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Residuals - Environmental Quality Management: A Framework for Policy Analysis

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RESIDUALS—ENVIRONMENTAL QUALITY MANAGEMENT: A FRAMEWORK FOR POLICY ANALYSIS†

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For a considerable time, economists, ecologists, engineers, politicians, and even the members of the silent majority who think seriously about such things as the quality of our environment have recognized that the external diseconomies caused by the discharge of wastes or residuals into our environment cannot be efficiently reduced or managed by considering the various environmental media—air, land and water—separately. They also realized that many environmental quality management alternatives are overlooked by accepting as fixed the quantities and sources of residuals that are released into our environment.

In spite of the rather widespread recognition of the strong interrelationships between the production and consumption of goods and services, residuals production, modification, treatment and disposal, and the quality of our air, land and water, only relatively recently have attempts been made to develop management techniques for defining and evaluating the effects on environmental quality of various residuals management policies. Except in a very general framework, relatively few have examined the environmental consequences of changing the manner and amounts of goods and services produced and consumed, the type and quantity of residuals treatment and modification, and the receptor protection measures that can be implemented for the purpose of reducing residual damages.

Some beginnings have been made toward structuring comprehensive environmental quality models for use as tools in defining and evaluating specific residuals management policy alternatives.[1] Progress to date provides only a framework. Nevertheless, it is a beginning and there is reason to believe that eventually some very useful tools will be available for assisting in the formulation of improved environmental quality programs and policies. It must be em-

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1. Russell and Spofford, *A Quantitative Framework for Residuals-Environmental Quality Management,* Natural Resource Systems Models in Decision Making 66 (1970).

phasized, however, that there are many difficulties and problems to overcome before such models become truly comprehensive tools for public policy decisions.

Our environmental quality is intimately related to our standard of living. It has been suggested that if we are really serious about improving the quality of our environment we must learn to produce and consume fewer goods and services such as cars, non-returnable containers, television sets, electric can openers, and even people! It involves much more than spending a few extra dollars for quieter cars, jets and air conditioners, more efficient waste treatment facilities, and larger land disposal sites.

Any significant improvement in our environmental quality will require some social and political adjustments. It would seem that these non-economic as well as economic adjustment costs (if they can be separated) must be considered in any analysis of residuals management policies if in fact comprehensive residuals management analyses are to provide useful information for policy decisions. The ultimate resolution of such public policy issues as environmental quality may well rest as much, if not more, on political feasibility arguments as on rational economic debate.

In addition to the problems of defining political and economic feasibility, let alone optimality, there are numerous informational limitations that currently restrict the formulation of truly comprehensive environmental quality management models. We know relatively little, for example, about the transmission of noise in an urban area, or about the ecological change that results, if any, from various industrial chemicals released into our rivers and lakes. We have been relatively unsuccessful in quantifying in any politically meaningful way just what the benefits or losses are associated with certain environmental quality parameters. Yet it is these and other economic, political and informational limitations that motivate many to structure both partial and comprehensive environmental quality models. Through such models analyses have been performed to obtain some estimate of the kinds of information and assumptions that are the most important and essential to the process of reaching desirable public policy decisions. Obviously as these models are further improved they will provide increasingly useful information to the decision making process.

A CONCEPTUAL ENVIRONMENTAL QUALITY MODEL

In order to have some basis for discussing environmental quality models and their contribution to public policy decisions, a very general and conceptual model will be structured. Only the functional form of many of the economic and technologic functions will be presented. The specific forms of many of these functions, in so far as we know anything about them, are described in the appropriate current literature.[2]

The conceptual environmental quality model that follows represents a static, partial equilibrium analysis. Not every activity of the region whose quality is of concern is included in the model. We assume that we know or can obtain everything we would like to have in the way of production functions and benefit, cost and damage functions. Explicit in the model is the existence of a politically viable institutional or governmental body responsible, and having the authority for the management of environmental quality. This body can apply both legal and economic measures for the purpose of improving environmental quality. It can set effluent standards and it can tax or subsidize, as necessary, to finance construction grants programs for facilities that modify residuals and/or the assimilative capacity of the environment (e.g. through flow augmentation and in-stream aeration). Finally, this environmental quality authority must pay its own administrative costs and at the same time insure that no individual's net welfare is reduced because of its environmental quality management program.

Even though some of these assumptions will be modified later, it is sometimes instructive to play "what if" games such as this. A knowledge of the kinds of information and institutional relationships that might be needed to achieve both a better standard of living and a better quality of our environment, together with estimates of what that standard and quality might be, could well provide powerful incentives for changing the way things are done today. At least it can point out where additional data and research are required and what institutional changes might be considered. Later we must discuss how this model and similar analyses can be made more effective in assisting the political process, but for now let us proceed with the basic framework of this residuals management model.

Figure 1 illustrates in a very general way, the system in which environmental (natural), human and material resources are transformed, through production and consumption processes, into goods and services, material by-products, and wastes or residuals. The residuals are usually released into our environment, either before or after some modification or treatment. They then may be partially assimilated and modified by natural or artificial processes within the

2. *See, e.g.*, A. Kneese and B. Bower, Managing Water Quality: Economics, Technology, and Institutions 164 (1968); R. Dorfman, H. Jacoby, H. Thomas, *et al.*, Models for Managing Regional Water Quality, forthcoming.

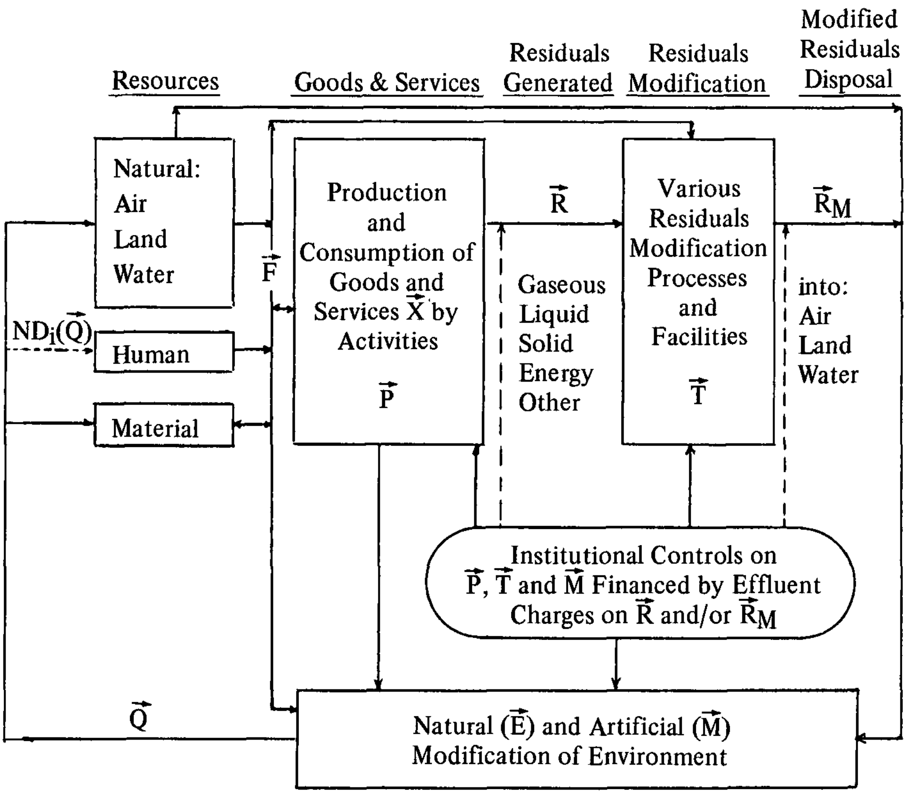

FIGURE 1
Residuals–Environmental Quality System

environment. Those of us living in the waste receiving environment may be affected by these residuals. The extent to which we are adversely affected depends on our location, experience, physical and mental health, education and numerous other factors. In some cases there exist protective measures that we can use to reduce these adverse effects.

Society's demand for an increased standard of living is the driving force behind the production and consumption of goods and services. Because both air and water (and occasionally land) have been free goods, the release of residuals into these media has reduced the cost of producing certain goods and services, often to the benefit of both the producer and consumer. Yet those whose environmental quality is decreased because of the production of these residuals may experience a loss in welfare. If there exists an institutional means whereby those experiencing an increase in welfare can allocate part of that increase to those whose welfare has been reduced, then it is possible to define, in the Pareto sense, an optimum environmental quality.

Referring to Figure 1, we describe $\vec{X}$ as the vector of all the goods and services produced from the vector of factor inputs $\vec{F}$, i.e., the natural, material and human resources used in production and consumption. Each vector of goods and services can be produced by a variety of alternative processes k. Each production alternative has associated with it a cost $\vec{C}_k$ $(F_k,\vec{P}_k,\vec{X}_k)$. This cost depends on the scale of the production processes $\vec{P}_k$, on the production inputs $\vec{F}_k$, and on the vector of goods and services $\vec{X}_k$ produced by that k^{th} alternative. The production of $\vec{X}$ by processes $\vec{P}$ using input factors $\vec{F}$ results in a vector of residuals, $\vec{R}=R(\vec{F},\vec{P},\vec{X})$. An essential part of the comprehensive residuals management problem involves the selection of the input factors $\vec{F}$, the goods and services $\vec{X}$ and the production processes $\vec{P}$ which in part determine the vector of residuals produced, $\vec{R}$.

In order to decrease the damages that could result from the production of the residuals $\vec{R}$, there exist various means for 1) modifying the residuals at their sources (i.e. within the production and consumption sector); 2) modifying the residuals released from the production and consumption sector in collective (regional or municipal) modification or treatment facilities; 3) increasing the assimilative capacity of the environment; and 4) protecting the individual from these partially treated and assimilated residuals that he experiences in his environment. Each alternative may require natural, human and material resources, $\vec{F}$, and in turn may generate its own residuals.

The modification of residuals, through by-product production, materials recovery and reclamation, if any, within the production and consumption sector we can denote as part of the processes $\vec{P}$. The scale of each collective modification process alternative j we will denote as $\vec{T}_j$, costing $C_j(\vec{F}_j,\vec{T}_j,\vec{R}_j)$, where for each process alternative j, $\vec{F}_j$ is that portion of resources used and $\vec{R}_j$ is that portion of the generated residuals $\vec{R}$ modified. The output from collective modification facilities is another vector of modified residuals $\vec{R}_M$ that is a function of the original vector of residuals $\vec{R}$ and those added residuals that are produced by the modification processes themselves. Thus $\vec{R}_M=R_M(\vec{F},\vec{R},\vec{T})$.

Next we must describe the change in each component of the residuals vector $\vec{R}_M$ as it is affected by the environment. The degree of residuals modification or assimilation, if any, between each residual source or collective modification facility and each individual or receptor is a function of numerous environmental factors, $\vec{E}$. In addition, there may also be numerous artificial methods ℓ, of scale $\vec{M}_\ell$ and requiring resources $\vec{F}_\ell$, to increase the natural environmental residuals assimilative capacity. These artificial methods cost $C_\ell(\vec{F}_\ell,\vec{M}_\ell,\vec{E},\vec{R}_M)$. The application of artificial means $\vec{M}$ together with the natural assimilative capacity $\vec{E}$ results in a modified residuals or quality vector $\vec{Q}=Q(\vec{F},\vec{R}_M,\vec{E},\vec{M})$. Again $\vec{Q}$ includes those residuals that may have been produced by the methods $\vec{M}$ used for artificially increasing the environmental assimilative capacity. Combining some of the above relationships we can write a general production function for predicting the vector of residuals or quality $\vec{Q}$ at all receptor sites: $\vec{Q}=Q(R_M(\vec{F},R(\vec{F},\vec{P},\vec{X}),\vec{T})\vec{F},\vec{E},\vec{M})$, or simply $\vec{Q}=Q(\vec{F},\vec{P},\vec{X},\vec{T},\vec{E},\vec{M})$.

At each receptor site there may exist various protective devices that reduce the damages caused by the remaining residuals $\vec{Q}$. We will assume here that each individual, or groups of individuals, i, will employ protective devices (e.g. ear plugs or water treatment plants) only to the extent that they minimize the sum of the damages incurred by the remaining residuals and the cost of the protection. This minimum sum will be termed net damages $ND_i(\vec{Q})$. This net damage function may be positive, indicating a loss in individual welfare, or negative, indicating a gain in welfare. (Some individuals may enjoy increased benefits from a particular residuals vector $\vec{Q}$ in the environment, e.g., heat discharge which improves fishing.)

Before proceeding to the construction of a model of this residual-environmental quality system we need to make some assumptions about how the system might be managed. Let us assume, for the purpose of illustration, that the net damages $ND_i(\vec{Q})$ can be measured in monetary terms and that the regional environmental quality agency has the power to charge or subsidize each individual, or group of individuals, based on the residuals they produce in order to maintain some desired or optimal level of environmental quality. The purpose of the model will be to estimate just what that optimal quality level might be, i.e., the level that maximizes total net welfare, and how it might be achieved.

For each individual or group i, within the region of interest, let $B_i(\vec{X})$ be his gross benefit associated with the vector of goods and services $\vec{X}$ produced and consumed, $C_i(\vec{X})$ his cost, $G_i(\vec{R}_i,\vec{R}_{Mi})$ his effluent charge ($G_i \geq 0$) or subsidy ($G_i \leq 0$) based on his residuals $\vec{R}_i$ and $\vec{R}_{Mi}$, and $ND_i(\vec{Q})$ his loss or damage resulting from a vector of environmental residuals $\vec{Q}$. Given this notation we can write the total net welfare objective as follows:

$$\text{Maximize} \quad \sum_i [B_i(\vec{X}) - C_i(\vec{X}) - G_i(\vec{R}_i, \vec{R}_{Mi}) - ND_i(\vec{Q})] \qquad (1.0)$$

This objective must be constrained in a number of ways. We need to define the technological relationships between the environmental factors, $\vec{E}$, the various decision variables, $\vec{F},\vec{P},\vec{X},\vec{T}$ and $\vec{M}$, and the level of resulting residuals $\vec{Q}$. As was previously defined, this relationship, in functional form, is simply

$$\vec{Q}=Q(\vec{F},\vec{P},\vec{X},\vec{T},\vec{E},\vec{M}) \quad (1.1)$$

Any new environmental quality program should insure that each individual's net benefit $NB_i(X,R,R_M,Q)$, after the implementation of the environmental quality management program, shall be no less than what it was before the implementation or change, NB_i. Thus for each individual i:

$$NB_i(\vec{X},\vec{R},\vec{R}_M,\vec{Q}) = B_i(\vec{X}) - C_i(\vec{X}) - G_i(\vec{R}_i,\vec{R}_{Mi}) - ND_i(\vec{Q}) \geq NB_i^{\circ} \quad (1.2)$$

Any new environmental quality program should also be self sustaining. We can insure this by having the total cost of all residuals modification $\vec{T}$ and environmental residuals modification programs $\vec{M}$, plus the cost of program administration, $C_g(\vec{R},\vec{R}_M,\vec{Q})$, be no greater than the net charges collected.

$$\sum_i G_i(\vec{R}_i,\vec{R}_{Mi}) \geq C_g(\vec{R},\vec{R}_M,\vec{Q}) + \sum_j C_j(\vec{F}_j,\vec{T}_j,\vec{R}_j) + \sum_\ell C_\ell(\vec{F}_\ell,\vec{M}_\ell,\vec{E},\vec{R}_M) \quad (1.3)$$

In addition it is reasonable to assume that the total cost of producing any vector of goods and services $\vec{X}$ will equal the amount paid for them by all individuals.

$$\sum_k C_k(\vec{F}_k,\vec{P}_k,\vec{X}_k) = \sum_i C_i(\vec{X}) \quad (1.4)$$

This completes our general and conceptual model. If the assumptions on which it is based are valid, and if satisfactory production, cost benefit and damage functions could be defined, the program suggested by the solution of this model would provide a possible framework for recommending changes in our present environmental quality policies. The two set of curves in Figure 2 illustrate what might happen if such a program were implemented for a system consisting of only two individuals holding $\vec{X}$ and $\vec{R}$ constant at $\vec{X}^{\circ}$ and $\vec{R}^{\circ}$. The upper set of curves are the net welfare functions of the two individuals as only $\vec{Q}$ varies from what now exists, namely $\vec{Q}^{\circ}$. Without any transfer of benefits from individual 1 to individual 2, the goods and services produced and consumed, $\vec{X}$, the residuals

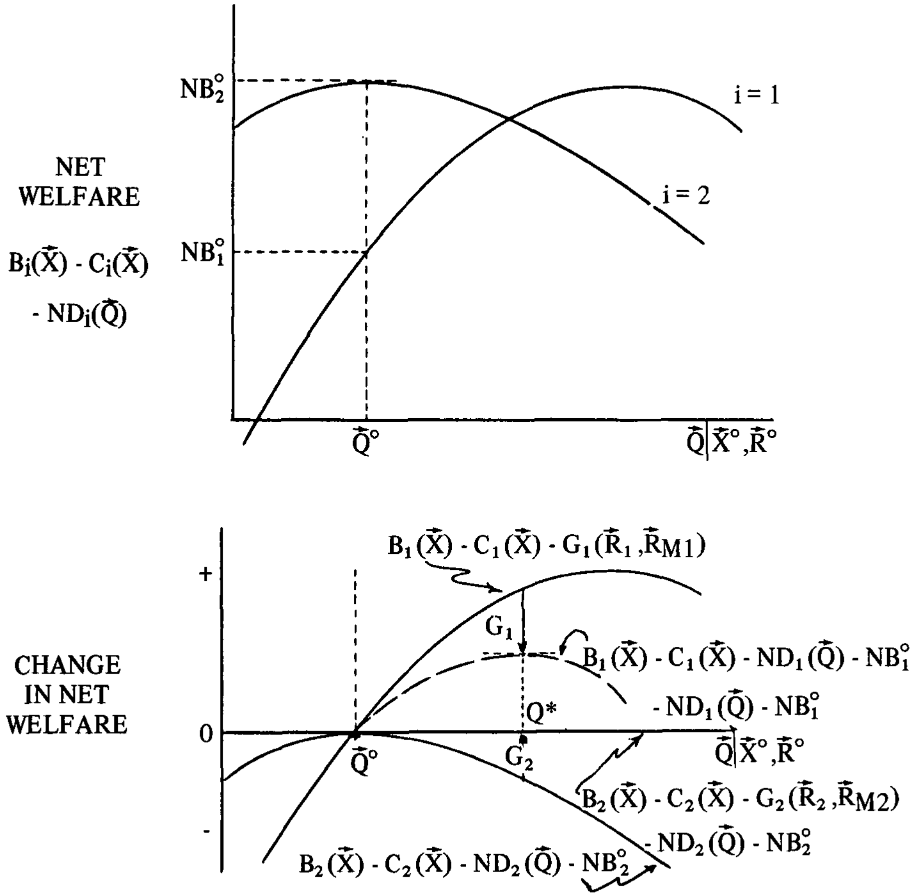

FIGURE 2
Net Welfare Before And After A Residuals–Environmental Quality Program

produced, $\vec{R}$ and the resulting environmental quality $\vec{Q}$ equal $\vec{X}^\circ$, $\vec{R}^\circ$ and $\vec{Q}^\circ$ respectively. Assume that this situation exists before the establishment of any environmental quality control program.

The highest and lowest set of curves are identical to the respective upper set of curves shifted vertically so that they intersect the abscissa at $\vec{Q}^\circ$. The ordinate of the lower set of curves now represents the *net* change in welfare given a change in $\vec{Q}$ from $\vec{Q}^\circ$ holding $\vec{X}^\circ$ and $\vec{R}^\circ$ constant. The establishment of an environmental quality authority would have the effect of keeping the net welfare of individual 2 the same as it was at $\vec{Q}^\circ$, namely along the abscissa, through the use of subsidy G_2 to individual 2 and increasing the net welfare of individual 1 through an effluent charge G_1. The difference between the effluent charge G_1 and the effluent subsidy G_2 is the cost of program administration, collective residuals modification and environmental modification as specified by constraint (1.3). In this case the environmental quality increases from $\vec{Q}^{\circ}$ to $\vec{Q}^{*}$ for a net gain in total welfare and no loss in either individual's welfare. However, if in addition to economic incentives in the form of effluent charges, legal constraints in the form of effluent or quality standards were imposed restricting the range of $\vec{P}$,$\vec{T}$ or $\vec{M}$, there may be some loss in individual welfare.

PROBLEMS AND APPROACHES FOR SOLUTION

Present knowledge prevents us from specifying in detail many of the functions assumed by this conceptual model and solving it in its present form. There are two main reasons for this: computational and informational. In addition to these two problems, there is a third, involving implementation of policy. This is the problem of political feasibility. Let us briefly examine these three problems, using the model just structured as a means of illustration.

A. Computational Problems

One of the main features illustrated by the above conceptual model is the nonlinear aspect of this residuals management problem. The state-of-the-art in mathematical programming methods for solving large nonlinear optimization problems is such that those of us who are interested in structuring models that can be solved relatively efficiently by other than highly skilled mathematical and computer programmers, and in having solutions that will include a detailed analysis of the sensitivity of the solution to changes in important variables and parameters, usually resort to either linear or dynamic programming whenever possible. For the residuals management problem the multiplicity of state variables, i.e., each good or service produced and consumed and each residual modified, suggests a dimensionality problem that would almost always preclude solution by dynamic programming. Thus we are often limited, in a practical sense, to algorithms for solving linear programming problems. However, as anyone who has struggled with large linear programming problems knows, what is advertised and what is possible are often several orders of magnitude apart. Because of the nonlinear nature of many residuals management models some assumptions and mathematical tricks are required in order to adapt them to solution by linear programming techniques.

Referring to the conceptual model presented above, a main source of nonlinearity stems from including as unknowns or decision variables both the residuals $\vec{R}$ resulting from the production and consumption of goods and services and the amount of residuals treatment and environmental modification. In other words the production function for environmental quality $\vec{Q}=Q(\vec{F},\vec{P},\vec{X},\vec{T},\vec{E},\vec{M})$ is nonlinear in $\vec{R}$ and $\vec{T}$ and $\vec{M}$. Some of this nonlinearity can be eliminated by dividing the model in two parts, namely an interindustry model and an environmental model and solving each part separately.[3] In the environmental quality model the variables $\vec{F},\vec{P},\vec{X}$ and $\vec{R}$ are held constant. The objective of the environmental quality model is to find the particular values of $\vec{T}$ and $\vec{M}$ that minimize the total net loss associated with the quality of the environment $\vec{Q}$, as affected by residuals discharge, i.e.

$$\text{Minimize} \quad \sum_i [ND_i(\vec{Q}) + G_i(R_i,R_{Mi})]$$

The interindustry portion of this conceptual model would have as its objective the maximization of benefits $B_i(\vec{X})$ less the costs $C_i(\vec{X})$ of goods and services and the costs $G_i(\vec{R}_i,\vec{R}_{Mi})$ of maintaining environmental quality $\vec{Q}$.

$$\text{Maximize} \quad \sum_i [B_i(\vec{X}) - C_i(\vec{X}) - G_i(\vec{R}i,\vec{R}_{Mi})]$$

The residuals modification $\vec{T}$ and environmental modification $\vec{M}$ variables are held constant, as determined from the environmental quality model.

The constraints of both models would include those previously discussed. Once the interindustry model is solved, the variables $\vec{F},\vec{X},\vec{P}$ and $\vec{R}$, can then be fixed and the environmental quality model solved again to obtain new estimates of the environmental quality.

There are, of course, some additional nonlinearities inherent in residuals management models. Some result from the inclusion of alternatives for environmental modification. Flow augmentation for improved water quality, for example, involves an extremely nonlinear set of production function constraints. In relatively simple cases an approximation technique may suffice, depending on the accuracy of other parameters and functions in the model. Artificial in-stream aeration is another alternative to environmental modification, which, in this case, results in a nonlinear objective function. Most residuals modification processes—materials recovery by-product production, treatment—involve economies of scale. Further, most treatment processes remove varying amounts of different residuals

3. *See, e.g., supra* note 1.

components and produce varying amounts of different residuals, depending on the efficiency of the processes themselves. Examples include the simultaneous removal of carbonaceous BOD, nitrogenous BOD and suspended sediment, and the production of sludge as well as wastewater effluent. These "joint product" effects often preclude the usefulness of techniques for linearizing segments of convex cost and damage functions or concave benefit functions for inclusion in linear programming models.

Finally, two more computational problems should be mentioned. The first is the stochastic nature of the residuals released into the environment as well as the stochastic nature of the assimilative capacity of our environment. Explicit consideration of these variabilities will no doubt considerably increase the size of these already large models. The second problem is, in fact, the size of any realistic residuals management model, even if it were deterministic, i.e. did not explicitly consider the stochastic elements. Even if we had all the information we desired, the most simple comprehensive environmental quality models, such as those developed in this paper, tax both the analytical and computational abilities of our present day solution algorithms and digital computer software systems.

B. Informational Problems

One of the characteristics of a systems analysis approach to problem solving is the requirement for being very explicit about the assumptions being made and the functions being used to predict quality, benefits, costs and damages. There is much we still have to learn about our residuals environmental quality system. We have problems even measuring environmental quality as well as in the quantification of resulting damages, if any. At present our knowledge of production functions, relating the input of resources to the production and consumption of goods and services and to the generation of residuals, is indeed meager. We know very little about the time and spatial pattern of residuals concentrations in the environment. The capacity of the environment to transmit, diffuse and assimilate residuals is not constant over time, yet a knowledge of the residuals concentration over time as well as space has important implications for decision making processes.[4] Further, we know very little about many of the interactions that may take place among different residuals released into the environment and between those residuals and the environmental media and those organisms living in it. Even if it were possible to determine the distribution, in time as well as in

4. *See* J. Carlson, *How much environmental quality should we buy?,* 6 Industrial Water Engineering 20 (1969).

space, of environmental quality resulting from a specified temporal and spacial pattern of residuals discharge, the resulting short and long run damages have not been quantified even for a single residual, let alone for multiple residuals.

Measuring the social benefits or the willingness to pay for certain vectors of goods and services is also difficult if not practically impossible in some cases. Yet the conceptual model presented above requires most of this knowledge if it is to yield meaningful information.

Probably one of the most troublesome informational and conceptual problems, that is often governed by computational limitations, is what to include within the model. If it is a region that is to be managed for environmental quality, how big should the region be; how many political districts and activities should be included within the residuals management system and which variables should be considered exogenous or outside of the system? The answers to these questions are not always easily obtained. They will largely depend on what is, or what may be, politically feasible for an environmental quality management agency to do. The importance of this aspect of systems analysis for deriving useful public policy information brings us to the third problem stated above, namely implementation. This warrants a few additional comments on the application of residuals management models in a political environment, the quality of which may vary considerably!

RESIDUALS MANAGEMENT AND PUBLIC POLICY

There is considerable debate today, in and out of government, over the extent to which we should use our environment to assimilate various residuals. Since our environment is essentially a common property resource,[5] its quality is and will continue to be largely a matter of public policy and of public or collective choice. To be useful, residuals management (and other) models for public policy decisions require a recognition of political constraints, political objectives, and—if you will—political opportunity costs, as well as the economic, ecological and technological ones. A sense of political feasibility and when and how to extend this feasibility is an essential attribute of successful public policy analysts.

If residuals management models are to be successful in influencing decisions they must fit into the political process and at the same time

5. *See* the discussion of this concept in A. V. Kneese and R. C. d'Arge, Pervasive External Costs and the Response of Society, *The Analysis and Evaluation of Public Expenditures: The PPB System,* A Compendium of Papers Submitted to the Subcommittee on Economy in Government of the Joint Economic Committee, 91 Cong., 1 Sess., 1969.

help to modify that process. While the range of alternatives must be chosen with a full knowledge of the political constraints and sensitivities, it is both the analyst's as well as the decision maker's job to try to extend what is politically possible and to recognize, identify and discuss publicly the issues involved.[6]

In addition to the political constraints, an awareness of the political objectives is just as important for successful public policy modeling. The conceptual residuals management model presented above assumes, initially, that efficiency is the sole objective. This objective can be expanded to include the political differences between various groups of individuals. Each group i would include those individuals who affect the residuals–environmental quality system in similar ways and who have similar political and economic objectives. Each group's total political influence relative to the other groups might be defined by a weight P_i that is included in the objective function, i.e.

$$\text{Maximize} \quad \sum_i P_i \, NB_i(\vec{X},\vec{R},\vec{R}_M,\vec{Q})$$

Similarly, if benefit and damage functions are lacking, we can use in the objective function the parameters themselves that result in benefits and damages. In this case the political weights would reflect the relative importance of various parameter levels (identified as issues or goals) i.e. how strongly each group considers and can influence the outcome of each issue or goal.

Clearly the value of these weights can only be known after the decision is made, but by assuming a variety of relative weights, thereby defining a variety of possible residual management alternatives, the analyst can provide the decision making process with an estimate of not only what can be done, i.e., what is politically admissible, but also the implications of each alternative on each group or goal. Such information should assist in improving, at least incrementally, public policies. The analyst cannot and should not make the decisions, or even think that he can by assuming only a single vector of relative weights associated with multiple groups or goals. The definition of our priorities remains a question to be answered by the political process. Thus, at least for those analysts interested in public policy problems, it would seem that this approach cannot actually *solve* any particular problem, it can only suggest possible "politically effective alternatives." Those alternatives that are con-

6. *See, e.g.*, R. Davis, The Range of Choice in Water Management: A Study of Dissolved Oxygen in the Potomac Estuary (1968).

sidered better than others will usually be those that politicians think they can sell. Politicians often search not only for efficiency or effectiveness but for a politically saleable product.

Public policy models are effective only in so far as they can help the decision makers evaluate various program modifications in terms of the tradeoffs between political saleability and program effectiveness in an economic sense. Of course either extreme may be undesirable and can decrease the potential of analyses such as those discussed above. If we always confine ourselves to those objectives defined by conventional political wisdom, or if we ignore this wisdom altogether, little progress can be expected.

SOME CONCLUDING COMMENTS

Analytical residuals management models, if properly structured, can assist our intuition and judgment in sorting out the effects of complex issues and objectives. These models can often say something about whether specified objectives can be achieved and if so how they must be achieved, but they can say very little about whether they are good or bad objectives. We never really "know" even our own individual objectives let alone public policy objectives. This is why decision makers spend much of their time arguing about little else. It is toward the identification of the more important and relevant objectives and issues and toward the elimination of those which have little effect either politically or economically, that public policy models can be of real value.

Public policy problems are too complex and influenced by too many seemingly non-rational political considerations to hope that even the most sophisticated set of analytical techniques would be capable of determining the optimum solution. Optimization is achieved only with relation to a particular set of technical, economic, legal and political assumptions, i.e., with respect to a particular model. This point merits emphasis. Failure to understand this meaning of the word optimization has led to many misunderstandings between systems analysts and decision makers. The most we can expect from residuals management and other models is a means of defining and evaluating alternative solutions based on various sets of assumptions. When an analyst can begin to get the decision maker to question the assumptions in his models rather than merely accepting or rejecting a particular solution, he has begun the sequential process of trial and error—of communication with feedback—so absolutely necessary for the successful application and implementation of analyses to residuals management and similar public policy questions.