceptualization of socially optimum resource allocation, a way of thinking about problems which lays great stress on the importance of alternatives and improvements through marginal "tradeoffs," and a certain amount of empirical information, along with a set of techniques for organizing, analyzing, and using this information.

Significance of "Value" Factors in Designing Water Resources Systems.

The fact that the economist's contribution is limited by frustrating lacunae in knowledge does not reduce its importance. Indeed, as emphasized in earlier sections, the whole point of government water resources development is the efficient accomplishment of socially valid objectives. The maximization of physical quantities can never do this adequately and where complex multi-unit, multi-purpose developments are at issue, the idea of physical maximization makes no sense at all. Even in a single purpose development, physical maximization would in virtually all instances result in uneconomical excessive output (i.e., the last additional units would not be worth what they cost to produce). In addition, the different products of multi-purpose development must be measured by a common numeraire if maximization is to have any meaning. Using pounds or cubic feet or other standard physical measures is of course completely unsatisfactory. The question of weighting alternate physical outputs in some meaningful commensurable manner inevitably arises and the weights logically must represent some measure of relative social worth.

A Simple Theory of Value as A Basic Model for Evaluation

The initial and unavoidable requirement of project evaluation is a theory of the social worth of different ways of using resources. At the risk of retracing a well-known path for some readers, it may be useful to sketch briefly the salient assumptions and conclusions of perhaps the simplest of all such theories. Despite its simplicity and abstraction, the simple value theory is the conceptual foundation for benefit-cost analysis.

Assume a market system in which the last dollar spent by any given consumer yields exactly the same satisfaction as the last one spent by any other.[6] Assume that pure competition prevails throughout (no barriers to entry into any industry, and no restrictions in the labor market), consumers and producers are aware

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[6] For this condition to hold rigorously, either the marginal utility of money is constant and identical for all consumers, or a public distribution policy equalizes the utility of money at the margin for different consumers.

of all feasible opportunities open to them, production and consumption units are not physically or psychically interdependent, all producers and consumers rationally try to maximize their own economic benefit, and there is full employment.[7]

Under these circumstances each consumer would be led to spend money on a particular good or service until the last dollar of outlay yielded exactly the same satisfaction as the last dollar spent on any other. Similarly, each producer would continue to hire or buy each productive factor until the last dollar spent on it would yield exactly a dollar's worth of output. Thus, private incentives would result in a situation in which the last unit of any factor hired yielded exactly a dollar's worth of goods in every line. This, of course, means that the consumer satisfaction yielded by the last unit hired would be equal in each case. When this situation exists, over-all satisfaction has reached a maximum for the society because any shift of a factor would necessarily result in a reduction. In other words, taking a factor away from one line of production and introducing it into another would result in less than a dollar's worth of output (satisfaction) in the industry to which it is shifted and the loss of a dollar's worth of output (satisfaction) in the industry from which it is shifted.[8]

Moreover, under the conditions outlined, the purchase price of a factor represents its value in alternative activities. When a dollar's worth of a factor is purchased and applied to one line of activity, this means that production (satisfaction) worth a dollar is foregone elsewhere. This idea of opportunities foregone elsewhere when factors are shifted, i.e., opportunity cost, is a basic one in reasoning about the effect of resource reallocations on welfare.

Now suppose that in this idealized economy the government finds that if it builds a dam and provides irrigation for a certain valley it can increase the value of crops by more than the cost of acquiring the necessary resources. Suppose further that as the scale of the irrigation project is expanded incremental cost rises while the prices of the products produced stay the same. Clearly the government should make some investment because by doing so it can increase the value of crops (satisfaction) by more than the value (satisfaction) of the alternatives foregone. Furthermore, it could continue to expand the project until the cost of a small further increase exactly cancels the increase in the values of product resulting therefrom.[9] Beyond this point it is obviously destroying more valuable opportunities than it is creating.

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[7] The assumption of a lack of extensive cyclical unemployment is adhered to throughout this paper as it simplifies the presentation and appears to be a reasonable assumption for the preparation of water resources development plans at the present time.

[8] The implied shape of the relevant cost and revenue function is explained in any economic theory text. A particularly good reference is Baumol, Economic Dynamics, ch. 5 (1st ed. 1951).

[9] Costs, of course, include the opportunity cost of capital.

While this simple model yields straightforward rules for government investment, they are also somewhat irrelevant, because if the conditions assumed held universally, the government would not need to invest. Private incentives would automatically produce the allocation of resources which maximizes welfare. Not everything works out so smoothly in the actual economy. Indeed in some sectors, water resources development for example, there are a number of reasons to suppose that unadorned private incentives would produce very poor results indeed.

The simple model of an ideal competitive economy sketched above is, however, in point. Economic evaluation of water resources projects makes extensive use of market prices, both for factors of production and for outputs. Behind this use of prices lies the presumption that the actual economy is enough like the highly idealized model to permit the use of factor prices as indicators of the values foregone elsewhere in the economy, if these resources are diverted to a new activity. Similarly, the presumption is that market prices for water derived products are a meausre of the social values they add. While there is no possibility of here detailing the pros and cons of these presumptions, it should be clear that precision in using prices, especially when they are projected into the uncertain future, can soon become spurious.[10] On the other hand, most economists would probably agree that in the U.S. economy, prices in general provide a usable approximation of marginal social values.

Factors Which Distort the Normative Character of Market Results

As implied above, however, a number of the types of situations which may cause distortions in desirable market results apply to water with particular force. A general statement of some of the major types of elements creating these distortions, and some specific examples of their application to water resources, will serve as an introduction to the following sections. At this point it may be useful to note several things about these factors specifically as they relate to water:

1. Most of them arise in one way or another from the special characteristics of water listed earlier.
2. They provide a justification for government action in the development of water resources.
3. They make the task of planning and evaluation complicated and difficult.

The factors that result in a distortion of normal market values are not mutually exclusive in particular situations, nor does the order in which they are stated below indicate priority of importance. They apply individually or in combinations, and with varying force in different circumstances. Points 4 and 5

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[10] For a detailed discussion of the relevant issues, see Krutilla, *Welfare Aspects of Benefit-Cost Analysis*, 69 J. Pol. Econ. 226 (1961).

in the following list, however, are perhaps the most pervasive foundations for government water resources development and the source of particularly difficult evaluation problems.

The five major factors are:

1. Private producers cannot enter an industry where production would be socially desirable because conditions of cost and demand are such that they cannot recover the full cost of production or because institutional obstacles exist.
2. Private producers will not carry output sufficiently far, because some degree of monopoly pricing and restraint on output exists in the industry.
3. The production of a commodity or service is complementary with another to which points 1 and 2 apply, or which, for any other reason, private enterprises have insufficient or no incentive to produce.
4. Conditions of supply of the commodity or service are such that it is difficult or impossible to parcel it out and sell it to individuals or firms.
5. Production of the commodity involves privately unrealized gains or uncompensated losses, i.e., it produces external economies and diseconomies.

Some elaboration of these points and some examples of the ways in which each applies to water resources follows:

1. Where there are economies of large-scale output, demand conditions may be such that no private entrepreneur charging a single price could recover costs. When this is the case it may be that production of the commodity is undesirable in the sense that consumers' over-all willingness to pay is less than the cost of producing any amount. On the other hand, this need not be true. The only way to determine whether or not it is, is to make reference to total cost and to total "willingness to pay" functions derived from demand curves. Willingness to pay means the total amount all individuals who buy the good would be willing to pay rather than be deprived of it altogether. In the simple value theory outlined earlier, willingness to pay is measured by the area under the demand curve, i.e., by integration, up to the relevant output. In instances where production is indicated to be justified by reference to total willingness to pay, it can occur only as a result of government investment and operation of government subsidy. Conditions of this character can occur with respect to power generation, flow augmentation for navigation and waste dilution, and perhaps other aspects of multi-purpose development. They present particularly difficult problems of planning and evaluation because conditions of demand must be known over comparatively wide ranges of output.

Institutional obstacles may also prevent entry of privately-owned firms into particular industries. Where efficient multi-purpose water resources development requires the acquisition of large tracts of land (say, for reservoir sites or recreational development), powers of condemnation are necessary to prevent holdout property owners from using "bottleneck" positions to obtain exorbitant prices or even to halt development. Moreover, and perhaps of greater importance, private developers would most often be unable to get sufficiently secure and well-defined property rights in the water itself to permit optimal development.

2. Where large-scale output has advantages, or where ownership of a scarce or unique asset gives a private developer market power, the marginal value of output to society tends to be held above opportunity cost. With respect to water resources, economies of large scale and ownership of scarce reservoir sites would inevitably bestow market power upon private developers. This does not necessarily imply the need for Government ownership but it does demand regulation. Where these situations are combined with conditions of decreasing cost at the point of optimal output, Government subsidy is implied for the private developer cannot cover his costs at prices which correspond to marginal resource cost. Government regulation, as well as Government development, requires a method or methods of output evaluation.

3. Economies achievable by multi-purpose development of land and water resources are a major justification for large-scale Federal undertakings. Multiple purposes—navigation, irrigation, waste, dilution, power production, flood control, recreation—are over certain ranges and in certain circumstances complementary but over other ranges and in other circumstances, competitive. However, over-all economies resulting from complementarity in large-scale developments are often achievable. When a set of purposes is complementary (if flow-augmentation for navigation keeps organic pollution at sufficiently low levels to avoid fish kills for example), the costs of achieving either purpose are lower than they would be in a single-purpose venture. In such instances single-purpose development (perhaps, because the private developer could not exact payment for fish kills avoided) would produce a less than optimum amount of output even if barriers to entry and cost economies did not prevent a competitive market from developing. Under private multi-purpose development any obstacles to the optimum scale of development of a particular project purpose will distort the development of competitive and complementary purposes as well.

4. Problems arising from the high cost or impossibility of parcelling out and selling the output to individuals or limiting access may require Government intervention. National defense and police protection, recreation, and stream sanitation present problems of this type. While they can often be comprehended in evaluation procedures by public bodies, they nonetheless present special problems which are discussed in more detail at later points.

5. The simple value theory sketched above, together with all its elaborations, requires that there be no technical links between independently managed pro-

duction processes if free markets are to maximize satisfaction. In water resources development, however, such links are manifold. An upstream impoundment increases downstream power generation capacity, flow augmentation improves navigation possibilities and critical low flows all along the stream, irrigation with surface water recharges aquifers used for pump irrigation, and the like.[11] On the other hand, recharge of aquifers may result in land drainage problems, releases of water with low dissolved oxygen content from the lower reaches of reservoirs deteriorate stream water quality and may kill fish, use of hydroelectric power for peaking purposes may alter stream flow in such a way as to reduce a stream's waste assimilative capacity and/or make it less suitable for navigation, and the return flow from irrigation may increase treatment costs by raising the level of dissolved solids. All of these factors would cause divergences between the apparent costs and real (opportunity) costs of private, fiscally independent, single purpose operations, thus destroying the parity between private and social costs. Similar considerations apply to benefits. Consequently, private development would not produce optimal results. Again the matter of such external economies and diseconomies poses special problems for planning and evaluation procedure.

One way of dealing with externalities which would result from the limited jurisdiction of individual private units is to expand the plan area sufficiently to include them. Indeed, this is perhaps the major argument for integrated basin-wide (or other large area) planning. This means, however, that internal as well as external alternatives must be considered when computing the costs and benefits of a particular project purpose or project increment. For example, if flood control competes with irrigation, the costs of the flood control feature are not fully registered by direct outlays on resources used but includes the net loss of irrigation value as well. Internal opportunity cost relations of this kind occur whenever technological links between project purposes or physically separated project elements produce relations of complementarity or competitiveness. These "links" are highly significant elements in the economics of water resources system design and evaluation and greatly influence the character of optimal systems.

Because of the comparatively large scale of water resources projects, other types of external economies may occur in the market area as well. These result from the fuller use of social overhead capital, economies of scale in processing, special locational advantages in the project area, and the like. While external economies of this "market" variety may exist, and while in special instances they may be sufficient to merit consideration, it is very difficult to compute their net amount. Alternative investments, public or private, might induce such economies to as great a degree as, or even to a greater degree than, the project, but their

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[11] For an excellent treatment of the role of external economies in efficient river basin development, see Krutilla & Eckstein, Multipurpose Water Resources Development (1958).

actual magnitude is almost always an unknown. Consequently, a good general rule is probably to ignore them unless there are strong reasons to suppose they are of unusual size or importance.

Uses and Limitations of the Simple Value Theory

While the special characteristics of water resources pose difficult problems, much can be learned about the evaluation of water resources projects and their efficient design from the simple value theory outlined earlier. Despite its simplifications, this theory provides a number of highly valuable ideas for use in water resource development planning. These include: 1) The implied emphasis upon marginal adjustments or "tradeoffs"; 2) The measurement of opportunity costs outside the water sector, and of benefits, by means of market prices or market imputed demand curves; and 3) The necessity of bringing effects of water development and use, which could be external to privately managed units, into the marginal benefit-cost framewrok.

These concepts go a long way toward providing a systematic foundation for maximizing the net benefits which society can secure from water resources.[12] In essence, they imply a public policy which would produce the normative results of competitive markets in a situation where a variety of factors prevent efficiently functioning competitive markets from developing. This means that each project purpose should be developed to the point where a further increase would raise costs (internal and external opportunities foregone) beyond the increase in benefits (consumer willingness to pay). Another way of saying this is that marginal opportunity costs and marginal social benefits should be equated for each purpose and each project element.[13]

The importance of these ideas is not to be minimized. However, a number of serious complications and limitations inhibit their application in a straightforward manner and require the application of special procedures. Among the most important of these are:

1. Problems of measurement, especially with respect to the increasingly important purposes of recreation and waste disposal.
2. Limitation imposed by data gaps.
3. The range of difficulties and imponderables introduced by time and uncertainty.
4. The inherent computational difficulty of, and extensive data re-

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[12] Underlying this article is the idea that the public wishes to get the *most* from its water resources for each dollar invested in development, not just a satisfactory amount. For an interesting discussion of the idea of "satisficing" rather than maximizing, see Simon, *Theories of Decision-Making in Economics and Behavorial Science,* 49 Am. Econ. Rev. 253, 262 (1959).

[13] This holds true unless the budget available for water resources developmentt is in itself an effective constraint. In that case, the marginal principles apply in modified form.

quirements for, designing a system which is expected to produce maximum net benefits.

These are discussed in the following sections:

Some General Problems of Benefit Measurement

When markets—or market-type imputations—can be relied on for the evaluation of goods and services, the primary problem is one of determining the appropriate magnitudes and projecting them into the future for a suitable period. In some instances determination of market values is so difficult and uncertain that alternative (but less satisfactory) procedures are indicated. In still other instances there are more fundamental objections to market-type valuations. These problems have often led to only vague considerations of project effects on recreation, aesthetics, and pollution, and even then only under the illusive title of intangibles. Further complications in the measurement of benefits arise from the uncertainty of hydrologic fluctuations affecting the system from month to month and from year to year.

Difficulties When Services are Not Marketable

The conditions of supply of some services are of such a character that if they are provided to one consumer they are automatically provided to others or costs of limiting access to them by others, are prohibitively high. These instances simultaneously imply public intervention and make measurement of the benefits it bestows unusually difficult. With respect to water resources, cases of this type can be divided into three categories:

1. *Where the service in question is not a "public" service but the administrative costs of controlling access are high.* Administrative costs of controlling access can cause a good to be undersupplied or not supplied at all. This may be particularly significant with respect to recreation. For example, a large acreage may be prohibitively costly to protect from unauthorized entry. As a consequence the private owner will not develop recreational property to provide services for which he cannot collect. Or, in cases where collection is possible, the administrative costs of limiting access may be sufficiently great to cause a less than optimal amount of recreation services to be provided. In such instances where access control costs are high, and where marginal costs of providing opportunities for additional users are relatively low (or perhaps even zero), appropriate social policy may be to provide the service free and finance it by some means other than entrance fees. Measurement and forecast of recreation demand are necessary in order to maximize project benefits, but difficult under the best of circumstances. While an ingenious method of estimating recreation demand has been suggested,[14] it appears that for the time being recreation must

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[14] See Clawson, *Methods of Measuring the Demand for and Value of Recreation*, Resources for the Future, Inc. (Wash. D. C., Reprint No. 13, 1959).

usually be handled in something like the less satisfactory manner suggested below.

2. *Where the service in question is "public" but its value can be deduced from what individuals would be willing to pay if they were rationally attempting to maximize individual benefit.* In the second instance a good or service is "public" in the sense that no market could possibly develop for it and there is no way to control the supply made available to individual economic units. In water resources development, flood control and flow augmentation for navigation and waste disposal present examples of such services. If they are supplied to one individual or firm in the relevant area, they are automatically supplied to others. To the degree that services of this character avoid damages, (flood control and waste dilution, particularly), or substitute for other services that are being or would be bought, values can be imputed to them. This can be done by reasoning about what a rational individual would be willing to pay. In the case of flood damages one may reason, for example, that an individual would be willing to pay up to the value of the property loss. This essentially amounts to finding points on the demand curve for flood control by vertically adding up prices at given outputs, i.e., levels of protection.

3. *Where the product is a "public" good and its value cannot be imputed by reasoning about rational individual choice.* This instance presents the most difficult valuation problem of all. This is the case where a public good does not result in the avoidance of tangible damages to marketable goods and services or does not substitute for a service of known or discoverable market values. General environmental benefits resulting from flow augmentation for waste dilution, where nuisance conditions would otherwise prevail, is an example. Here the issues are very complicated. While alternative means for coping with the nuisance situation may exist, no market for them develops either, because they too would result in a "public" good. In cases of this character, (certain aspects of public health fall in the same category), there is simply no way at hand to impute values based on individual preferences. Some indirect exploration of social preferences may be possible, however, via experiments with costs. This possibility is described further below.

Hydrology and Net Benefits

A problem which quite generally besets benefit measurement—even when "public" goods or services are not involved—results from the fact that the output of the system in any given year is (strictly speaking) unpredictable. Since hydrology is a critical factor in the outputs attained, this follows even disregarding errors which are likely to exist in the projection of economic variables such as demand for system outputs and the relative prices of system inputs. Hydrological variation therefore means that the prediction of the value of system outputs for (say) a given year must necessarily be probabilistic rather than determinate (i.e., it is a stochastic variable). Since net benefits are greatly influenced by the way in which system units are operated to take account of hydrological variation, some means must be devised for designing the system for the expected hydrologic variation. Possible approaches are the introduction of stochastic variables into the maximization procedure used for system design, or running an actual or synthetic hydrological record through a model (mathematical simulation) of the system in such a way that economic losses and gains from alternative systems, in response to variations in flow, will be registered. The difficulties of dealing adequately with complex hydrologies in terms of the variation in net benefits they produce, have given rise to the use of various physical rules of thumb in system design, such as the specification of minimum irrigation water deficits and minimum design-flows for the determination of pollution abatement benefits. Indeed, pollution control combines the problem of handling extreme hydrological events and problems of benefit measurement of the types sketched in the preceding section.

Pollution Abatement—A Specific Illustration of Planning and Evaluation[15]

Planning for optimal pollution abatement clearly illustrates some of the uses and weaknesses of the simple valuation model with respect to water resources project evaluation and design. For this reason, and because pollution has received little attention in the literature, some added discussion of it may be a useful way to make more concrete some problems of benefit estimation and to sketch means of dealing with them. The reader will be aware, of course, that pollution abatement has been chosen for more extensive discussion than other aspects of multi-purpose development in part because of the unusual difficulties it presents. Procedures with respect to other aspects of multi-purpose design—hydro-electric power, irrigation, and flood control—are vastly more straightforward—more directly amenable to market-type benefit measurement—and more fully developed.

Pollution, of course, presents a classic example of external diseconomies. Ordinarily, the entire cost of waste disposal into water courses is imposed on downstream users. The complexities and distortions which can occur in a heavily loaded stream can readily be imagined; there will usually exist numerous separately managed water supply intakes, sewage outfalls, and publicly and privately used intervening stretches of stream and shoreline. The pollution caused links among these fiscally independent units would under unregulated market conditions tend to result in inefficient waste disposal systems, in excessive

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[15] For a more detailed discussion of the issues raised in this section, see Kneese, *Water Pollution—Economic Aspects and Research Needs,* Resources for the Future, Inc. (Wash. D.C. 1962).

waste disposal, and in a non-optimal distribution of social costs. There would be a bias in favor of water supply treatment and a bias unfavorable to sewage treatment as well as other means of pollution abatement such as stream flow regulation. The over-all costs of putting wastes into water courses would be underestimated by polluters because costs fall upon other, fiscally independent, units. Costs would be imposed upon some economic units, not as a result of their own productive activities (as our simple value theory requires), but as a result of the productive activities of others, thus tending to distort the optimal allocation of resources.

A requirement for the mitigation of these distortions is that a public authority take account of the technical links between independently managed units and plan for a system of waste disposal which minimizes social costs associated with waste disposal in the planning area. The emphasis, it should be noted at this point, is upon costs, not upon achieving certain specific standards of purity in the stream.

If all pollution damages and costs of all abatement measures are measurable in terms of market values, a simple criterion for minimizing the social costs of pollution can be specified on the basis of the simple value model. Ideally the public authority should plan and implement a system which equates the marginal costs of waste disposal in all directions.[16] The costs of waste disposal include all manner of waste treatment and water supply treatment, methods of flow regulation, methods of conforming waste discharge to streamflow, changes in industrial processes, *and pollution damages.* If costs were not equated at the margin, it would be possible to "trade off" in such a manner as to reduce the over-all costs of waste disposal. For example, if the cost of a small increase in residual pollution damages (say, corrosion of equipment) is less than the cost of treatment to prevent it, over-all costs are reduced by trading the damages for the treatment.

It is evident that recognition of waste disposal as a problem of optimal system design extends the water resources planning problem beyond the confines of dams, power plants, and diversion works to the full range of alternative means of reducing the costs of waste disposal. Moreover, relationships of complementarity and substitution exist between flow-augmentation and other aspects of multi-purpose development such as navigation, irrigation, flood control and hydro-electric power generation. As indicated earlier in this article, these relationships must be considered in computing the opportunity costs of utilizing flow regulation for pollution abatement. Thus the problem of planning efficient

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[16] Since the resulting system would not necessarily imply an appropriate distribution of costs, a system of charges and bounties would have to be devised. One object of such a system would be to impose the cost of an increment of waste disposal on the polluter.

waste disposal-water supply systems is an integral element of the over-all water resources planning effort.

Ideally, therefore, the public planning authority would take into consideration the following factors:

1. All alternative water uses.
2. The effects on quality of the various uses.
3. The losses imposed on other uses by quality deterioration (for example, damages to equipment, and foregone recreation opportunities).
4. Increased costs of treating industrial and municipal supplies.
5. The value of all relevant water derivative uses.
6. The complementary and substitution relationships between development of the various uses (internal opportunity costs).

In sum, the results of all relevant alternative system designs and operating procedures would have to be considered and a solution derived which simultaneously indicated the optimum combination of system elements and their operating procedures. If this were successfully done the solution would be "efficient" (in the context of the simple value theory), maximum benefit would be obtained from the available water resources, and, as the latter implies, the real cost of waste disposal would be minimized. The complexity and difficulty of setting up and solving a maximization problem of this character can be imagined even if the stream hydrology and other types of imperfect knowledge did not complicate matters further, which, as will be seen subsequently, they do. While less than ideal formulation and solution must be accepted, stating the problem in this idealized form does help to make clear the far-reaching way in which economic elements are involved in the design problem. Moreover, swift development of electronic computer procedures and some specific applications to water resources design problems hold out considerable promise for greatly improved means of dealing with complex multi-purpose, multi-unit, maximization problems.

The problem of designing optimal waste disposal systems in conjunction with over-all basin planning gains further in complexity when hydrologic variability is explicitly considered. The concentration of most pollutants in stream waters is inversely related to the rate of flow. Consequently a problem arises concerning the critical flow against which protection is to be sought. Analogous considerations occur with respect to criteria for the design of flood control structures, except of course that the focus is upon high, rather than low, flows.

Protection against pollution damages during the lowest imaginable flow would be analagous to protection against the "maximum probable flood."[17] In present

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[17] See Leopold & Maddock, The Flood Control Controversy 117 (1954).

practice, designing pollution abatement facilities so as to achieve the maximum degree of protection is generally considered infeasible and some lesser goal is chosen—usually a conventional rule-of-thumb flow standard. Often standards are specified by state law, a favorite being a mean 7-day low-flow with a probability of recurrence of once in 10 years. This means that some parameter of pollution (say, dissolved oxygen) is not to drop below a specified level (say, 4 ppm) at any flows equal to or in excess of that indicated.

In practice the choice of design flow is quite important because it directly affects the degree of pollution damage against which protection is provided. Essentially, of course, the choice of optimum levels of protection is an economic problem largely symmetrical to the choice of the size of flood against which damages are to be sought. In principle a reasonable rule for flood control measures, consistent with the simple value model, is that all relevant flood control measures should be expanded to the point where further expansion would result in an increased cost of floods. Or to put it more conventionally, until the marginal cost of a further increment of flood protection exceeds the mathematical expectation of damages avoided with the cost of protection including, of course, the value of other project purposes foregone.

Similarly, protection against pollution should be extended until the costs of all relevant means of avoiding damage of waste disposal and the mathematical expectation of damages avoided are equalized at the margin. This principle would be rather straightforwardly applicable if the probable costs imposed by pollution (equipment damage, increased treatment cost, recreational opportunities foregone, environmental deterioration, etc.) could reasonably be integrated into a single monetary measure of value. Pollution, however, involves significant effects which are not measurable by market prices or market imputed values. For one thing, many recreation opportunities, (which as pointed out above are usually not "public" values but which present particularly difficult problems of measurement), are intimately involved with the quality of water bodies. Moreover, as previously indicated, a polluted body of water to which the public is exposed causes aesthetic damages of public character. No private market will develop for ameliorative measures because an individual who provides relief for himself automatically provides it for others as well. Consequently, private preferences will not be revealed.

The public health aspects of water pollution, in addition, present serious difficulties for evaluation. To the extent that communicable diseases are at issue, a type of interdependence in consumption exists not unlike that which water pollution causes between producers. Since some of the benefits attained when an individual avoids a communicable disease accrue more widely to the community, the community may wish to set standards of public health higher than those which would be set by the collectivity of individuals. Even where infectious disease is not involved, most individuals may simply prefer to live under conditions where the spectacle of mass illness does not confront them. Thus the community may wish to overrule the market's verdict and set a higher standard of health.

Water quality promises to become a progressively more important variable in system design and evaluation. Consequently, the evaluation difficulties presented by it are a matter of some concern. Similar sorts of problems are by no means absent, however, from other aspects of multi-purpose development. For example, difficult to value recreation opportunities are created and destroyed (often simultaneously) by reservoirs, withdrawals of water for irrigation, and the use of power plants for "peaking."

Incorporating "Public" Goals Into Planning and Evaluation—A Constrained Objective Function

A means must be found whereby the social value of recreational opportunities,[18] environmental benefits of stream sanitation, social public health values, and perhaps others, can be reflected in efficiently designed systems, even though no direct means exists for guaging relative individual preferences for them. Ordinarily, project results of this general character have been labeled intangibles and more or less disregarded in the process of planning and designing water resource systems. Then when the projects are ready for consideration by representatives of the public, side information about these so-called "intangibles" has been provided to aid the decision makers in determining to accept or reject specific facilities or combinations of facilities. This includes general information on aesthetic effects, public health, and other matters considered relevant to arriving at a decision in the public interest.

The alternative approach is to initially and explicitly include a judgment concerning non-market derived goals in the process of system design. This can be done by initially treating these goals, expressed in physical terms, as limitations upon the over-all objective. To return to the example of an optimal waste-disposal system, (a sub-system of the plan for maximizing the net benefits which can be secured from the water resource), certain goals would be treated as constraints upon the cost minimization objective. For example, if a politically expressed social choice indicated that streams must at all times (or under specified conditions) contain a specified minimum amount of dissolved oxygen, public policy would be to produce a system which minimizes the real cost of waste disposal subject to the constraint that the indicated dissolved oxygen level is to be maintained. Conceivably this would require a very different combination of units, with differing operating procedures, than a system designed without the

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[18] At least until more fully developed measures of demand come into existence.

constraint. Presuming the constraints are effective, (i.e., not automatically achieved if costs are minimized), it would result in a higher cost system than could otherwise have been achieved. The extra cost represents the limitation which the constraint places upon the objective.

The distinction between objectives and constraints can be somewhat troublesome when "policy" constraints are involved. "Technological" constraints, which set the physical framework within which maximization (or minimization) is carried out, are usually comparatively clear-cut. For example, such a constraint might be that water cannot flow uphill. "Policy" constraints, however, can be viewed as requirements set on certain results which constrain the effort devoted to the attainment of other objectives. In a polution problem, for example, one of the policy constraints might be the one outlined in the previous section, (i.e., a minimum level of dissolved oxygen).

As a generalization, the following distinction has been proposed: "[A] practicable distinction between constraints and objectives might go as follows: A requirement is a constraint if (a) it must not be violated at any cost however high or with any probability however low, and (b) there is no gain or advantage in overfulfilling it. On the other hand, a requirement is one of the objectives . . . if it can be violated, though at a cost or penalty, or if there is an advantage in overfulfilling it."[19] Constraints meant to represent public values often do not fully meet the rigorous conditions described and certainly those set out in a model intended to deal with pollution would have difficulty in doing so. This emphasizes the importance of not considering constraints immutable and of testing the sensitivity of costs and desirable effects they represent to them. Rational choices via public policy can be greatly facilitated if the costs (in terms of the objective) of a variety of constraint levels and associated effects are known to the policy maker.

Although extra costs are involved if policy constraint limitations upon objectives are allowed, marginal conditions analogous to those indicated earlier (i.e., the equalization of marginal costs in all directions) must still hold in order for the cost minimizing objective to be fulfilled. In other words, the optimum system is not attained until a situation is reached in which it is impossible to make marginal "tradeoffs" (say, between waste treatment and pollution damages) which lower costs without violating the constraints. The marginal costs affected by the constraints (say, waste dilution) now, however, contain an imputed element which derives from the limited supply of the constrained input (say, dissolved oxygen).[20]

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[19] Dorfman, *Operations Research,* 50 Am. Econ. Rev. 575, 609 (1960).

[20] In principle the problem of finding an optimum system under constrained conditions is solvable by the use of differential calculus and a method known as La Grange multipliers. See *Appendix*: *The Simple Mathematics of Maximization,* in Hitch & McKean, The Economics of Defense in the Nuclear Age 361 (1960).

It must be made clear that while the constrained objective function type of framework is very flexible and can be used to comprehend goals not strictly commensurable with those derived from market valuation, the inclusion of the latter means that the procedure cannot lead to a full optimum but only to a sub-optimum, i.e., an optimum subject to higher level decisions constraining the minimization (maximization) process.[21] From the point of view of achieving maximum efficiency, this means that the policy constraints should be considered "provisional" and viewed as a subject matter for research and study with a view to expanding their meaning with respect to the preferences of society.

One way of studying them from this point of view is as suggested earlier, to test their cost sensitivity. By varying a constraint by small amounts, redetermining the optimum system, and collating the change in costs with the associated physical changes, (i.e., effects on oxygen levels, appearance, aquatic life, etc., in specific stretches of stream) information can be provided which permits considered choices to be made by representatives of the public. This provides a means of, in a manner of speaking, exploring a politically articulated collective demand function, thus permitting a closer approach to meeting the preferences of society.

One useful way of stating the results of experiments with the constraints which are not commensurable with the object, (i.e., not valued directly by or imputable from the market), is in terms of what they must "at least be worth." Suppose for example, that social judgment were to direct that algae growth is to be restricted, because of its effect on the appearance of the water, beyond the point indicated by the cost minimizing solution (i.e., algae limitation is an effective constraint). It would, of course, not be possible to say precisely what the avoided destruction (real cost) of aesthetic pleasure is worth. By comparing the optimum system with and without the constraint, however, it would be possible to indicate to the public representatives what the *least* value is that must be attached in order to make that level of control procedures worth while.

While the above sketch of the constrained objective framework was developed largely in terms of pollution abatement aspects of system design and evaluation, it can, of course, apply to any analagous situation where market type valuation is not possible or acceptable. Moreover, it can be used to implement objectives not based upon efficiency, such as income redistribution. For example, it may be considered desirable to improve the income position of a group of Indians in the project area. In this case, presuming the desired income redistribution does not come about automatically when an optimal system, based on

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[21] For an instructive discussion of optima and sub-optima, see Hitch & McKean, *supra* note 20, or for a discussion more directly addressing water resources issues, see McKean, Efficiency in Government Through Systems Analysis (1958).

efficiency, and possibly constraints of the type described, is built, income redistribution may be introduced as a constraint upon the objective function.[22]

Obstacle to Achieving Maximization of an Objective in Practical Situations

As stated earlier, the objective of this paper is not primarily to describe present practice or even the immediately practical but to probe into the economic and social choice aspects of water resources planning problems. The concept of a constrained objective function provides a convenient framework for this purpose. The actual problems involved in attempting literal maximization of an objective in a practical situation, however, are very difficult indeed. It makes great demands upon concepts and data, upon ingenuity to devise improved means of solutions, and upon actual computation.

Deficiencies in Data

Maximizing a constrained net benefit objective involves, in part, prediction of the uses to which the resources of the relevant area will be put under alternative water resources development plans. This requires, in the ideal sense, complete knowledge of the countless production functions that are feasible for various uses which may occur, not only in space (in this case a river basin area), but also over time. In actual situations consideration can often be limited to comparatively few major economic alternatives. Usually it is possible to limit the list of likely alternatives simply on the basis of general knowledge.

There appear to be relatively few uses, for example, for large expanses of the arid uplands in the Colorado River Basin which are included in a water quality management study currently underway.[23] Here the conditions are so limiting that probable economic activities may consist of perhaps mining, grazing, forestry, and general recreational pursuits. The alternative activities in the river valleys in this region, however, are much more numerous. Although, at present, a given valley may be devoted primarily to irrigated cropland, in the future, demands for urban manufacturing and transportation activities may

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[22] For an extensive discussion of income distribution as a goal, its treatment as a constraint, and a means of inserting it directly into the objective function, see Maas, Hufschmidt, Dorfman, Thomas, Mauglin and Fair, Design of Water Resource Systems, Chapter II (1962).

[23] The Colorado River Basin Water Quality Control Project was initiated by the U.S. Public Health Service in July 1960 at the request of a conference group consisting of representatives of the water pollution control agencies of the seven basin states and the Public Health Service. The project has two major objectives: (1) Determination of specific pollution problems that now exist along with providing information for establishing priorities for remedial action; and (2) Development of a comprehensive plan and program of water quality control for multiple water use. Five or more years will be required to carry out this study.

develop. Still, through judgment, the list of most likely alternatives can be shortened considerably.

Even with a comparatively circumscribed number of potential alternatives, however, prediction of the course of development of a particular area remains seriously inhibited by data and informational deficiencies. Among these are:

1. There is a lack of adequate input-output information and of data bearing upon location factors for any activity and virtually no information exists for the simultaneous analysis of several potentially competing activities.
2. Commonly the various feasible kinds of resource combinations within the area under study are not adequately identifiable with existing data. For example, only fragmentary data on hydrology, mineral deposits, soil characteristics and the like are available for the Colorado River Basin.
3. Prices of inputs and outputs fluctuate widely through time and there are no firm grounds for the projections of relative price change.
4. Technology is changing rapidly and new techniques often have differing effects upon input-output relationships for different kinds of resource combinations. Data on the effects of technological change on optimum resource combinations are virtually nonexistent and the projections of technological change involves great uncertainty.
5. Institutional arrangements may substantially affect optimum water development. The long-term effect of systems of taxation, ownership patterns, market facilities, water law, the modes of behavior of ethnic groups, and numerous analogous considerations are often unknown but highly important.

Because of these informational deficiencies, economic analysis must often depend on a variety of data sources, rely on rule-of-thumb projection techniques, and involves a large measure of judgment in arriving at forecasts. This currently leaves the highly valuable concepts of production functions, willingness to pay as an indicator of benefits, and highest benefit solutions largely in the position of systems of thought that are useful in helping to unify and interpret fragmentary evidence in the process of arriving at practical but far from ideal solutions. Moreover, it stresses the importance of research and improved data gathering, not only in the scientific and engineering fields but in the economic as well.

The kind of data gaps that limit adequate analysis of alternative uses, and the difficulties of filling them are illustrated by the relatively extensively studied field of irrigation agriculture. In this single water use possiblity, many input factors are used and the amount of output is determined not only by the kinds and amounts of inputs and the ways they are combined, but also by weather, changes in product demand, and other things not under the farmer's control. In a strict sense, we cannot determine how much product will be produced until the crop is harvested. It is possible, however, to make an intelligent guess providing there is adequate information on what kind of land is likely to be irrigated, frequency data on climatic conditions, expected farming practices, and various other information about the kinds and amounts of inputs.

A large group of professionals is constantly working to provide the kind of data needed for this kind of analysis, but the surface has barely been scratched in regard to relevant basic data for water resources planning. Consequently, imagination as well as effort is required in order to provide appropriate methods for obtaining data, and judgment must be exercised with respect to the amount of detail which the planning situation demands. It is easily possible to demand such precision that uneconomical if not impossible data requirements are imposed. Irrigated agriculture is perhaps the most intensively studied of all water uses but we still suffer from a lack of adequate information. Other aspects of water resources planning and development are limited even more from a lack of the types of data which intelligent social choice requires.

As indicated earlier, water quality is rapidly becoming a major consideration in river basin planning and poses a particularly clear need for comprehensive integrated planning. This is an area, however, in which research focused upon regional planning is still in its infancy.

Among the types of water quality data which are necessary, but as yet largely unavailable, for basin planning are:

1. Information on what happens to wastes in long stretches of receiving waters and their effects on the water, particularly in regard to those wastes which cause tangible changes in the water itself, or significantly affect successive uses.
2. Information on the costs of waste disposal in suitable form for system analysis. These include sewage treatment, water supply treatment, reclamation of waste materials, industrial process changes, methods of controlling streamflow or conforming waste discharges to flows, and pollution damages (including those which occur indirectly, say, as a consequence of algae growth).
3. Improved means for the prediction of pollution loadings—especially those resulting from industrial waste disposal. These should provide a reasonable forecast of the effects of environmental conditions such as water costs, technological changes, and various kinds of public policies.
4. Information on the economics of re-using water. Little work in the economic aspects of water reuse has been done and information is lacking on the effects of reuse on net depletion and on net waste loads delivered to streams.

Another potentially important area in which there is virtually no information available is that of the conjunctive use of ground and surface water. While waste disposal and ground water are particularly striking examples of limited knowledge, it is easy to cite an array of basic data deficiencies in almost every area entering into water resources planning. This fact, plus uncertainties arising from unpredictable technological and market changes, puts a premium upon flexibility in project design and makes it necessary to allow for uncertainty, if only by comparatively crude methods.[24]

Discounting for Time

Temporal sequences present difficult problems for benefit estimation and the establishment of investment criteria. They are, as some of the above discussion has implied, nevertheless fundamentally involved in the planning and evaluation of water resource systems. The very dependence of system returns (and to a degree costs) upon hydrology intimately introduces a particular sequence of events into the value of specific projects and logically, into the determination of optimal system design. Moreover, generally speaking the further economic magnitudes are projected into the future, the less sure one can be of their accuracy. As has already been indicated, the latter consideration make it necessary to take account of uncertainty in some fashion when investment criteria are established.

Time also enters into investment decisions (public and private) for two other reasons. One is that investments alternative to water resources development earn a positive rate of return per unit of time and the second is that people (acting as individuals or as a society) may not be indifferent to the configuration of returns through time.

An illustration of the effect of alternative investment opportunities, reinvestment opportunity, and time preference on investment decisions

These considerations, which are directly relevant to water resources planning decisions, can be simply illustrated by regarding alternative investments which last for two periods. Assume the amount invested is the same in each of the following instances and the figures in the middle two rows indicate the net returns in periods 1 and 2.

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[24] The problem of accounting for true uncertainity, *i.e.*, the situation where the moments of probability distributions for significant variables cannot be computed, is not discussed in this paper. Considerations of space plus the fact that economics offers no firm guides to decisions in this regard account for its omission. For a lucid discussion of issues and approaches, see Eckstein, *A Survey of the Theory of Public Expenditure Criteria*, Public Finance Needs, Sources and Utilization 486ff, Nat'l Bureau Econ. Research (1961).

Investment No.	Returns in Period I	Returns in Period II	Total Return Without Reinvestment
1	$ 9.00	$ 9.00	$18.00
2	10.00	10.00	20.00
3	11.00	9.00	20.00
4	9.00	11.00	20.00

It is apparent that anyone attempting to maximize his economic position would prefer all the other investments to investment No. 1. This is because all the others yield more in total and at least as much in the first period.

Investment No. 2, while clearly more desirable than No. 1, is probably less desirable than No. 3. The total yield of the two investments is the same, but the yield of No. 3 is higher in the first period. Either or both of two (highly probable) circumstances would cause an investor to prefer No. 3 to No. 2. If the investor has the option of investing the returns in the first period in any investment yielding a positive return, he will prefer the investment that has the higher return earlier. Similarily, if for any reason he prefers to consume (or build up his assets) earlier rather than later, he will prefer No. 3, (i.e., if he has a positive time preference). If neither of these conditions holds, he would be indifferent as between the two investments. Under these conditions, No. 4 also presents an alternative of equal desirability with 2 or 3 but if either condition holds he will find No. 4 less desirable than either 2 or 3.

To sum up, the benefit maximizing investor will certainly prefer each of the other investments to No. 1.[25] He would prefer 2 or 3 to No. 4 if reinvestment were possible or if he had a positive time preference and under either or both of these circumstances No. 3 would be the most highly preferred.

The simple value theory — time preference and reinvestment

The simple value theory surveyed earlier suggests simple investment decision rules which take into account time preference, reinvestment, and the productivity of alternative investments. Again, if we assume all markets (including capital markets) are competitive, the results of economic behavior can be accurately forecast, and individuals rationally maximize benefits, then there will tend to be a single rate of interest determined by the time productivity of investment and the willingness of people to save. In the simple value theory the latter is viewed as a function of time preference. Thus assume an individual finds himself in the position where the last dollar saved, plus x interest, yielded $1.10 in the second period. Assume further that his time preference is such that it requires only $1.05 in the next period, at his current level of saving, to equal the satisfaction he obtains for the last dollar consumed in the present period. Such an individual would be induced to increase his saving. He would reduce

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[25] Certainty of return is assumed throughout.

consumption until the satisfaction obtained from the last dollar's worth of consumption today equaled the satisfaction attainable by consuming a larger amount tomorrow (a dollar saved plus interest). In equilibrium the interest rate would equate the productivity of investment and marginal time preference for each individual.

Once an interest rate was established at which borrowing and lending could take place, the individual could always determine the desirability of a specific investment opportunity by considering its "present value." The present value of a stream of returns can be found with the aid of a formula which gives greater weight to near-term as contrasted with longer delayed returns in accordance with the rate of interest.[26] Essentially this is a way of valuing a stream of (not necessarily regular) returns taking reinvestment at a given interest rate into account. The present value is simply the amount which would have to exist now for investment, at the given rate of interest, in order to earn, during the same period, the total of returns which actually accrue over the life of the investment in question. In other words, it is what the investment is worth now, given the going rate of interest. Thus at a 10 percent rate of interest $10 now is worth the same as $11 one period from now.

It is notable that if a given interest rate prevails at which lending and borrowing can take place, present value, as an investment criterion, does not depend upon subjective time preference of the investor. This is because the benefit maximizing investor can always maximize his position by undertaking the investments with the highest present value.

Nevertheless, in the simple value theory the equation of the interest rate with marginal time preference has an important normative significance. If the distribution of income is correct, the interest rate serves as a very important price in a fashion symmetrical with that of the prices of factors of production and of goods and services. It not only represents the marginal productivity of investment in the economy, but it simultaneously expresses the relative marginal valuation which all private individuals taken together put upon present as contrasted with future goods and services.

Discounting and water resources projects

Discounting of returns plays an extremely important role in the planning and evaluation of water resources systems. For hydrological as well as other reasons, costs and benefits vary over the life of the project and a means must be found to evaluate commensurately, projects, and project designs, with varying streams of net benefits. Under the simple value theory, conversion of the net

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[26] For a particularly good brief discussion, see Baumol, *supra* note 8, at 63ff. For a more formal discussion of investment under certainty and some extensions of and exceptions to the present value rule, see Hirschleifer, *On the Theory of the Optimal Investment Decision,* 66 J. Pol. Econ. 329 (1958).

benefits stream to its present value, by the use of *the* rate of interest, serves this function admirably. It simultaneously registers what the productivity of the capital would be if it were left to earn a return in the private sector and provides an expression of the relative marginal valuation of present and future goods. In this scheme of things, the higher the present value the greater the net benefit of the project and all projects are to be expanded until the present value of a further increment is zero.

The ideas just described underlie most (sophisticated) suggestions that the rate on long-term Federal Securities be used for discounting purposes on Federal water projects. It is held that this rate may be taken to represent an approximation of a riskless rate of return equated with the marginal time preference of savers.

Recently much discussion has arisen among economists concerning the significance of several exceptions to the view implied by the simple value theory. They can be classified into two categories:

1. The view that private time preference as reflected in market interest rates does not represent an appropriate rate of social time preference.
2. That capital markets are so imperfect that no single market interest rate can satisfactorily represent opportunities foregone in the private sector.

In the following few pages we briefly spell out some of the major implications of these two points, individually and in combination, for investment criteria.

Let us assume initially that all aspects of the simple value theory hold except than an appropriate social rate of time discount is not given by the market. The possibility of a divergence between private time preference registered by market rates and "socially" optimum distribution of production and consumption through time has often been argued. Some arguments have simply amounted to the assertion that private time preference reflects an irrational myopia which should not enter into Government decisions. Others have argued in a fashion analogous to the external economies framework we described earlier with respect to production. They point out that each individual in an economy would be willing to save a slight additional amount if he could be assured that others would do so. In other words, in order to secure the large effect which an increase in aggregate saving could have on future income, each individual may be willing to give up a small additional amount of consumption.

If a situation of this character occurs, it is fairly obvious that the society is not saving and investing at an optimum rate and that a policy to increase investment (i.e. changes in the monetary-fiscal mix, consumption taxes, subsides to investment etc.) should be undertaken. If for any reason general policies to increase investment are not possible, some "second best"[27] improvement could nevertheless occur if the discrepancy between public and private time preference were taken into consideration in Government investment decisions. However, to do so in the straightforward fashion of applying a lower rate of discount to Government projects than to private projects would tend to produce inefficiency. Assuming, to begin with, that an additional Government water resources project displaces an investment of equal resources cost in the private sector, the result would be investment in a water project with a lower present value than the private alternative if the latter's stream of benefits were discounted at the same rate (representing "social" time preference).

It has consequently been suggested[28] that appropriate policy would be to discount both streams at the social rate and select only those Government projects having a higher present value on that basis.[29] Or, putting the principle differently, a marginal benefit-cost ratio in excess of unity would be required of the projects discounted at the lower social time preference rate. In the extreme case where the marginal water project always displaces an equivalent cost private investment, application of the lower rate would not raise over-all investment above the level which would have occurred if the market rate had been used. The sole effect of the precedure is upon project design. More capital intensive projects with larger construction periods would tend to result from application of the lower rate, reflecting the emphasis on futurity of return which it implies.

It is arguable that the social rate of time discount should be zero—mirroring the fact that Government is virtually immortal and should give no preference to one generation of its citizens as against another. In this case, the sole limit upon Government investments (with some excess of undiscounted benefits over undiscounted costs) would be the productivity of foregone alternatives. Any project would be undertaken, therefore, so long as its present value exceeded the present value of the private alternatives discounted at any rate—however low. Applied to the economy as a whole, rather than just to water projects, this would suggest a policy of fostering every investment with a positive rate of return at any rate of discount however low. Probably few would seriously advocate such a policy because of the large contribution (entailing great amounts of presently foregone consumption) it would make to future income, which in any case would be higher than present income. Thus Government planners

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[27] See Meade, Trade and Welfare (Vol. 2 series on Economic Policy, Oxford University Press, 1955) for a detailed discussion of the "second best" solution.

[28] Eckstein has most fully developed this line of approach. See Eckstein, *supra* note 24.

[29] For a clear exposition and advocacy of this criterion, see Report of Panel of Consultants to the Bureau of the Budget § II, *Standards and Criteria for Formulating and Evaluating Federal Water Resources Developments.* (1961).

could be expected to impose some time discount[30] but its precise level cannot readily be determined.

Another extreme case occurs where financing of projects forecloses only private consumption. In cases of this character the selected rate of social discount would govern since the productivity of alternative investments is not at issue under these circumstances and application of the social rate would result not only in more durable projects but in an actual increase in over-all investments. In mixed cases a weighted average of rates would apply.[31]

The argument that capital markets are too imperfect to permit a single rate of discount for projects, even when there is no reason to suspect a discrepancy between social and private rates of time discount, also imposes complexities upon the choice of an investment criterion. When this situation exists it is necessary to identify specific groups upon whom the impact of the financing falls.[32]

For example, if it is assumed that an agreed upon rate of social discount exists and capital markets are imperfect, the rate of return in the specific sectors from which financing is drawn represents the opportunities foregone. It is to this rate that the (presumably) lower rate of social time discount must be applied in order to establish a minimum marginal benefit-cost ratio. The problem becomes even more complex if capital markets are imperfect and there is no social rate of discount but private preferences to govern investment decisions. In this instance the foregone opportunities again are to be found in the sector from which the financing is drawn but it makes no sense to apply the rate of time preference implied by the interest rates in those sectors. Rather it is to the beneficiaries whose weighting of benefits accruing at different times that it should apply. In other words, both the marginal opportunity cost and the rate of time preference of specific beneficaries must enter the criterion if capital markets are imperfect and if private preferences are to furnish the foundation for the time discount.

With respect to the appropriate discount rate for Government projects, as in regard to other issues of social choice previously discussed, the present state of economic and political knowledge does not permit an ideal solution. Pending additional theoretical and empirical work, the best that can be done is to select a rate of discount which provides some protection against the displacement of more productive alternatives and simultaneously adjusts for lack of indifference concerning the configuration of the time stream of benefits. Perhaps a rate near that of long term Government bonds would serve as well as any.

The simple examples of factors governing investment decisions, as well as

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[30] Plus a time limit or horizon beyond which no returns are counted because of the extreme uncertainity of far distant economic events.

[31] See Report of Panel of Consultants to Bureau of the Budget, *supra* note 29.

[32] Attempts to do this have been made; see Krutilla & Eckstein, *supra* note 11.

the more complex discussions of social time preference and imperfect capital markets, serve once more to illustrate some of the difficult issues of social choice presented by water resources system planning and evaluation. These issues are messy and methods of dealing with them seldom have the ring of concreteness that engineering principles and even essentially meaningless cliches like "full development of water resources" have. Nevertheless considerations of this character are an inevitable accompaniment of planning in an economy where authoritarian dispensations are ruled out.

The Problem of Devising Procedures for Approximating Optimum Systems

As reiterated several times above, substantial expansion in information and the adequacy of concepts is a prerequisite to the design of even approximately optimal systems.[33] Moreover, a great conceptual and computational challenge is presented by the actual process of utilizing data to solve for an optimum design of a system involving the complexities of multi-purpose, multi-unit river basin development.

Substantial and promising efforts have been made to utilize advanced methods of model solution in water resources system design problems. These efforts suggest that the application of simulation and/or modified linear programing techniques hold considerable promise.[34]

Neither one of these methods is intuitively most attractive to economists.

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[33] A distinction should be made between the methods which have been applied to problems of attaining efficiency in system design by Government agencies and formal maximation procedures which are actually aimed at determining *the* optimum system. The optimum system is the one which best fulfills the objective given the constraints—for example, the particular system which produces maximum net benefits. The "conventional" methods have several shortcomings as compared with an ideal procedure. Among these are the consideration of comparatively few alternate designs and the use of physical maximization or rules of thumb, when explicitly economic variables are relevant. An example of the latter is the use of minimum deficits (below design standards) of water for certain system purposes or, in the case of pollution, the use of a conventional design flow. The application of rules of thumb and the economic investigation of only small numbers of alternatives largely arises from the extensive data requirements and the substantial complexity and difficulty of conceptually more satisfactory methods. However, even "conventional" methods are inhibited by data deficiencies of the type outlined earlier.

[34] See, *e.g.*, Heady, *Mathematical Analysis: Models for Quantitative Application in Watershed Planning,* Economics of Watershed Planning (Tolley & Riggs eds. 1961), and in the same volume, Dorfman, *Mathematical Analysis: Design of the Simple Valley Project.* A general outline of the first two years work of the Harvard Water Resources Seminar is found in Mass & Hufschmidt, *Report on the Harvard Program of Research in Water Resources Development,* Resources Development—Frontiers for Research (Univ. Colo. Press 1960). The Maas-Hufschmidt paper presents a particularly lucid exposition of several aspects of optimal system design. For further detailing of the work of the Harvard Resources Seminar see Maas & Hufschmidt *op. cit. supra* note 22.

Economists generally are accustomed to thinking in terms of marginal relationships and incremental changes. Marginal and other closely related methods of maximizing an objective function have several weaknesses, however, in dealing with problems of the type presented by water resources system design. Perhaps the most important is that computations required become very extensive when numerous variables and constraints are involved.

Regardless of the method of solution used, however, the optimum system must meet marginal conditions, i.e. no marginal trade-offs must be possible which improve the situation. With respect to the objective of maximizing net benefits this means that no marginal adjustments must be possible which cause the excess of benefits over costs to rise and still permit the specified constraints to be met. Consequently the method of marginal approximations can be a useful supplement to other methods after they have identified a design near the optimum.

Simulation

Simulation of systems is a very flexible aid to planning. Simulation may take the form of actual physical models (such as a wind-tunnel) but more frequently the essential elements of a system are initially represented symbolically. Thus the significant elements of the relevant processes are translated into a set of status variables, input variables, output variables and relations. These elements are combined into a model which can be used to test the implications for, say, the output variables of a change in the input variables, in the relation of one component to another, or in the initial status of the system.[35]

Thus in a water resources system design problem, by the variation of inputs (dam sizes, generating plant sizes, etc.) and output goals, the results of different system designs and operating procedures (i.e. rules for releasing water, impounding water, etc.) can be tested for, say, the known or a synthetic hydrological record. The results of each of these "runs" may be thought of as ". . . an experiment performed upon the model."[36] The result of a single run is specific and provides no evidence concerning efficiency. Indeed the result may be highly inefficient and in violation of the constraints. If the model is programmed for computer use—the only practical procedure in a problem of this kind—a great number of "runs" can be made very quickly and those which violate constraints, or are inefficient, can be eliminated. By making numerous "runs" and applying sampling techniques, a constrained optimum (net benefit maximizing) system design can be approached. (The closeness of the approach is limited by the range of alternatives, and the operating procedures programmed into the machine, and by the limitations of the sampling procedure.) Random sampling of "runs",

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[35] See Orcutt, *Simulation of Economic Systems,* 50 Am. Econ. Rev. 873 (1960).

[36] See Orcutt, *supra* note 35.

however, has a particularly attractive feature in that it permits probability statements to be made about the results. In other words, it is possible to calculate the probability that the best system in the sample lies within a certain range of the best system in the total population of system designs. Once designs with high net benefits have been established, the random sampling technique can be supplemented by others which permit a closer approximation to *the* optimum system.[37]

A major advantage of simulation is its flexibility and consequent applicability to diverse situations. Its greatest disadvantages are that it does not provide an automatic method for converging on an optimal solution and that the operating procedures must be externally supplied to the machine.

Mathematical programing

Mathematical programing techniques recommend themselves as an alternative to simulation for solving models because they are well adapted to problems involving a number of linear constraints and, under appropriate circumstances, are capable of proceeding directly to the specification of an optimum system.[38] The setup of a linear programing problem is such that it can incorporate values as an integral part of the iterative process leading to the determination of an optimal feasible program.

Among the most difficult obstacles confronting efforts in applying programing techniques to basin planning have been non-linearities in input-output relationships and the incorporation of stochastic elements into the program. Stochastic or "probability" elements are an essential part of the basin planning problem because of the crucial role played by hydrology. In addition, non-linearities resulting from diminishing marginal rates of substitution are probably fairly common in production, including some of the processes resulting in water derivative goods. Furthermore, if the area (say, a large river basin) being analyzed is comparatively large, prices of outputs may not be independent of production.

Price variation can be avoided by dealing with relatively small areas but non-linearity in input-output relationships cannot. The latter difficulties can be dealt with by defining a number of vectors and activities for each product which can then be treated as a production function composed of linear segments.

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[37] See Maass & Hufschmidt, *supra* note 34, who discuss alternative sampling methods, some of their merits and demerits, and the benefits of using them in combination.

[38] The "dual" of the solution to a linear programming problem imputes marginal values to the effective constraints. These express the opportunity cost of the constraint in terms of the objective function. For example, the marginal net (measurable) benefit foregone in order to maintain four (4) ppm dissolved oxygen in the stream. Simulation could be used to test the cost sensitivity of constraints by successive optimizing simulation procedures each using a different value for a constraint.

Other approaches have also been outlined, including some capable of dealing with simple price output dependency relationships.[39] Also, promising steps toward introducing stochastic elements into the mathematical programming of water resource development systems have been made.[40] All of these extensions and modifications of the basic model, however, lead to (often greatly) increased computational complexities.

Application of simulation and linear programming techniques

While the procedures mentioned in this section are promising and powerful methodologies for discovering water resource system designs which best fulfill a stated economic objective, their application has thus far been predominantly to simplified prototype systems with simple objective functions. Moreover, they have not comprehended water quality within the analysis. It is important that work on these procedures continue in order to expand their applicability to actual design problems.

On the other hand, development of empirical information and improved understanding of the nature of intelligent social choice is fundamental to any marked improvement of the decision making process in the water resources field. Thus, for example, choice of a rate of discount is a continuing issue among professional economists. The range of opinion is so wide that at one extreme almost all planned Federal projects would be eliminated by the rate considered appropriate.[41] This is the kind of difficulty which improved technique, of course, cannot ameliorate. Moreover, decision models can only help to make consistent choices among stated alternatives given a criterion—they cannot generate alternatives. The correct identification of significant alternatives is at least as important as the use of superior techniques for choosing among them. Furthermore, the level of precision attained in the identification and forecasting of physical and economic relationships limits the precision of the solution which even the best methodology can produce. While in many ways the techniques and information for Government decisions with respect to water resources are superior to those for some other areas, as indicated earlier the field by no means consists of an array of closed issues.

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[39] See references in Heady, *supra* note 34, at 212. Even cases of decreasing cost which are probably relevant to basin planning problems discussed above may be amenable to solution using programming techniques. Markowitz & Manne, *On the Solution of Discrete Programming Problems,* 25 Econometrica 84 (1957).

[40] See Maas & Hufschmidt, *supra* note 34. Further information on developments in the handling of true, nonlinearities and stochastic elements in programming procedures will be found in Maas & Hufschmidt, Design of Water Resources System. See note 22 *supra.*

[41] See Hirschleifer, De Haven & Milliman, Water Supply, Economics, Technology, and Policy (1960).

Implications of Economic Analysis in Planning and Administrative Structures for Water Resources Development

Relationships of complementarity and competitiveness in a basin (use of water at an upstream point reducing the quantity and/or quality available for the same or another purpose downstream, flow-augmentation for navigation simultaneously abating pollution, etc.) strongly indicate the desirability of integrated multi-purpose planning for the areas within which technical and economic interdependency is significantly large. In other words, planning aimed at maximizing an objective function must take account of all significant opportunity costs (including those internal to the plan) and all significant relationships of complementarity among the planned outputs. These considerations, which on a general level are fairly obvious, have led to frequent proposals for comprehensive integrated basinwide planning and, to a degree, to actual planning on that basis.

Development of a comprehensive multi-purpose planning approach

Traditionally, water resources planning has been a responsibility divided among several levels of Government and numerous Government agencies. Often this division has not had a clear-cut rationale either in terms of the area comprehended or scope in terms of project purposes. Increasingly, however, the idea of comprehensive multiple-purpose planning is coming to hold sway.

"In the public debate of water policy issues over the past two decades, three concepts have become accepted: (1) that the Federal Government has a major responsibility for river basin development; (2) that water resources projects should be designed to serve multiple purposes; and (3) that the river basin should be the unit for planning, development, and management of water resources programs. Yet, opinion continues to differ sharply as to what system of organization is best for Federal river basin activities."[42]

Water quality control offers an example of the gradual evolution of the planning concept and an excellent example of the numerous (but for the most part, not fully integrated) approaches to planning which have developed. Pollution control planning and practice has traditionally been the province of the States but even so, not all States have passed comprehensive pollution control legislation. Justification for this allocation of responsibility was clear-cut during a time when sources of pollution were scattered, the character of most pollutants was not persistent, and consequent damages, if any, were confined to small areas. As the pollution loading of streams rose, external diseconomies imposed became more significant and frequent interstate problems developed, the

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[42] Fox & Picken, The Upstream-Downstream Controversy in the Arkansas-White-Red Basins Survey, The Inter-University Case Program (Univ. Ala. Press 1960).

Federal Government and interstate agencies assumed increasing roles in pollution control.[43]

National policy in the development of water resources is to a large degree an outgrowth of the Jeffersonian ideal of independent freeholders and was developed under the influence of the laissez faire philosophy. Federal activities in the water resource development field were designed initially to facilitate private use of water and were not undertaken until it became clear that non-Federal interests alone could not adequately develop and maintain the water resources needed.

The evolution of Federal planning concepts can be traced from an initial concern for navigation followed in turn by a national interest in western land reclamation through irrigation activities, the concern over flood damages and more recently in the consideration of recreation and pollution control activities in river basin planning.[44] The post-war period has seen the creation of a number of Federal interagency committees to coordinate the water resource development programs of the States and Federal agencies within major river basins. Also since the war, the Delaware Basin Survey and the Potomac Basin Survey, carried out under the direction of the Corps of Engineers, have adhered to the concept of comprehensive multi-purpose planning.[45]

Moreover, Federal Government participation in comprehensive planning for water resources development, including water pollution control, is expressed in the creation of U.S. Study Commissions, two of which have been in operation, one in the southeast, and the other in Texas. Participants in these Commissions were drawn from the Federal agencies and from the States involved. The Commission's responsibilities were to plan comprehensively in cooperation with the Federal, State, and local agencies and their powers were recommendatory only.

Perhaps the most ambitious effort of the Federal Government in water quality management and development is reflected in the activities currently under way by the Public Health Service of the Department of Health, Education, and Welfare. Under the authority contained in the Federal Water Pollution Con-

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[43] The Water Pollution Control Act of 1948 was the first comprehensive federal legislation in this field. The powers in the 1948 Act were extended and strengthened by the Federal Water Pollution Control Act of 1956 and the Federal Water Pollution Control Act amendments of 1961. The most important feature of the latter-mentioned legislation extends federal pollution abatement jurisdiction to all navigable waters, including intrastate and coastal waters.

[44] For a particularly good discussion of the evolution of federal planning concepts, refer to Gertel, *Economic Elements of National and Regional Planning for Development and Use of Water Resources,* Proceedings of the Missouri Basin Research and Development Council (Kansas City, Kan. 1959).

[45] For a discussion of the evolution of the comprehensive planning concept in the Potomac Survey, refer to Nobe, *Another Look at River Basin Planning,* 16 J. Soil & Water Conservation 5 (1961).

trol Act of 1956, the Public Health Service, in conjunction with the several States, is engaged in a number of water quality enforcement actions involving interstate streams.[46]

In addition, section 2 of the Act requires the Public Health Service to assume leadership in the preparation of comprehensive water development and pollution control programs in interstate streams and their tributaries.[47] The surveys are being carried out by major river basins. Long range planning studies, initiated under various Congressional acts including both Section 2 and the enforcement authority of Public Law 660, are currently underway in the Arkansas-White-Red, Colorado, Columbia, and the Great Lakes-Illinois River basins. Similar studies have been initiated for the Ohio and the Chesapeake Bay Basins, and eventually it is anticipated that water quality control plans will be developed and kept up to date for all the major river basins in the nation.

Actually predating the more compresensive Federal efforts in the pollution field (and in general water resources planning) were several interstate compacts devoted exclusively to pollution problems. At the present time there are seven interstate agencies recognized by the U.S. Public Health Service as engaged in water pollution control.[48] These compacts differ in detail but in general are devoted to the stimulation and coordination of pollution control efforts in the municipalities and industries of the States. Enforcement powers exist but are used primarily at the request of the States. A minimum of incursion on State sovereignty is involved and the Commissions created by the compacts do not directly participate in the construction, operation or financing of treatment works.

The Interstate-Federal Compact for the Delaware Basin goes a long step further in granting powers to an Interstate Commission in which the Federal Government for the first time is an active participant. In general it has created a

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[46] Comprehensive planning activities can be carried out in conjunction with these enforcement actions. The long-range planning phase of the Colorado River Basin Water Quality Control Project is an example.

[47] The authority for the preparation of comprehensive water development and pollution control programs rests in Section 2 of the Federal Water Pollution Control Act of 1956, 70 Stat. 498 (1956), 33 U.S.C. § 466a (1957). The Act states: "The Surgeon General shall after careful investigations and in cooperation with other Federal agencies, with State water pollution control agencies and interstate agencies, and with the municipalities and industries involved, prepare or develop comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries thereof and improving the sanitary conditions of surface and underground waters. In the development of such comprehensive programs due regard shall be given to the improvements which are necessary to conserve such waters for public water supplies, propagation of fish and aquatic life and wildlife, recreational purposes, and agricultural, industrial, and other legitimate uses."

[48] Cleary, *The Needs of Obligations of Interstate Agencies,* (A paper presented at the National Conference on Water Pollution, U.S. Dep't of Health, Education, & Welfare, 1961).

strong, integrated, regional agency empowered to do a total job of water resources administration. In regard to pollution, the Commission was given, among others, the power to "undertake investigations and surveys, and acquire, construct, operate and maintain projects to control potential pollution and to abate or dilute existing pollution of the water resources of the basin."[49] Its powers with respect to other purposes of water resources planning are of similar scope.

Suggestions for Improvement

Much of what has been said in this article in a general way strongly supports regional water resources planning, utilizing analytical methods aimed at best realizing social objectives. Responsibility by a single regional authority (not necessarily of the Interstate Compact variety) has considerable intuitive appeal in this regard. Moreover, recent studies of the less far-reaching techniques which have been used in an effort to achieve coordination among the various existing planning agencies have tended to emphasize their deficiencies.[50]

Suggestions for reform have grown out of these negative judgments concerning the effectiveness of existing approaches. One analyst has suggested, for example: "Two long-term approaches remain. One would require consolidation of Federal water resource functions at the top, and their administrative decentralization to major regions or river basins. The other approach is the establishment of regional water-resources agencies either Federal, as in the TVA, or by interstate compacts in which the Federal Government is a partner, as in the Delaware Basin. In some cases, such as in California and Texas, a regional agency can be the creation of a single state. These two approaches need not be mutually exclusive. It is possible to visualize them as mutually supporting."[51]

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[49] Water Resources Association of the Delaware River Basin Special Bull. (1961). In international experience, Germany and Britain have taken two very different administrative routes in coping with pollution. The powers of the German-River-Basin Associations are not unlike those of the Delaware Compact. "[T]he legal structure of the (German river-basin) Association was designed to let it investigate, plan, design construct, operate, maintain, repair and replace all necessary installations or regulation works for the abatement of pollution in a given river basin and for the general management of its waters." Fair, *Pollution Abatement in the Ruhr Valley of Western Germany,* Resources for the Future Forum on Comparative Resources Policy and Administration 8 (1961).

In contrast, the British river boards have much more limited powers. These boards investigate and report on pollution, issue permits for new outfalls and can (but have not yet) by the passage of bylaws to the Prevention of Pollution Act of 1951 set standards for effluents. They do not, however, construct or operate abatement projects. Klein, *Legal Aspects of River Pollution,* Aspects of River Pollution, ch. 2 (1957).

[50] Martin, River Basin Administration and the Delaware (Syracuse Univ. Press, 1960); Fox & Picken, *supra* note 42.

[51] Hufschmidt, *And Not a Drop to Drink: Water Resources Planning and Administration,* 21 Pub. Admin. Rev. 81, 88-89 (1961).

To recapitulate, current practice and proposals present a wide array of procedures aimed at coordinating planning both with respect to areas tied together by technical interdependency and in regard to the multiple-purpose character of development. A considerable body of opinion has begun to develop, however, which sees a number of weaknesses in existing approaches which seek to consolidate numerous (and often conflicting) agency and sectional interests and which favors thoroughly integrated regional approaches such as those outlined in the above quotation. This reflects an effort to devise administrative forms which correspond with the function of planning agencies in the economic-social decision process.

The different methods for producing degrees of coordination and integration affect variables which are not completely amenable to economic ratiocination, however, (and those who have suggested new approaches are not unaware of this). They vary in the degree to which they maintain traditional Federal, State, and local power relationships. They vary in impact upon the regional distribution of political power. They vary in the degree of modification of the roles of different Federal agencies in water resources development. In choosing among them, careful consideration of the consistency between administrative form and economic function can provide valuable guidance. The range of questions having to do with the provision of appropriate planning and administrative structures for effective and efficient water resources development is certainly among the most important and research worthy in the related fields of economics and political science.