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STATE-OF-ART REVIEW: WATER POLLUTION CONTROL BENEFITS AND COSTS

VOLUME I

by

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ABSTRACT

This report presents a survey and assessment of the state-of-art of economic analyses dealing with water pollution control benefits and costs. The investigation includes the extension of traditional benefit cost analysis into the area of pollution control. Implications for planning and research plus some directions of needed study are also developed.

A conceptual basis for benefit cost analysis involving water quality management is suggested. An economic concept of a social welfare function is presented as the most widely accepted public criterion which embodies environmental quality concerns. Problems of efficiency, equity, externalities and social discount rates are summarized.

Water pollution control costs are a function of a host of factors including water quality criteria, specific pollutants, treatment strategy and design capacity. These and other factors are described. The types of available cost estimates--both fixed point and functional, are outlined. Also, the adequacy of such information is assessed.

Benefit measurements of water quality factors are meager and underdeveloped. A variety of partial-equilibrium approaches to benefit measurement are outlined and some problems, including the planning horizon (time profile), are described.

To assess benefit cost impacts of water pollution control, location-preserved analyses are necessary. An aggregation framework which accounts for spatial interdependencies is needed, and an assessment approach is also proposed.

General systems analysis approaches are implicitly required to measure benefits and costs of pollution control. Recent developments in the literature have begun to directly assess impacts of environmental quality management. In this setting, benefit cost analysis effectively becomes a supplementary analysis of alternative sets of simulated general equilibrium types of economic solutions.

This report was submitted in fulfillment of Project Number 21-AQJ-05, Contract Number 68-01-0744 by Development Planning and Research Associates, Inc., Manhattan, Kansas, under the sponsorship of the Environmental Protection Agency. Work was completed as of May, 1973.

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LIST OF EXHIBITS

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Many DPRA staff members and associates contributed to this project. Samuel Unger, Jarvin Emerson and David Jordening shared responsibility in writing this report. We, as economists, especially thank Larry Erickson and L. T. Fan for general 'engineering' inputs. Linda Erickson, Ron Dorf, Keith Leitner and M.Y. Chow provided technical support. Fred Mangum and Arlo Biere served as reviewers of draft materials and provided a variety of suggestions to help shape the final report. Frances Moyer and other secretarial support staff worked diligently to prepare draft and final materials.

Finally, we thank the many persons and authors whose ideas we have reviewed and summarized. We hope we accurately represented the views of others in this report. We believe the problem of water quality management can be better understood given this type of overview effort.

STATE-OF-ART REVIEW: POLLUTION CONTROL BENEFITS AND COSTS WITH EMPHASIS ON WATER

SECTION I

INTRODUCTION

The state-of-art survey presented attempts to classify and assess benefit cost analyses applied to water resource management problems in light of relatively recent serious concerns involving environmental quality issues. Rather piece-meal analyses have been completed. Traditional benefit cost analyses have incorporated little regarding either costs or benefits which fall outside market-oriented systems. Qualitative factors of value which are not reflected in some market exchange system have generally not been quantified in past studies. Only recent studies have introduced 'proxy' type variables which indirectly measure benefits and costs in common-denominator dollar terms.

Critics (or fear by economists of alledged critics) of non-traditional quantification procedures--to place some value on qualitative non-market phenomenon--have perhaps stifled efforts to incorporate externalities in economic-oriented benefit cost studies to date. As a consequence, past experiences by economists involving empirical benefit and cost (especially benefits) results are glaringly meager.

Report Objectives

Two principal objectives of this report are to present:

(1) A state-of-knowledge summary concerning both water pollution control costs and benefits, and

(2) A general statement of implications for planning and research (theoretical, methodological and data implications).

This report covers developments in the first of a three-phase program:

Phase I: State-of-Art Review
Phase II: Specification of Research Needs and Priorities
Phase III: Selected Implementation Research

A major function of this report is to provide a needed assessment of both 'what is' and perspective viewpoints of 'what ought to be' based on theoretical and applied experience in developing benefits and costs of water pollution control.

Emphasis is given toward an economic approach and assessment of water pollution control problems. The rationale for doing so is that a public awareness exists and a national commitment is planned for water pollution control. Alternatives for control have been identified and associated implementation research efforts are being pursued. Choices among alternative policies, programs and other control activities need to be made, in many cases urgently, and economic analyses are desired in decisions of choice.

As will be described, the needed 'economic' assessment of benefits and costs and trade-off implications require embodiment of factors and variables from virtually all disciplines of knowledge. A particular branch of economics, i.e., welfare economics, has historically embodied the kinds of interdisciplinary factors required in environmental quality management issues such as the one proposed. However, numerous gaps in knowledge, and particularly understanding of complex interrelationships among the many factors involved, result in failures of traditional economic methods and approaches. Hence, while emphasis is cauched mainly in economic terminology, general systems theory concepts and approaches, which are deliberately expansive versus contractive, are clearly needed to achieve comprehensive understanding of environmental pollution control problems.

Basic Problem Definition

Water pollution control, or more broadly, water quality management implies and involves regulation of effluents, emissions and substances into water receptors which contaminate or otherwise alter the quality of water.

Pollution refers to the act of being or of making unclean, but pollution control does not necessitate, per se, the exclusion of pollutants from receptors of concern. Control (regulation) includes but is not limited to, exclusion of pollutants.

A generally recognized characteristic of most water receptors, especially flowing rivers and streams, is the natural assimilative capacity to absorb and/or adsorb foreign substances without detrimental impact upon the affected intermediate or terminal receptors and/or processes therein. In fact both naturally occurring organic and inorganic substances are integral elements in diverse and complex life-support ecosystems which have and are evolving. Without some 'pollution', or perhaps for the purpose of distinction, without residuals (wastes) from both natural/physical and biological processes, various life-support ecosystems (food-chains) would collapse.

In contrast, residual flows containing undesired volumes of wastes and/or specific toxic contaminants (including various natural and synthesized chemicals) may 'exceed' the assimilative capacity of receptors to the detriment of desired ecosystem functions. Detrimental impacts may be local and/or global in scope.

While much is known concerning impacts of many organic and inorganic (and other, e.g., radioactive) substances in water, in terms of their impact on affected ecosystems, much more is probably unknown. Consequences of the presence of persistent residuals, e.g., heavy metal molecules such as mercury, have only recently been discovered in relation to human health. Cumulative impacts, or build-up over time of other chemicals and chemical compounds, e.g., DDT, have also only been recently discovered.

Renewed focus is now being placed by scientists on the possible impacts of other identified persistent and potentially toxic substances. Water quality management entails complex and possibly long-term concerns. Unknown as well as known factors are involved. 'Mixing' effects of various residuals appears generally unexplored.

Economic analysis of benefits (in many cases damage reductions) and costs of water pollution control is at best limited to the known aspects of water quality management. (Although, as is subsequently presented, the concept of assigning and insurance-value for risk and uncertainty pertaining to unknown elements of water quality management is believed applicable.) As will also be explained, economic analyses fall far short in assessing economic and social impacts of known aspects of water quality management. Esthetic properties of water quality appearance involve additional dimensions of concern which are introduced by the social sciences, e.g., sociology and psychology. Such concerns also have economic implications and consequences.

The basic problem addressed in this study is to survey and assess the state-of-art of economic analyses dealing with water pollution control benefits and costs. 1/

An Introductory Perspective

Water pollution control is one aspect of a larger environmental quality management problem which not only the U.S., but other nations of the world, are vitally concerned. Water quality management cannot, however, realistically be divorced from air, land and other ecosystem quality issues. Neither can environmental quality management efforts be pursued as a unique problem of the U.S. public. That is, other major issues are also of current critical concern, such as population control, malnutrition, energy supplies, natural resource depletion, international relationships and national security.

The above problem areas are both directly and indirectly intertwined. Some cause-effect relationships can be cited. Also, the political environment calls for concurrent efforts such that only limited resources and commitments can be expected toward any single issue.

In such a setting water pollution control (or more broadly, water quality management) is seen as but one of numerous serious problem areas of collective responsibility.

1/ A conceptual management framework suggesting needed considerations in water quality management is outlined in Appendix A.

The aim of this report is to separate so far as possible the water pollution control problem from other problems and to focus on pollution control costs and benefits. Such a procedure is desired in order to bring into sharper focus the nature of water quality problems.

As is described herein, the scope and severity of water quality problems is believed serious throughout our nation. Damages have already reached phenomenal levels and continued degradation of water quality in general is believed by many as a threat to human survival--often in very subtle and seemingly obscure ways.

Control of water pollution will require numerous types of effort and cost. Perhaps even life-styles and changing production/consumption patterns will be required for control to be effective. Such costs and possible changes will naturally be resisted by those most directly affected. Collective and public decisions and commitments are required. Costs of control are ultimately a collective and public cost.

Benefits of pollution control are also ultimately collective and public. Unanswered in this logic, however, are equity issues both in terms of cost burdens and benefit distribution. During perhaps a rather long transitional period, various inequitable disruptions and consequences of water pollution control can be expected. Efforts to compensate for such transitional costs must also be considered in policies, programs and actions associated with water pollution control.

Benefits from water pollution control will be both tangible and intangible. Tangible benefits will include numerous 'damage reductions' to water users as outlined below. Intangible benefits involving sight, color, odor, taste and other esthetic qualities of clean water are expected.

Benefits of water pollution control are expected to be publicly demanded as well as desired as long as such benefits exceed perceived and actual costs of control. Herein lies the main general reason for this review of water pollution control benefit and cost studies.

In our representative form of government, political leaders will adopt and support policies and programs which can be shown to collectively benefit the public. Such actions require public support and commitment, however. Also, as briefly noted, water pollution control competes with numerous other issues for both political and public support.

Reasoned and objective study of water pollution control costs and benefits is needed. Benefit cost tradeoffs can be expected in comparing water pollution control alternatives relative not only to other environmental quality management issues, but other critical issues as well.

Public awareness and concern toward water pollution in general has reached a point where it is clear that: "Water pollution control is a desired national objective."

Damages (negative benefits) have, are and/or are expected to occur in a variety of ways. As mentioned, intangible values are also placed on clean water. A brief listing of some of the known private and public concerns involving water quality in oceans, lakes, reservoirs, rivers, streams and underground aquifers is shown in Exhibit I-1. These factors, even though they may lack adequate empirical quantification, are nonetheless the type of concern giving substance to the notion that water pollution is a serious problem deserving of conscious and concerted effort by the American public.

A final introductory perspective viewpoint is a materials-balance concept of the residuals (waste) and related pollution control problems. As depicted in Exhibit I-2, the environmental biosphere is both the source of materials and the receptor of residuals from human-controlled extraction/processing, production, distribution, and consumption activities. The law of Conservation-of-Mass indicates that, aside from rather short-term accumulations, all materials extracted from the environment are necessarily returned to the environment even though their form and location may change. In other words, residual mass is effectively equal to that initially extracted. The earth is for all practical purposes a 'closed system' with respect to mass. Mass can be transformed but not destroyed. Pollution of air, water and land receptors can and does occur in the biosphere if residuals are not returned to the biosphere in an environmentally acceptable form.

Although not pursued further here, another fundamental law, known as Conservation-of-Energy, is also important. In effect, energy can also neither be created nor lost in a universal setting. However, unlike mass, the earth is considered to be an 'open system' with respect to energy. Solar energy is perhaps the most obvious energy source originating outside the earth's biosphere. The economic value of energy is dependent on energy forms (electrical energy is more valuable than heat). Energy conversion often results in material residuals especially when fossil fuels provide the primary energy source. Consideration of pollution due to energy-induced residuals may significantly affect energy policies. Such policies in turn affect water pollution control activities and associated economic consequences.

Exhibit I-1: Outline Description of Environmental Impacts of Water Pollution and Its Control

General Environmental Impact	Type of Economic Consequence	Type of Water Pollutant	Description
HEALTH [1/]	Medical Service Demands Productive Work (Man-Hours Lost Human Life Lost	Microbiological Inorganic Chemicals Organic chemicals Radioactivity Physical	Health effects on man include acute and chronic illnesses, alteration of physiological function, and sensory irritations. Water quality may affect health through public water supplies, food chains, transmission of communicable diseases, bodily contact with water and through other environmental changes resulting from water pollution. Examples of health impacts include hepatitis, cholera, malaria, mercury poisoning, eye irritations, leptospirosis, salmonellosis, dysentery, endemic fluorosis, cadmium poisoning, alteration of liver function, schistosimiasis and methemoglobinemia.
ESTHETICS	Private property damage and subsequent value reduction Public property damage and subsequent value reduction Recreation alterations "Quality of life"	Materials that will settle to form objectionable deposits. Floating debris, oil, scum and other matter. Substances producing objectionalbe color, odor, taste or turbidity	Esthetic effects include all direct and indirect public and private property damage and subsequent value reduction resulting from undesirable qualities of surface water. It further includes all alteration in water quality (including subjective qualities) so as to destroy or alter the esthetic qualities intrinsic with the water itself or the surrounding environment including all primary and secondary contacts with the environment.

1/ Appendix B presents a representative summary of known health impacts stemming from primary and secondary exposure to surface waters possessing various undesirable characteristics or components.

Exhibit I-1 (continued)

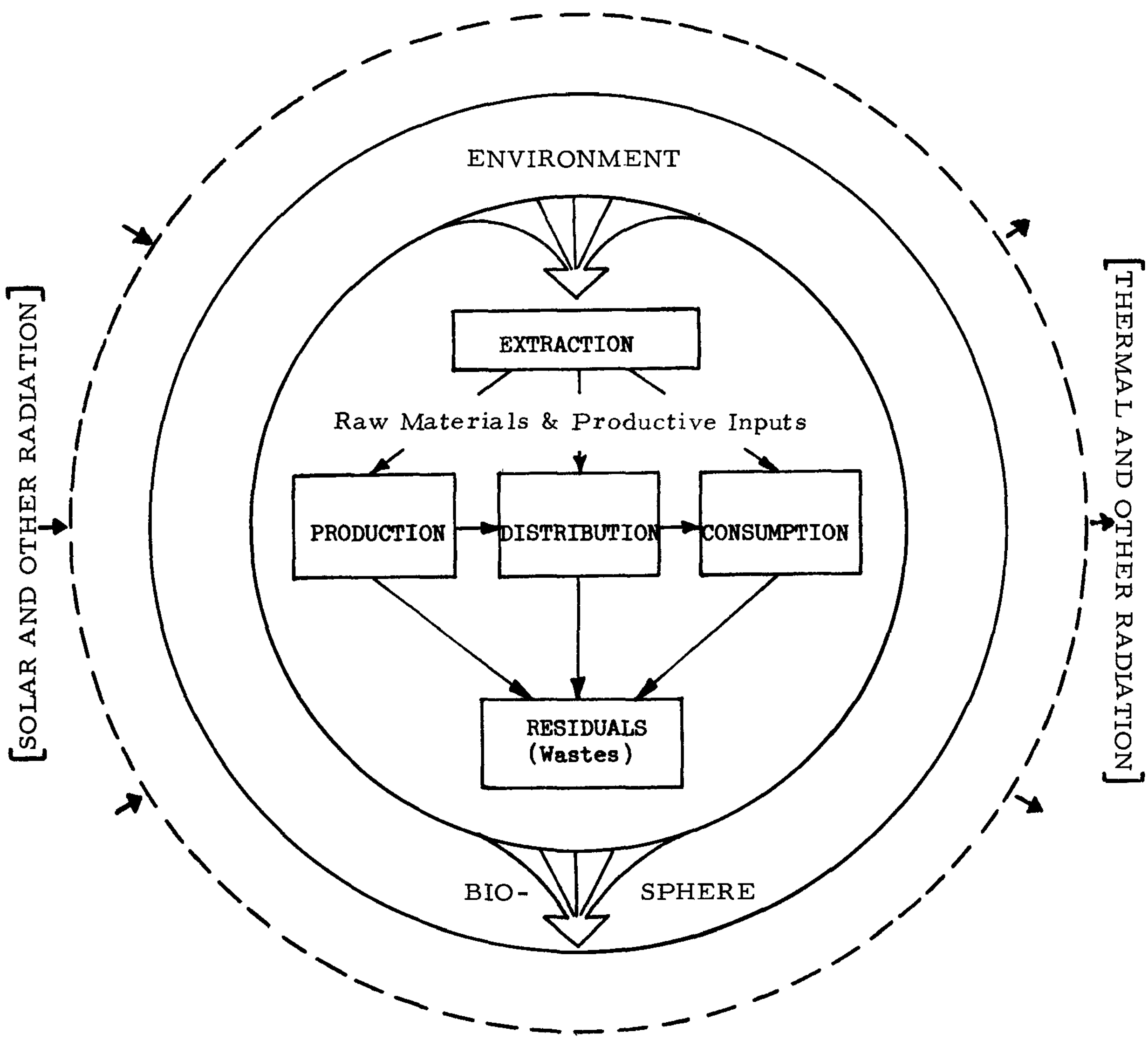
General Environmental Impact	Economic Consequence	Type of Water Pollutant	Description
		Materials including radionuclides in concentration or combinations which are toxic or which produce undesirable physiological response in animal and plant life.	Esthetic impacts are frequently associated with but not limited to material spills, acid mine runoff, feedlot runoff, turbidity, marine discharges, industrial discharges and thermo pollution all of which directly or indirectly alter water quality. These factors are frequently grouped under a single heading--quality of life. Both public and private property values reflect some esthetic qualities but suitable market-based valuation reflecting all esthetic qualities either have not been discovered or do not exist in current exchange systems.
PRODUCTION (ACTIVITY) IMPACTS 2/	Raw material refinement, treatment and substitution Process changes Employment changes Industrial structure changes Regional and area dislocations Final product prices Input costs Income redistribution International trade	Physical constituents Microbiological organisms Inorganic chemicals Organic chemicals	Production impacts include all raw material refinement, treatment and substitution changes necessitated by deteriorating water quality or stemming from water quality controls that were heretofore unnecessary due to adequate water quality or absence of controls. It further includes all agricultural, municipal and industrial structure changes, resulting capital losses, employment impacts and relocation losses resulting from environmental degradation and/or manditory pollution abatement standards.

2/ Appendix C presents a summary of various economic impacts frequently associated with internalized waste water treatment costs.

Exhibit I-1 (continued)

General Environmental Impact	Type of Economic Consequence	Type of Water Pollutant	Description
UNCERTAIN ECOLOGICAL DISRUPTIONS	Unknown economic consequences affecting all health, esthetic, production and consumption facets of life.	Any unknown undesirable concentration and combination of physical, microbiological, unorganic chemicals, organic chemicals and radioactive pollutants.	The disruptions of presently unknown but vital life support cycles and systems resulting in unknown and unpredictable social, economic and ecological consequences. An increasing array of toxic and potentially harmful persistent pollutants have become the focus of scientific physical/biologic research. Among the most threatening classes of pollutants thus far identified are mercury, lead, arsenic, sodium-nitrilotriacetate acid (NTA), cadmium, polyclorinated biphenyl compounds (PCB), beryllium, dioxins, and others.

Exhibit I-2. Environmental Biosphere



SECTION II

SCOPE

A state-of-the-arts survey of benefits and costs of pollution control is an elusive goal in this new and rapidly changing field. As will become apparent, most of the relevant literature has appeared in the last five years.

The boundaries of the investigation include the extension of traditional benefit cost analysis into the area of pollution control. It is constrained by the relatively meager state of knowledge that currently exists. As with any state of knowledge review, the process must be selective but representative. This report is no exception.

It is instructive to outline the scope of the following survey and the general approach taken. The main remaining sections and a brief description of contents in each are as follows:

Section	Content Description
Benefit Cost Framework	A conceptual basis for benefit cost analysis is suggested. An economic concept of a social welfare function is presented as the most widely accepted public criterion which embodies environmental quality concerns. Problems of efficiency, equity, externalities and social discount rates are introduced and briefly summarized.
Pollution Control Costs	Control costs are a function of a host of factors or variables including water quality criteria, specific pollutants, treatment strategy and design capacity. These and other factors are described. The types of available fixed cost estimates and cost function estimates are outlined. Also, the adequacy of such information is assessed.

Section	Content Description
Benefit Measurement	A variety of partial-approaches to benefit measurement are outlined and some problems, including the planning horizon (time profile) are indicated. Benefit measurements of water quality factors are meager and underdeveloped. Some problems in estimating pollution control benefits are outlined.
Benefit Cost Aggregation Framework	Benefit cost impacts of water pollution and its control are intrinsically location dependent. Location-preserved analyses are necessary. An aggregation framework which accounts for spatial interdependencies is needed. An assessment approach is also proposed based on development by the Water Resources Council.
General Equilibrium Models	Benefit cost analysis effectively becomes a supplementary analysis of alternative sets of simulated general equilibrium types of economic solutions. This conclusion seems to follow given the types of recent developments in the literature which have begun to directly assess impacts of environmental quality management. General system analysis approaches are implicitly required.
Summary Observations	A number of summary observations regarding the current state-of-art are presented. Some conceptual problems, data problems and others are briefly sketched.

Section	Content Description
Implications for Planning and Research	This final section outlines some directions of needed study. As a foundation for 'prescribing' such directions, some procedures, perspective viewpoints and a refinement of the problem definition are presented.

The primary intent of this report is to provide a working framework for subsequent research. The final section draws on information and knowledge outside the scope of the state-of-art survey, per se. Such a step is needed, however, if water quality management problems are to realistically be analyzed and evaluated in the desired benefit cost framework.

SECTION III

BENEFIT COST FRAMEWORK

A variety of conceptual issues are fundamentally involved in discussions of water pollution control benefits and costs. In this section, the principal concepts are briefly presented to form a framework for describing and assessing benefit cost analyses.

Welfare Economics: A Conceptual Basis for Benefit Cost Analysis

Maximization of social welfare (the sum of both public and private net benefits) is the generally accepted public criteria or objective expressed by a branch of economics known as welfare economics. This branch of study endeavors to formulate propositions (policies and rules) by which to rank economic alternatives open to society. That alternative or situation which maximizes social welfare might therefore be identified.

Problems not only of efficiency but equity are of concern. Values and tastes enter the analysis. Social (public and private) values are the foundation of the implied social welfare function.

The issues, as described, are in large measure precisely the types of concerns embedded in environmental quality management problems. That is, implied if not actual social values and preferences affect policy choices toward achievement of desired environmental quality. Movement toward improved environmental protection will involve efficiency and equity questions. Values and tastes are changing, and consequences on matters of social choice need to be assessed.

Unfortunately, the discipline of welfare economics has itself failed to resolve questions of efficiency and equity involving the aggregation of complex interpersonal relationships implicit in identifying social values and social welfare. Problems in determining collective rationality, in choosing among alternatives which yield efficient solutions but only with some inequities present, and in internalizing all externalities not expressed in market-based exchanges are among the difficult unresolved questions. Valuation of social welfare in common-denominator terms (whether in dollars or in some non-dollar terms) is critical in such discussions.

Despite this clouded picture of the state-of-art of applied welfare economics, it remains as a primary discipline in which individual values and concerns to protect individual liberties within a collective value system are studied. Lessons from welfare economics, however weak they may at first appear, are nonetheless relevant in a most fundamental way in matters of environmental quality in our democratic society. The freedom and right of individual expressions of value and preference are basic to the notion of a collective social welfare function in a democracy.

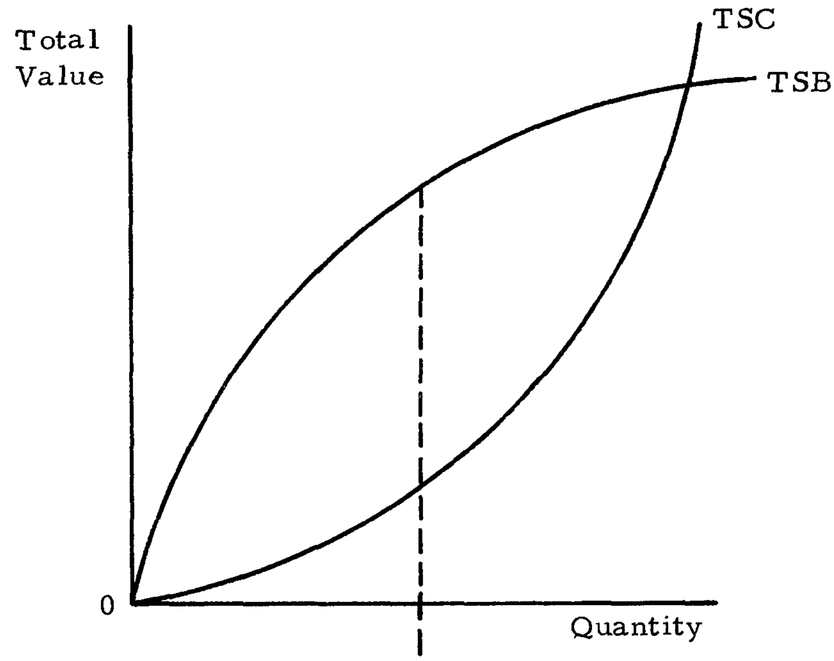
Social welfare ideas, as only briefly and partially outlined above, are implicitly embodied in benefits and costs of water pollution control. The relevancy of this brief background setting will hopefully become more apparent in the following discussion.

Efficiency Criterion

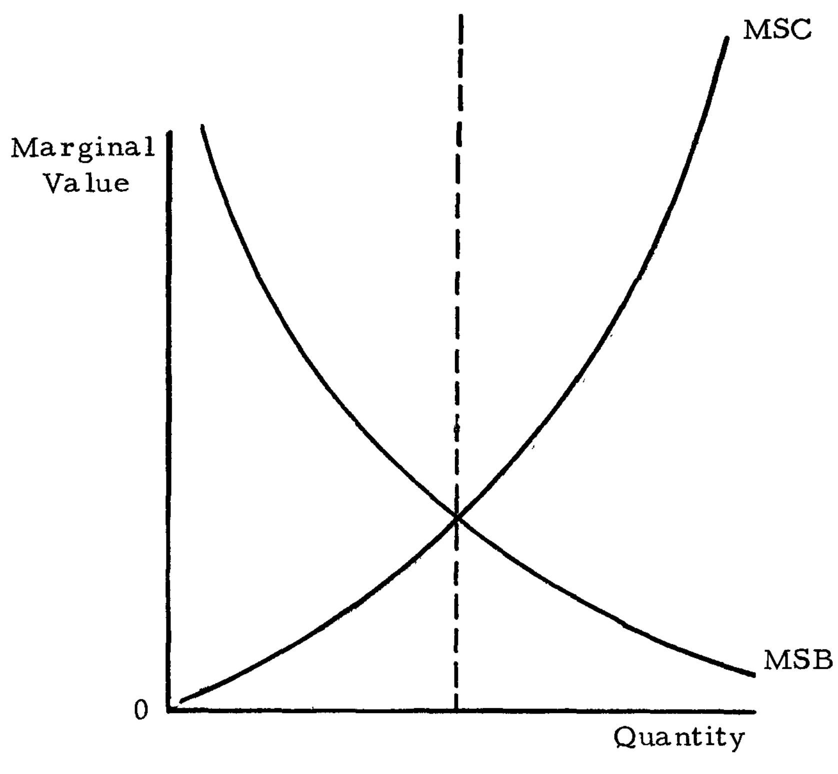
The problem of evaluating water pollution control mechanisms is basically a problem in efficient resource allocation. As such the decision-making criterion becomes an evaluation of total social costs and total social benefits in an effort to arrive at a position where the positive difference between the two is greatest. Alternatively stated, net social benefits should be maximized. The decision criterion can also be viewed in a marginal context. The relationship between the two is expressed in Exhibit III-1. Marginal social benefits (MSB) are equal to marginal social costs (MSC) where the difference between total social benefits and costs is greatest.

A problem arises when there is significant divergence between private costs and benefits and social costs and benefits. Markets frequently do not reflect total social costs and benefits and actual or potential inefficiencies occur. Some benefits and costs are accurately registered by market prices, some are inaccurately reflected by market prices, some are not registered in markets although simulated market values can be computed, while for others it is nearly impossible to conceive of an adequate market (dollar-based) valuation process.

Exhibit III-1. Total and Marginal Social Welfare Concept



Total Social Benefits and Costs of Production
and Consumption of a Commodity



Marginal Social Benefits and Costs
of Production and Consumption of a Commodity

Externalities

An externality exists where an economic action affects parties not directly involved in the transaction. Benefits or costs spillover on parties other than the primary participants in the transaction thereby falling outside the reach of the price system. A negative externality exists where a person incurs identifiable costs for which he receives no compensation. A positive externality occurs where a person benefits from the action of another without being required to make compensation.

The concern over externalities stems from the breakdown in the market mechanism and a corresponding divergence of equity and efficiency solutions expected of the free market. From an equity viewpoint some persons are "harmed" and others "helped" through no action of their own. Also, if externalities are present in the production of a good, a nonoptimal quantity of the good will be produced. Lets examine this latter statement in more detail.

Suppose that the market equilibrium price and quantity for a product is represented by P_0 and Q_0 in Exhibit III-2 where SS and DD are the corresponding supply and demand curves with all costs and all benefits embodied in each. At this equilibrium marginal benefit equals marginal cost. But if there are externalities, some of the benefits and/or costs are not included in the demand and supply curves. For instance, if some of the costs are excluded from the market supply curve as in S'S', the market price will be lower and the quantity produced will be greater than the optimal price and quantity, P_0 and Q_0. Conversely, where benefits are excluded from the market demand curve, the output and price will be lower than the socially optimum level. This situation is illustrated in Exhibit III-3. In either the case of the cost or the benefit externality, a less than socially satisfactory market solution is achieved. Examples of externalities are numerous throughout the economy. One example might involve a meatpacking plant where, although the private costs of processing meat are included in the supply curve, any uncontrolled water pollution costs are not. These spill over on society in general.

The inability of markets to correctly reflect total social costs and benefits necessitates a variety of conceptual and empirical challenges called benefit cost analysis.

Exhibit III-2. Socially Optimum Market Conditions vs. Cost Externality

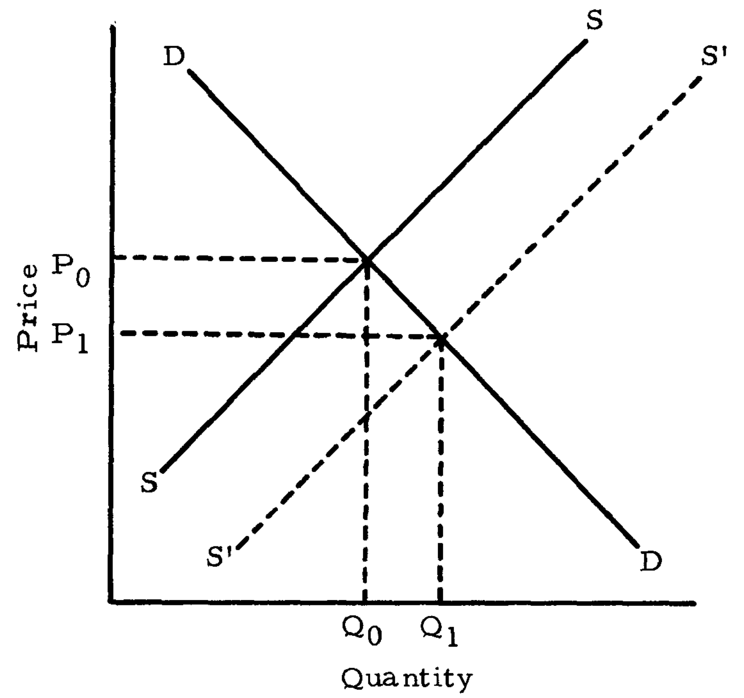
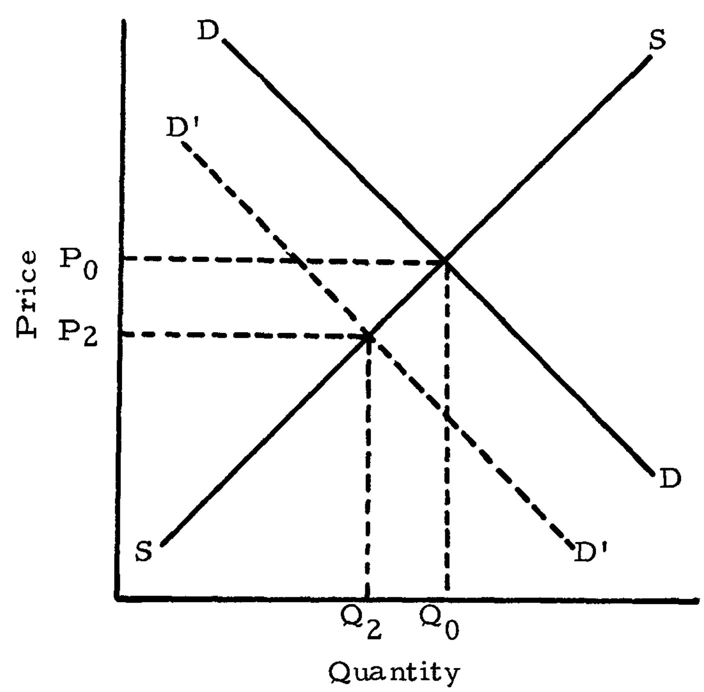


Exhibit III-3. Socially Optimum Market Conditions vs. Benefit Externality



Traditional Benefit Cost Analysis

Benefit cost analysis is often the approach used to assess the desirability of a particular investment or pricing alternative. Changes in resource allocation are expected. Traditionally benefit cost analysis has focused on investment projects undertaken by a governmental unit. The need for such analysis usually reflects weak or non-existent price signals in the market.

The history of benefit cost analysis originates with Dupuit's classic paper on the utility of public works in 1844 (Dupuit, 1844). The major thrust for such studies in the United States came from the River and Harbor Act of 1902 as an administrative device to evaluate navigation improvement projects. Subsequent alterations in the framework of benefit cost studies attempted to increase the scope of the benefits and costs included in the analysis, but nearly all analyses were of specific investment projects and were confined to tangible costs and benefits.

The basic problem of benefit cost analysis is to maximize the present value of all benefits less that of all costs, subject to certain constraints. Operationally this breaks down into identifying the costs and benefits to be included, determining how the costs and benefits are to be valued, determining the discount rate, and specifying the relevant constraints.

The first issue is externalities, the spillovers of benefits and costs to parties other than the direct participants. Because of externalities, the identification of costs and benefits may be a difficult task. Both neglect of externalities and controversy over appropriate estimation characterize the literature.

In valuing costs and benefits in monetary terms, common price levels are sought which usually involves adjustments for relative price changes. If the project is of sufficient size, it may exert a significant influence on market prices which creates the problem of the proper prices for valuing the change in output levels. But, market prices cannot be used to value benefits which are not capable of being marketed. Since most water projects are of the collective goods nature, revealed consumer preferences are elusive, if nonexistent. In addition numerous intangible benefits and costs complicate the valuation process.

The interest rate is an attempt to reflect the marginal productivity of investment and time preference. On one hand, it has been argued that social discount rates should be higher than private discount rates because private interests tend to undervalue the future. In contrast, it is also argued that the social discount rate should be lower than the private (market) rate to better reflect long-term consequences on future generations (both benefits and costs, including externalities).

The relevant constraints must be specified to reflect physical and institutional realities. Technology dictates a feasible range of production possibilities which may be further constrained by legal provisions. A project may have a significant impact on the distribution of income. Such an effect may be considered desirable within certain limits such that the optimal solution becomes constrained by such considerations.

Weaknesses of Traditional Benefit Cost Analysis for Dealing with Environmental Quality

Traditional benefit cost analysis has numerous short falls as a management tool to evaluate policies designed to improve environmental quality.

"Most benefit cost approaches are inadequate not because there is anything wrong with using a benefit cost ratio per se, but because frequently the benefit estimations, a good many of the cost estimations, the treatment of uncertainty, and all of the time discount rates are improperly derived." (Whipple, 1971)

Two general limitations of benefit cost analysis have been concisely summarized by Prest and Turvey (1965). "First, cost benefit analysis as generally understood is a technique for taking decisions within a framework which has to be decided upon in advance and which involves a wide range of considerations, many of them of a political or social character. Secondly, cost benefit techniques as so far developed are least relevant and serviceable for what one might call large-size investment decisions. If investment decisions are so large relatively to a given economy . . ., that they are likely to alter the constellation of relative outputs and prices over the whole economy, the standard technique is likely to fail us, for nothing less than some sort of general equilibrium approach would suffice in such cases."

The Prest-Turvey critique implies that benefit cost analysis can be applied to environmental problems only with great difficulty and may be conceptually and empirically inappropriate.

Traditional benefit cost analysis has evolved as an analytical device for measuring development effects rather than environmental repercussions. The result is that a general conceptual framework for evaluating pollution abatement policies has not been formulated which has received a generally favorable review. The major difficulty revolves around the identification and measurement of benefits from pollution abatement. Traditional benefit measures used in evaluating development projects have limited application to environmental repercussions because they have failed to embody externalities on affected processes. It is noted, however, that development effects are also a major component of social welfare. Both private and public asepcts are involved.

SECTION IV

POLLUTION CONTROL COSTS

Pollution control costs depend on many diverse physical, engineering and economic factors and consequently are difficult to estimate in aggregate. Some factors that heavily influence pollution control costs are type of treatment, plant capacity, effluent removal efficiency, influent loads, effluent loads, type and concentration of effluents, desired water quality objectives and a host of other economic, engineering, climatic, physical and spatial considerations.

The diversity, complexity and interaction of the determinants of water pollution control costs necessitate approaching national pollution cost estimates through a regional or highly disaggregated framework. For the same reason, almost all available water quality control cost data are project oriented in that they refer to specific treatment strategies, specific engineering parameters and stipulated effluent flow objectives.

Some of the more salient factors influencing pollution control costs--water quality criteria, design capacity, specific pollutants and treatment strategy--are discussed below.

Water Quality Criteria

One critical factor (perhaps the most important factor) influencing the cost of water quality management is the desired or target water quality. The imposed quality requirements directly influence the selection of the appropriate treatment strategy. If the imposed quality standard is, for example, designed to satisfy the Public Health Service drinking water standards, the treatment of all waste water discharges would require multistage treatment and in general a more sophisticated treatment process than if the water quality objectives tolerated higher effluent loads.

Realizing that surface water is often withdrawn for public use with the major treatment being disinfection, one water quality criteria that has been advocated for adoption is that all surface waters meet Public Health Service drinking water standards. Exhibit IV-1 presents the permissible and desirable

Exhibit IV-1. Surface Water Criteria for Public Water Supplies

Constituent or characteristic	Permissible criteria	Desirable criteria	Paragraph
Physical:			
Color (color units)	75	<10	1
Odor	Narrative	Virtually absent	2
Temperature *	do	Narrative	3
Turbidity	do	Virtually absent	4
Microbiological:			
Coliform organisms	10,000/100 ml [1]	<100/100 ml [1]	5
Fecal coliforms	2,000/100 ml [1]	<20/100 ml [1]	5
Inorganic chemicals:	(mg/l)	(mg/l)	
Alkalinity	Narrative	Narrative	6
Ammonia	0.5 (as N)	<0.01	7
Arsenic *	0.05	Absent	8
Barium *	1.0	do	8
Boron *	1.0	do	9
Cadmium *	0.01	do	8
Chloride *	250	<25	8
Chromium,* hexavalent	0.05	Absent	8
Copper *	1.0	Virtually absent	8
Dissolved oxygen	≥4 (monthly mean) ≥3 (individual sample)	Near saturation	10
Fluoride *	Narrative	Narrative	11
Hardness *	do	do	12
Iron (filterable)	0.3	Virtually absent	8
Lead *	0.05	Absent	8
Manganese * (filterable)	0.05	do	8
Nitrates plus nitrites *	10 (as N)	Virtually absent	13
pH (range)	6.0–8.5	Narrative	14
Phosphorus *	Narrative	do	15
Selenium *	0.01	Absent	8
Silver *	0.05	do	8
Sulfate *	250	<50	8
Total dissolved solids * (filterable residue).	500	<200	16
Uranyl ion *	5	Absent	17
Zinc *	5	Virtually absent	8
Organic chemicals:			
Carbon chloroform extract * (CCE)	0.15	<0.04	18
Cyanide *	0.20	Absent	8
Methylene blue active substances *	0.5	Virtually absent	19
Oil and grease *	Virtually absent	Absent	20
Pesticides:			
Aldrin *	0.017	do	21
Chlordane *	0.003	do	21
DDT *	0.042	do	21
Dieldrin *	0.017	do	21
Endrin *	0.001	do	21
Heptachlor *	0.018	do	21
Heptachlor epoxide *	0.018	do	21
Lindane *	0.056	do	21
Methoxychlor *	0.035	do	21
Organic phosphates plus carbamates.*	0.1 [2]	do	21
Toxaphene *	0.005	do	8
Herbicides:			
2,4-D plus 2,4,5-T, plus 2,4,5-TP *	0.1	do	21
Phenols *	0.001	do	8
Radioactivity:	(pc/l)	(pc/l)	
Gross beta *	1,000	<100	8
Radium-226 *	3	<1	8
Strontium-90 *	10	<2	8

* The defined treatment process has little effect on this constituent.

[1] Microbiological limits are monthly arithmetic averages based upon an adequate number of samples. Total coliform limit may be relaxed if fecal coliform concentration does not exceed the specified limit.

[2] As parathion in cholinesterase inhibition. It may be necessary to resort to even lower concentrations for some compounds or mixtures. See par. 21.

Source: Report of the National Technical Advisory Committee to the Secretary of the Interior, Water Quality Criteria, Federal Water Pollution Control Administration, Washington, D. C. April, 1968.

characteristics for surface waters used to satisfy public supplies. It is not advocated herein that this criteria be adopted but only suggested that the selected quality criteria is one of the most critical water management cost variables. The desired water quality objective generally dictates the type of treatment required.

Design Capacity

In several studies, design capacity, or a proxy variable for design capacity such as population served or average daily effluent loads, has been shown to be a dominant variable in estimating waste water treatment plant costs for a given treatment strategy. While it is recognized that many factors influence treatment cost, several studies have indicated that this one factor is frequently the most significant (Tihansky, 1972). In situations where a fixed quantity of waste effluent is treated, waste removal efficiency or effluent quality replaces plant capacity as the single most important cost determining variable (Tihansky, 1972).

Specific Pollutants

Water quality management costs also depend on the specific pollutants present and the volume and concentration of such pollutants. Along with the volume and type of emissions, many other physical and ecological factors influence the severity and subsequent cost of local water quality management.

One very broad indication of the nature and magnitude of local water quality management problems can be acquired by assessing the socio-economic profile of a region. For example, the distributions of population and industry throughout a given region can indirectly provide a broad indication of the type and concentration of specific pollutants and may also be suggestive of the area resource management problems. Data on industrial and municipal waste discharge is therefore useful to help identify specific pollutants and further refine the problem.

Exhibit IV-2 is a summary of specific characteristics or constituents of surface waters that have been used by selected industries. This type of data along with the knowledge of existing water treatment facilities and the assimilative capacity of local streams can be used to ascertain the area effluent flows, the severity of local pollution, the required treatment strategies and the subsequent cost incurred from water quality management.

Other studies have addressed these particular questions by correlating surface water quality and specific pollutants to the social, economic and physical characteristics of the river basins. One such study is MRI's report on "Systems Progress for the Analysis of Nonurban Nonpoint Sources of Pollutants in the Missouri Basin Region." (1971). In this report, data was collected in the following categories:

Water Quality
Climatology
Hydrology
Land Use
Topography
Soil Classification
Livestock Distribution
Pesticide Use
Fertilizer Use
Demography

From the above information, the following two-parameter correlations were developed:

(1) BOD in the river streams versus number of cattle in the immediate upstream drainage area
(2) Sediment yields versus percentage of land covered by forest, range and pasture
(3) Fertilizer application versus nitrates in water
(4) Fertilizer application versus crop value
(5) Acres in pasture versus acres treated with herbicides
(6) Pesticides versus fertilizers
(7) Streamflow characteristics versus basin characteristics

Although these relations are very loose, they might be applied to estimate pollution variation in each region contributed

Exhibit IV-2. Summary of Specific Quality Characteristics of Surface Waters That Have Been Used as Sources for Industrial Water Supplies

[Unless otherwise indicated, units are mg/l and values are maximums. No one water will have all the maximum values shown.]

Characteristic	Boiler makeup water: Industrial 0 to 1,500 psig	Boiler makeup water: Utility 700 to 5,000 psig	Cooling water: Fresh: Once through	Cooling water: Fresh: Makeup recycle	Cooling water: Brackish[1]: Once through	Cooling water: Brackish[1]: makeup recycle	Process water: Textile industry, SIC–22	Lumber industry, SIC–24	Pulp and paper industry, SIC–26	Chemical industry, SIC–28	Petroleum industry, SIC–29	Prim. metals industry, SIC–33	Food and kindred products, SIC–20	Leather industry, SIC–31
Silica (SiO_2)	150	150	50	150	25	25	-----	-----	50	-----	50	-----	For the above 2 categories the quality of raw surface supply should be that prescribed by the NTA Subcommittee on Water Quality Requirements for Public Water Supplies.	
Aluminum (Al)	3	3	3	3	-----	-----	-----	-----	-----	-----	-----	-----		
Iron (Fe)	80	80	14	80	1.0	1.0	0.3	-----	2.6	5	15	-----		
Manganese (Mn)	10	10	2.5	10	0.02	0.02	1.0	-----	-----	2	-----	-----		
Copper (Cu)	-----	-----	-----	-----	-----	-----	0.5	-----	-----	-----	-----	-----		
Calcium (Ca)	-----	-----	500	500	1,200	1,200	-----	-----	-----	200	220	-----		
Magnesium (Mg)	-----	-----	-----	-----	-----	-----	-----	-----	-----	100	85	-----		
Sodium and potassium (Na+K).	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	230	-----		
Ammonia (NH_3)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----		
Bicarbonate (HCO_3)	600	600	600	600	180	180	-----	-----	-----	600	480	-----		
Sulfate (SO_4)	1,400	1,400	680	680	2,700	2,700	-----	-----	-----	850	570	-----		
Chloride (Cl)	19,000	19,000	600	500	22,000	22,000	-----	-----	200[2]	500	1,600	500		
Fluoride (F)	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	1.2	-----		
Nitrate (NO_3)	-----	-----	30	30	-----	-----	-----	-----	-----	-----	8	-----		
Phosphate (PO_4)	-----	50	4	4	5	5	-----	-----	-----	-----	-----	-----		
Dissolved solids	35,000	35,000	1,000	1,000	35,000	35,000	150	-----	1,080	2,500	3,500	1,500		
Suspended solids	15,000	15,000	5,000	15,000	250	250	1,000	(3)	-----	10,000	5,000	3,000		
Hardness ($CaCO_3$)	5,000	5,000	850	850	7,000	7,000	120	-----	475	1,000	900	1,000		
Alkalinity ($CaCO_3$)	500	500	500	500	150	150	-----	-----	-----	500	-----	200		
Acidity ($CaCO_3$)	1,000	1,000	0	200	0	0	-----	-----	-----	-----	-----	75		
pH, units	-----	-----	5.0–8.9	3.5–9.1	5.0–8.4	5.0–8.4	6.0–8.0	5–9	4.6–9.4	5.5–9.0	6.0–9.0	3–9		
Color, units	1,200	1,200	-----	1,200	-----	-----	-----	-----	360	500	25	-----		
Organics:														
Methylene blue active substances.	2[4]	10	1.3	1.3	-----	1.3	-----	-----	-----	-----	-----	-----		
Carbon tetrachloride extract.	100	100	(5)	100	(5)	100	-----	-----	-----	-----	-----	30		
Chemical oxygen demand (O_2).	100	500	-----	100	-----	200	-----	-----	-----	-----	-----	-----		
Hydrogen sulfide (H_2S).	-----	-----	-----	-----	4	4	-----	-----	-----	-----	-----	-----		
Temperature, F	120	120	100	120	100	120	-----	-----	95[6]	-----	-----	100		

[1] Water containing in excess of 1,000 mg/l dissolved solids.
[2] May be ≤ 1,000 for mechanical pulping operations.
[3] No large particles ≤ 3 mm diameter.
[4] 1 mg/l for pressures up to 700 psig.
[5] No floating oil.
[6] Applies to bleached chemical pulp and paper only.

NOTE.—Application of the above values should be based on Part 23, ASTM book of standards (1) or APHA Standard methods for the examination of water and wastewater (5).

Source: Report of the National Technical Advisory Committee to the Secretary of the Interior, Water Quality Criteria, Federal Water Pollution Control Administration, Washington, D. C., April, 1968.

by agriculture, forest and farm animals. Quantification of the above relationships is an additional aid in the selection of the appropriate treatment strategy.

The above factors--water quality criteria, design capacity and specific pollutants--are not an exhaustive listing of the determinants of waste water treatment costs; but they are representative of factors that vary throughout the spatial landscape influencing local water pollution control costs. A summary listing of these plus some additional key economic, engineering and physical factors influencing water pollution control costs is presented below:

Natural effluent flows or loads
Topography
Climatic and water temperature
Industrial discharge
Municipal discharge
Plant capacity
Type of treatment strategy
Peak effluent loads
Influent loads
Type and concentration of effluents
Desired water quality objective
By-product recovery
Recirculation
Removal efficiency
Wage rate differentials
Water transport distance
Local land costs
Assimilative capacity

Considering the number of variables and the interdependence and interaction of these variables, it is not surprising to find that most water pollution control cost data are highly project oriented, reflecting specific engineering parameters, and local physical and economic environments. This also explains the abundance of fixed cost or point estimates and the relative scarcity of cost functions.

Fixed Cost Estimates

The most sizeable body of literature related to benefit cost analysis of water pollution control is fixed cost studies for specific treatment strategies. The large number of such studies is at least partially explained by their relative simplicity. The results of such studies are essentially single observations on the cost of a specific type of pollution control.

This type of study potentially offers two contributions to a more rigorous analysis. First, the cost components of a pollution control strategy are identified. Most frequently these are direct investment costs within an engineering framework. Second, such studies may provide the basis for constructing cost functions.

Among the major deficiencies of such studies are their lack of generality (no functions) and the inability to consider trade-offs. Further, in most instances only one or a few of the costs are considered, generally the cost of the pollution control equipment. Costs such as installation, operating power, and engineering design are too often omitted.

Fixed cost estimates are generally concerned with direct fixed capital investments at a point in time and space. Rules of thumb are generally used to determine indirect costs. A common ratio of indirect to direct costs is one-fourth. The spatial variation in costs may be substantial. Because of large differences in land costs from place to place, these are most often not included in the estimates. But even equipment and installation charges may vary significantly from area to area (Zepp and Leary, 1960, Hummel and Smith, 1970).

An example of one of the better industry cost studies is Koenig's study which resulted from cost audits made on 30 plants in 1965 (Koenig, 1967). The study includes unit costs of investment and water treatment factors, a portion of which are contained in Exhibit IV-3. Investment costs were confined to the treatment plant and pumping station and did not include peripheral equipment such as conveyance lines for water or booster station. All investment data were adjusted to 1964 prices and for regional variations. Operating costs included chemicals, energy, manpower, maintenance and repair and a miscellaneous category.

Exhibit IV-3. Design Capacities, Operating Conditions, and Unit Factor Costs at Capacity of 27 Plants Reported by Koenig

Plant No.	Design Capacity K, mgd	Operating Conditions: Average Production, mgd	Use Rate U, fraction	Average Operation Time, hrs/day	Days 32° and Below, days/yr	Capital Cost per Unit Capacity,* ¢/gpd	Unit Costs at Capacity† (¢/kgal.): Chemicals	Pumping	Heating	Manpower	Maintenance‡	Misc.
1	6.00	1.87	0.31	24	11	16.6	0.88	1.59		0.44	0.06	0.03
2	9.00	7.09	0.79	24	17		1.27	1.89		1.58	0.15	0.26
3	8.00	5.82	0.73	24	48	17.8	1.04	0.74		1.05	0.40	0.07
4	6.00	4.71	0.79	24	33	37.3	0.65	2.04		2.16	0.07	0.20
5	0.500	0.166	0.33	8.1	81		1.30	3.26		8.5	0.51	0.11
6	0.500	0.163	0.33	8.7	63	32.2	2.30	3.50		6.0	0.51	0.11
7	0.500	0.342	0.68	17	63	48.6	2.00	3.25		7.80	0.50	1.65
8	0.500	0.157	0.31	7.7	80	46.0	0.80	4.30		7.40	0.72	0.06
9	6.00	1.57	0.26	15	37		0.53	3.90		0.91	0.29	0.03
10	0.300	0.078	0.26	24	85	70.0	4.40	4.8	0.04	1.98	0.58	0.11
12	12.00	11.3	0.94	24	94	5.5	1.78	1.42	0.03	0.89	0.63	0.11
13	4.00	1.87	0.47	16	100	10.1	0.75	1.72	0.04	2.20	0.34	0.11
14	0.432	0.198	0.46	24	148	47.0	0.23	4.63	0.82	5.80	2.92	0.11
15	12.00	4.91	0.41	23	144	17.7	0.61	1.79	0.09	1.76	0.03	0.11
17	12.00	9.25	0.77	24	144	15.0	0.24	0.97	0.08	2.84	0.04	0.02
18§	0.300	0.169	0.56	24	144	29.5	0.81	3.2	0.32	3.30	1.57	0.09
19	8.00	5.66	0.71	24	144	13.7	0.33	0.75	0.13	4.16	0.59	0.13
21	7.50	8.87	1.18	24	11	24.6	0.44	2.68		1.39	0.48	0.12
22	6.81	2.11	0.31	24	65	14.2	1.22	2.02		0.88	0.20	0.11
23	0.576	0.129	0.22	24	65		2.20			7.26		
24	0.504	0.328	0.65	15	83	23.8	3.50		0.006	6.7	0.18	0.02
25	0.504	0.127	0.25	11.5	73	30.0				7.38	0.34	
26	0.500	0.174	0.35	18	70	34.8	2.70	4.30		4.82	0.17	0.05
27	0.486	0.440	0.89	15	70	41.2	0.60	1.46		3.08	0	0.16
28	1.00	0.297	0.30	8	66	27.1	1.77	2.89	0.02	4.80	0	0.11
29	8.00	5.29	0.66	24	59	22.6	1.23	1.61	0.01	1.79	0.16	0.11
30	6.81	3.51	0.52	24	65		0.69	1.15		0.89		0.11

*Data cover the treatment plant and the raw water pumping station. They have been adjusted to 1964 price levels and deregionalized with the Water Treatment Plant construction index.

† All costs are at 1964 price levels.

‡ Values represent $U^{-0.6}$ times the costs at actual use rates reported by Koenig.

§ The only plant using slow sand filtration.

Source: H. Hinomoto, "Unit and Total Cost Functions for Water Treatment Based on Koenig's Data," Water Resources Research, October, 1971.

Cost Function Estimates

Koenig's average cost estimates were developed into unit and total cost functions by Hinomoto (1971). Hinomoto points out that theoretically the relationship between capacity and capital cost can be illustrated by Exhibit IV-4. The capital cost or total operating cost increases with an increase in capacity but at a decreasing rate as indicated in the concave region. The cost then increases at an increasing rate in the convex region of the curve. Such a relationship would indicate why economies of scale dictate the installation of a large unit rather than several smaller units. Using this relationship, Hinomoto uses Koenig's data to obtain the results indicated in Exhibit IV-5.

A variety of factors influence unit cost functions, the most significant of which are summarized in Exhibit IV-6 (Tihansky, 1972; Eckenfelder and Ford, 1967).

Municipal waste treatment cost functions have also been estimated by Smith and Eilers (1970) and Smith and McMichael (1969) based on field surveys. Exhibit IV-7 presents the regression results of these two studies, to indicate the cost components considered in an investigation of this sort.

A digital computer program has also been developed for estimating the capital cost, the amortization cost and the operating and maintenance cost for conventional wastewater treatment plants made up of subsets of the processes listed in Exhibit IV-6, as reported by Eilers and Smith (1971). In this program approximately one hundred cost relationships developed by Black and Veatch Consulting Engineers, Kansas City, Missouri under the terms of Contract No. 14-12-462 with the EPA (1971) were used. Exhibit IV-8 lists the processes that can be costed.

Opportunity Cost Framework

Trade-offs are ignored in the majority of the literature. A notable exception is a study by Krutilla, Cicchetti, Freeman and Russell (1972) in Kneese and Bower (1972).

Exhibit IV-4. Typical Relationship Between Capacity and Capital Cost or Total Operating Cost for Capacity Operation

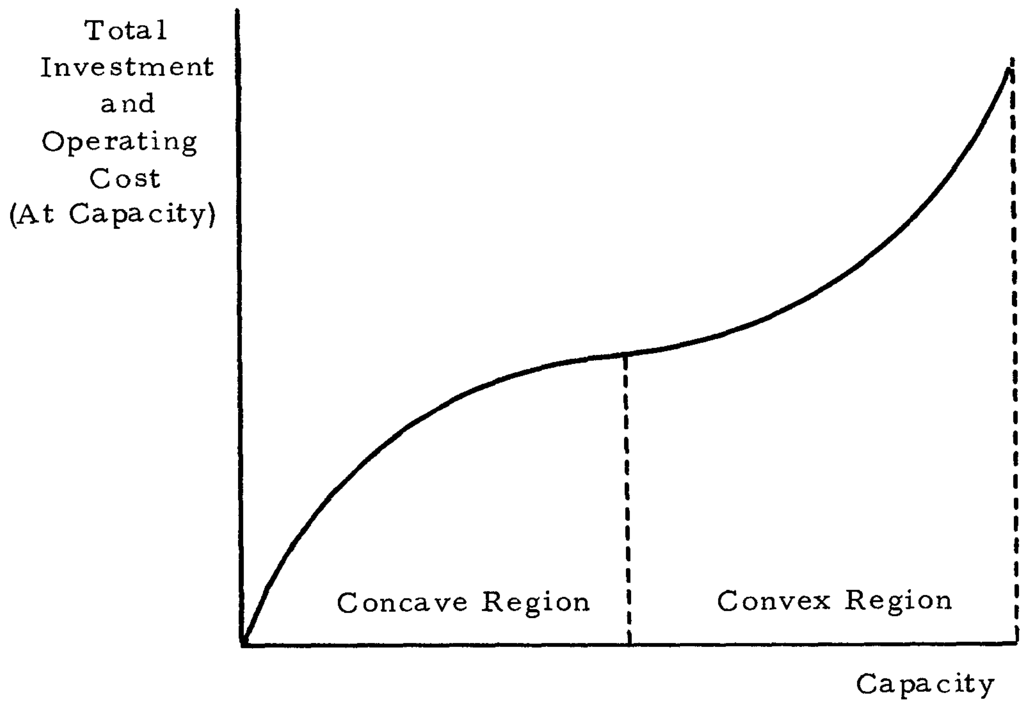


Exhibit IV-5. Unit Cost Functions of Factors of Water Treatment and Their Variability With Daily Use

Rate U

Factor of Water Treatment	Regression Analysis: Data Points Used	Regression Analysis: Coefficient of Determination, r^2	Unit Cost Function for Capacity Operation, plant capacity K, mgd	Cost Variability with U
Capital investment*	21	0.595	30.86 $K^{-0.323}$ (¢/gpd)	Fixed
Chemicals	26	0.192	1.20 $K^{-0.236}$ (¢/kgal.)	Variable with U
Pumping energy	18	0.517	2.78 $K^{-0.262}$ (¢/kgal.)	Variable with U
Heating energy (140 days below 32°F)†	5	0.827	0.307 $K^{-0.519}$ (¢/kgal.)	Fixed
Manpower‡	15	0.320	2.73 $K^{-0.313}$ (¢/kgal.)	Fixed
Maintenance and repair	24	0.311	0.405 $K^{-0.421}$ (¢/kgal.)	Variable with $U^{0.5}$
Miscellaneous	25	0.013	0.102 $K^{-0.070}$ (¢/kgal.)	Fixed

* Data points do not include plant 18, the only plant using slow sand filtration.
† Data points are related to plants in the climatic zone having 140 days below 32°F a year.
‡ Data points are related to plants operating 24 hours a day.

Source: H. Hinomoto, "Unit and Total Cost Functions for Water Treatment Based on Koenig's Data," Water Resources Research, October, 1971.

Exhibit IV-6. Most Significant Determinants in Unit Treatment Cost Functions

Primary Treatment	Basic Determinant
Equalization	Volume (gal.)
Neutralization	Flow rate (mgd)
Oil Separation	Flow rate (mgd)
Sedimentation	Surface Area ($ft.^2$)
Biological Treatment	
Activated Sludge	Volume (mg)
Aerated Lagoons	Volume (mg)
Aeration Basin	Volume (mg)
Final Clarifier	Surface Area ($ft.^2$)
Lagoons	Surface Area (acre)
Tertiary Treatment	
Adsorption (carbon)	Flow Rate (mgd)
Filtration	Flow Rate (mgd)
Ion Exchange	Flow Rate (mgd)
Sludge Handling and Disposal	
Flotation Thickening	Flow Rate (mgd)
Thickening	Volume (gal)
Total Sludge Disposal	Flow Rate (mgd)
Vacuum Filtration	Area ($ft.^2$)

Source: Tihansky, Dennis. Water Pollution Cost of Control Functions: A State-of-the-Art Review, Economic Analysis Branch, EPA, Washington, D. C., 1972. (Unpublished Report)

Exhibit IV-7. Cost Functions of Municipal Waste Treatment

	Regression Coefficients			
	Capital Costs		O & M Costs	
Technology	a	b	d	e
Ordinary Treatment				
Primary Sedimentation	675.7	-.33	25.0	-.26
Activated Sludge	912.7	-.31	30.1	-.25
Trickling Filter	942.0	-.31	55.0	-.36
Waste Stabilization Ponds	2,863.1	-.61	17.4	-.42
Upgrading Primary to Activated Sludge	1,484.0	-.41	--	--
Ancillary Works*	86.3	-.09	--	--
Tertiary Treatment				
Microscreening	9.4	-.12	.3	-.04
Filtration	207.1	-.34	51.3	-.38
Two-Stage Lime Clarification				
-Less than 10 mgd	140.9	0.26	148.6	-.44
-Greater than 10 mgd	50.1	-.18	12.0	-.23
Lime Recalcination				
-Less than 10 mgd	1,903.2	-.50	30.0	-.30
-Greater than 10 mgd			9.4	-.21
Ammonia Stripping				
-Less than 10 mgd	22.7	-.10	35.5	-.33
-Greater than 10 mgd			3.5	-.13
Carbon Adsorption				
-Less than 10 mgd	1,439.6	-.40	1,418.9	-.55
-Greater than 10 mgd	76.0	-.14	23.9	-.20

Source: Tihansky, Dennis. Water Pollution Cost of Control Functions: A State-of-the-Art Review, Economic Analysis Branch, EPA, Washington, D. C. 1972.

Smith, R. and R. Eilers, "Cost to the Consumer for Collection and Treatment of Wastewater," NTIS, July, 1970, PB210 199, Rept. 17090.

Smith, R. and W. McMichael, "Cost and Performance Estimates for Tertiary Waste Water Treating Processes," EWQA, Cincinnati, June, 1969.

Exhibit IV-8. Treatment Processes that can be Costed by the Wastewater Treatment Plant Cost Estimating Program

Raw Sewage Pumping
Preliminary Treatment (Grit Removal, Flow Measurement)
Preliminary Treatment (Grit Removal, Flow Measurement, Screening)
Primary Sedimentation (Single Basin)
Primary Sedimentation (Multiple Basin)
Primary Sludge Pumping
Aeration Basin Structure
Aeration Diffused Air
Mechanical Aeration Equipment
Flocsillator
Trickling Filter
Intermediate Pumping
Final or Intermediate Sedimentation (Single Basin)
Final or Intermediate Sedimentation (Multiple Basin)
Recirculation Pumping
Stabilization Ponds
Sludge Thickener
Anaerobic Digestion and Building
Aerobic Digestion
Sludge Holding Tanks
Vacuum Filtration (Landfill Disposal of Sludge)
Vacuum Filtration (Incineration Disposal of Sludge)
Centrifugation
Sludge Drying Beds
Sludge Lagoons
Multiple Hearth Incineration
Fluidized Bed Incineration
Chlorination Building and Equipment
Chlorination Contact Basin
Administrative and Laboratory
Garage and Shop
Yardwork
Laboratory - Activated Sludge
Laboratory - Trickling Filter
Laboratory - Primary Plant

Source: R. G. Eilers and Robert Smith, "Wastewater Treatment Plant Cost Estimating Program," Environmental Protection Agency, Water Quality Office, Advanced Waste Treatment Research Laboratory, Gincinnati, Ohio, April 1971.

The basic objective of this study is to provide a framework of analysis to determine the opportunity cost as well as the preservation value of an irreplaceable asset. Although three types of irreplaceable assets are mentioned, the main portion of the paper emphasizes "gifts of nature" irreplaceable assets resulting from accidents of geomorphology, biological evolution, and ecological succession. For the purpose of developing their model as well as for illustrative purposes, the authors use the Hells Canyon case in discussing the economics of irreplaceable assets.

The model is developed by first considering the proposed hydroelectric alternative in the Hells Canyon case. A rather straightforward approach is utilized for this purpose by deriving a formula which gives the present value of the development alternative for the Hells Canyon region. One interesting modification to the traditional present value technique is the fact that it takes into consideration the depreciation through obsolescence resulting from changing technology in the production of energy from alternative nonhydroelectric sources. This tends to give a more accurate account of the benefit derived from developing an irreplaceable asset.

For the purpose of evaluating the benefits derived from the development alternative, the authors consider at this point in the analysis the preservation alternative. It is found that as a result of changes in income, population and tastes, a point will be reached beyond which the use of the area by one or more individual per unit time will result in a lessening of the utility obtained by others using the area. The authors define this point to be the capacity of Hells Canyon for the purpose of the analysis since it provides for a quantity of constant quality services.

Growth in the demand for services of the area and a capacity constraint introduce some complications in the analysis. First, as income, population, and tastes change through time, the usual ceteris paribus assumption must be relaxed. Accordingly, the shape and area under the demand curve may be expected to change with temporal shifts in the demand curve. Such shifts are incorporated into the benefit estimating procedure and are treated separately. Secondly, the capacity constraint presents another complication since it sets a limit on the range over which the quantity demanded can be summed without further adjustments.

With these complications acknowledged, the authors proceed to derive the present value formula for the preservation alternative.

While some of the values of the preservation alternative are measurable, the values of others are not yet open to economic measurement according to the authors. As a result, the analysis does not try to calculate the present value of services yielded from Hells Canyon. Instead, the authors ask what this value would need to be in order to equal or exceed the present value of the development alternative. Additionally, they ask what the base year's annual benefit would need to be to have a present value equal to or greater than the development alternative. This latter step is of considerable analytic assistance by virtue of the difference in the relation between the initial year's benefit and the total present value for the two alternative uses of the area. This is because of the asymmetry in the behavior of the value of the output streams from the two incompatible uses of the site. Accordingly, although the annual benefit of the developmental alternative in the initial year may be quite large, given the relation between the rate of growth in annual benefits for the preservation alternative and the discount rate in the present value computational model for preservation benefits, the initial year's benefits of the latter may need to be only very modest.

At this state in the analysis, the computational results of the model for the Hells Canyon region were presented. Since the readily observed initial year's benefits appeared to be in excess of the minimum that would be required to have their present value exceeded by the present value of developmental benefits, it was concluded that the preservation alternative should be preferred to the development alternative for the Hells Canyon case.

One final complication considered in evaluating preservation benefits referred to the option value of a preservation alternative. According to the authors, when an irreplaceable asset providing services without close substitutes is under consideration for development, there are individuals who are uncertain potential demanders of the services of such an existing asset who should also be taken into account in a decision regarding the continuation or discontinuation of the services of the facility in question. The option value may, therefore, be a very important factor in terms of whether the irreplaceable asset is preserved or developed. As a result, the analysis proceeds to consider the two measures of consumer surplus and to define option price and option value rigorously and to distinguish these concepts from the two measures of consumer surplus so that double counting does not arise.

Programming Models

Because of the difficulties in estimating benefits, a common approach is that of assuming certain standards to be met and proceeding to minimize costs in attaining these standards. A variety of linear and non-linear programming models have emerged (Lee, Erickson and Fan, 1971; Kneese, 1967).

These models are more concerned with form than data. The optimizing techniques provide a framework within which certain trade-offs can be considered. Most frequently the models are developed without data.

New techniques more efficient in dealing with nonlinearities, stochastic variables and other complications have increased the practicability of many heretofore unrealistic programming models. One promising type of programming model that is becoming increasingly useful is the river basin simulation model. This model allows one to introduce a variety of institutional, economic and physical changes in the model area and observe the various impacts as well as trace the interactions through the system via the simulation framework.

Even though there are limitations in the number and type of functions that can realistically be incorporated in programming models, as well as computer storage and time constraints, an increasing number of programming models are being developed and utilized with increasing success.

Many of the programming models prevalent in the literature deal with quantity as opposed to the quality facets of water management. It is further characteristic of many programming models to develop theoretical relationships and mathematical formulations that offer little in the way of application or implementation value. One notable exception, however, is the pioneering Delaware estuary study. The preliminary report was issued by the Federal Water

Pollution Control Administration in 1966--Delaware Estuary Comprehensive Study: Preliminary Report and Findings, in Kneese, Rolfe and Harned (1971).

With the aid of a rigorous mathematical model an attempt was made to represent the assimilative and waste transport capacity of the estuary to ascertain the effects of increased or decreased waste discharges on any part or all of the estuary. The study further combined many physical, biological and chemical water quality relationships of the estuary into an economic optimization (linear programming) model with the objective of developing a systematic analysis of regional water quality.

An explicit attempt was also made to measure all external costs and to determine the total cost of meeting various selected water quality standards. For example, Exhibit IV-9 presents the computed cost of achieving four water quality objective functions.

One of the more interesting and unique features of this study is that it also explored the feasibility of implementing effluent taxes or charges as an economic incentive for controlling waste discharge. The consensus of the Federal Water Pollution Control Administration staff was that the imposition of effluent taxes or charges should be seriously considered as a method of attaining and maintaining water quality improvement. Further advances have been made with this large-scale study, including linkages between water quality and other environmental resource qualities.

Pollution Control Cost Summary

Water pollution control cost estimates are by the intrinsical nature of the problem highly project and area oriented and consequently are not amenable to generalization. First of all water quality control cannot be characterized by a single variable but instead depends on many interrelated physical, engineering, economic and social factors which, due to their varying nature cannot be easily generalized. Secondly, there are unique costs associated with varying degrees of control, effluent loads, influent loads and treatment strategies.

Exhibit IV-9

Summary of Total Costs of Achieving Objective Sets 1, 2, 3, and 4
(Costs include cost of maintaining present (1964) conditions and reflect waste-load conditions projected for 1975-80.)
Flow at Trenton = 3,000 cfs

(million 1968 dollars)

	Uniform treatment			Zoned treatment			Cost minimization		
Objective set	Capital costs	O&M costs[a]	Total costs	Capital costs	O&M costs[a]	Total costs	Capital costs	O&M costs[a]	Total costs
1	180	280 (19.0)	460[b]	180	280 (19.0)	460[c]	180	280 (19.0)	460[c]
2	135	180 (12.0)	315[c]	105	145 (10.0)	250[c]	115	100 (7.0)	215[c]
3	75	80 (5.5)	155[c]	50	70 (4.5)	120[c]	50	35 (2.5)	85[c]
4	55	75 (5.0)	130	40	40 (2.5)	80	40	25 (1.5)	65

[a]Operation and maintenance costs, discounted at 3 per cent, twenty-year-time horizon; figures in parentheses are equivalent annual operation and maintenance costs in millions of dollars/year.

[b]High-rate secondary to tertiary (92-98 per cent removal) for all waste sources for all programs. Includes in-stream aeration cost of $20 million.

[c]Includes $1-$2 million for either sludge removal or aeration to meet goals in river sections #3 and #4.

Source: A. V. Kneese and B. T. Bower, Managing Water Quality: Economics, Technology, Institutions (Baltimore: Johns Hopkins Press, 1968).

To further complicate the problem, the economic and physical properties of any area are not static, but dynamic in nature. That is, demographic and production patterns change over time, thereby creating or changing economic and demographic agglomerations which in turn create differential impacts on effluent flows and consequently environmental quality. There is also evidence to indicate that as the degradation of the environmental quality increases, the costs associated with restoring or maintaining a given level of environmental quality may increase at an exponential rate.

Changing pollution abatement technology (also in an infancy-stage of development) further increases the uncertainty of estimating waste management control costs.

These factors further reiterate the need to devise an aggregation framework to arrive at national water pollution control cost estimates. There is also the obvious need to develop methods whereby pollution control cost estimates can be generalized to the extent that they can be applied to homogeneous regions, processes and pollutants.

SECTION V

BENEFIT MEASUREMENT

Estimation of benefits of water pollution control is the most underdeveloped aspect of benefit cost analysis. It is both difficult to determine the nature of the benefits and to measure them once they are identified. The lack of price signals to indicate private benefits plus the existence of strong externalities which would result in a departure between social benefits and private benefits complicates the task of benefit identification and measurement.

Numerous benefits result from water pollution control programs such as a more economic utilization of natural resources, preservation of fish and wildlife, and protection of the region's health and welfare. Detailed specification and quantification of such benefits is meager, first, because the area has only recently come under serious investigation, and, second, because the benefits are primarily intangibles. How much is more palatable drinking water worth? From a recreational standpoint how much is a "clean" river worth? A wide spectrum of benefits are of this elusive type. Industrial water quality benefit estimate problems are little different as a result of variations in operating policy, type of construction, method of water use, and degree of water treatment.

Some Benefit Measurement Approaches

A variety of approaches to benefit measurement resulting from and/or expected with water pollution control have appeared in the literature. In general each approach only attempts to partially estimate benefits rather than to comprehensively assess health, esthetic, production and other ecologic-based benefits. A brief outline of these approaches is as follows.

(1) Direct Benefit Measurement. Several attempts have appeared in the literature to directly estimate benefits. Among the benefits specified are factors of improved health, esthetics, and greater production or income. Most of the studies choose to focus on a single measure of benefit based on the assumption (or hope) that the single variable will capture the effects of

a multiplicity of benefits. The difficulty with direct measures is both conceptual and empirical. No single measure is adequate and it is difficult to quantify several measures in an additive manner.

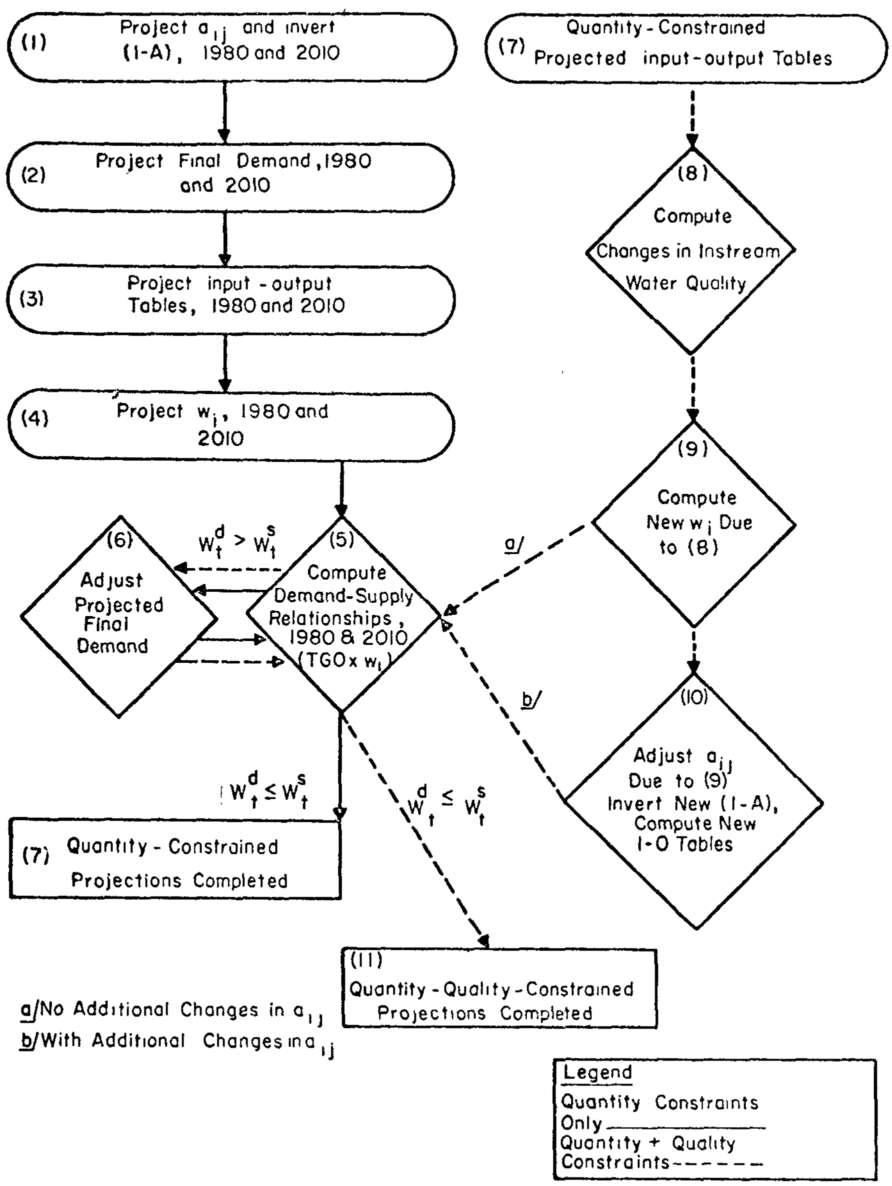
Estimation of actual or potential damage reductions as a result of water pollution control have also been attempted. The users of polluted water incur some type of harm which may be translatable into a pecuniary cost. Often studies of this sort may be concerned only with estimating damages from imposing water quality constraints. An example of such a study which can be translated into a useful measurement of benefits is the Colorado river study. A flow diagram of the projections model used in that study appears below in Exhibit V-1 (Miernyk, 1969).

(2) Attitudinal Analysis. An effort has been made by psychologists to provide cardinal measures of consumer value of water projects via attitude analysis, (Deal and Halbert, 1971). Attitude factors toward recreation which were analyzed included feelings about self and nature, sociability, feelings for the ocean, physical comfort, physical activity and accomplishment in hiking, privacy and solitude, opposition to park development, the existence of parks, and rest. Factor analysis was used to answer a multiplicity of questions asked of park visitors in order to obtain a dollar value of a particular park.

(3) Intangible Benefit Analysis. Intangible benefits have been approached from several directions: the monopoly and discriminating monopoly methods, consumer surplus method, the expenditures method, the Gross National Product method, cost method and the market value method. The discriminating monopoly approach was developed by Clawson (1959) and set off a series of extensions (Knetsch, 1963 and 1964; Merewitz, 1966; Stevens, 1966).

Merewitz computed consumer surplus in estimating recreational benefits for part of the Lake of the Ozarks. Stevens utilized the same concept explicitly in a recreation study where he identified recreational benefits as the consumer surplus that would result from the prevention of water pollution. Stevens used market demand curves for sport fishery expressed in terms of both price and quality of water.

Exhibit V-1. Flow Diagram, Colorado River Basin Input-Output Projections



Source: Miernyk, William H., An Interindustry Forecasting Model with Water Quantity and Quality Constraints, Reprint Series III, No. 8, Reprinted from Systems Analysis for Great Lakes Water Resources, Proceedings of the Fourth Symposium on Water Research of Ohio State University, Water Resources Center, October 1969, Regional Research Institute, West Virginia University, Morgantown, 26506

A major recent contribution to benefit estimation enables the derviation of the willingness to pay for public goods on the basis of information on demand functions for private goods (Mäler, 1971). The key to the approach is the identification of a private good that is complimentary to a public good. Revealed preferences in the market can then be transferred from the private good to the public good. The approach can specify both Marshallian and Hicksian demand functions.

(4) 'Proxy' Variable Approaches. Various attempts have been made to associate water pollution control benefits with quantifiable 'proxy' variables such as property value levels and travel cost estimates. These variables are believed to represent multiple health, esthetic and production-oriented impacts.

The property value method can be represented in the following manner (Rothenberg, 1967).

$$\Delta P = \Delta P_e + \Delta P_d + \Delta P_l$$

where

ΔP = the total change in property price

ΔP_e = the change in property price attributalbe to technical enhancement

ΔP_d = the change in property price attributable to demolition of previous existing properties

ΔP_l = the change in property price attributable to changes in locational advantages

Benefits of urban water resources property values were analyzed with regression analysis which included distance from an urban lake and quality of property with benefits in the $1.3 to $1.5 million range.

The property value model has two theoretical limitations. The value of property does not reflect consumer surplus and benefits to users outside of the region are not captured.

The travel cost proxy method is of the following form (Merewitz, 1966 and 1968):

$$\frac{V_i}{P_i} = \frac{1}{b} [(t_i+f)-a]$$

where

V_i = visitor days per year from zone i

P_i = population of zone i

t_i = travel cost from zone i

f = gate fee

a,b = parameters

Consumer surplus was estimated for the same lake with 20, 50, and 100 year life with estimated benefits of $165,000 to $201,000 for residents within 3,000 feet.

(5) Multiple Benefit Component Approaches. The combined effects of several variables are included in Battelle's three stage recreation model (Cesario, 1971). A schematic diagram of the model is presented below. The resulting output of the model are demand curves for recreation. Participation is measured via population, socioeconomic characteristics and accessibility. This phase of the model is essentially a travel cost model. The distribution component a gravity model to the analysis. A demand curve is developed using cost increments corresponding to travel costs.

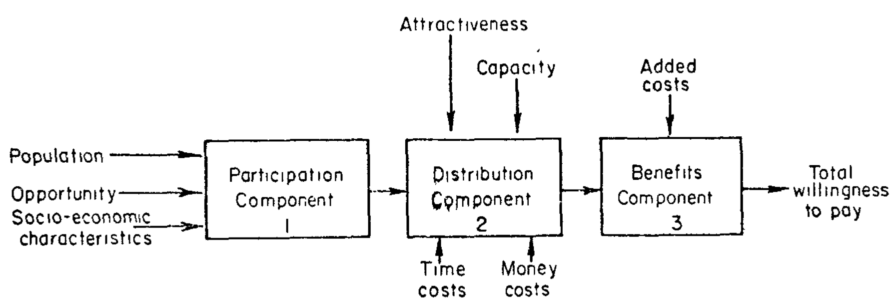


Exhibit V- 2. Schematic Three-stage Battelle Recreation Model

Time Profile

The question of the time path of benefits of water pollution control has been investigated to determine temporal benefit functions (Parker and Crutchfield, 1968). Parker and Crutchfield conclude that there are three benefit functions over time: constant, increasing at a constant rate, and increasing at a compound rate. The latter two types result in the significant portion of the benefits accruing in the later years.

In order to adequately measure benefits over time, projections are required for the factors benefiting from a pollution control project.

An important aspect of the analysis of public policy alternatives which operate over several years is the choice of the proper interest rate for discounting future (projected) net benefits. If one alternative has a greater net benefit in each year than that of any other, there is no question as to the identification of the superior alternative. If no alternative dominates over all periods, it is necessary to compare the present value of the net benefits generated by each. In order to compute the present value, the rate of interest must be specified. A high interest rate is favorable to alternatives with high initial net benefits and short life. A low interest rate is favorable to extremely long benefit streams which may initially be quite low.

It is proposed by some that the social rate of time peference is the proper choice of interest rate for discounting public benefit streams. Externalities in the consumption sphere will result in a social rate of time preference that differs from the private rate of time preference. Marglin (1963) has demonstrated the situation in which each individual is not willing to provide for future generations separately, but operating as a group they find it desirable to provide for the future. Eckstein (1961) concludes that even from the narrow view of economic efficiency the selection of a discount rate cannot be solved without the use of strong value judgments. Marglin, as well as others, suggests that the solution of the social rate of time preference is determined by the community through the political system. It might seem logical that society as a whole may place a higher value on providing for future generations than would be demonstrated in the market.

Problems in Estimating Pollution Control Benefits

The benefit measurement approaches outlined reflect that only fragmentary and non-comprehensive approaches have been used to estimate water pollution control benefits. Approaches used have a common characteristic of being individual-receptor oriented.

The latter condition is appropriate, but little serious attention has been previously given to 'aggregating' receptor-oriented benefits on region-wide or national bases. This could be anticipated, however, since no single agency has heretofore been responsible for such aggregations.

Even now that EPA has at least an implicit if not explicit responsibility to pursue such aggregations-of-benefit from pollution control, then the first mentioned problem remains. That is, only fragmentary approaches which are non-independent and incomplete are known. It is not expected that the sum of fragmentary pieces, even if they could readily be estimated, would necessarily equal the as yet unidentified 'total' benefit. Criticism would be aimed at the presumed overlapping benefits of multiple approaches, especially the proxy variable approaches. While one might attempt to only aggregate a single type of benefit, e.g. esthetics, so as to avoid the problems of double counting, then it remains that such an aggregate would fail to comprehensively estimate pollution control benefits.

These types of problems need to be dealt with directly rather than side-stepped as in the past if meaningful benefit cost analyses are to evolve. Conventional procedures appear inadequate in dealing with the types of benefits involved with environmental quality issues. In order to discover improved methods of 'quantifying' or otherwise valuing environmental benefits, it should be expected that innovative and thus unconventional procedures will become involved.

Some implications for planning and research are subsequently presented in this report. A conclusion at this point is simply that traditional benefit measurement methods have failed to adequately value the consequences of water pollution externalities.

SECTION VI

BENEFIT COST AGGREGATION FRAMEWORK

Two distinct sets of information and data are important in this study: (1) pollution control benefits and (2) pollution control costs. This information and data should be generated so that comparable aggregations of benefits and costs (estimates and functions) can be made. In this way economic trade-offs can be measured and various policy alternatives assessed. Such a framework is also desired in order to meaningfully develop research needs and priorities.

Source-Receptor Orientation

As has been described, water pollution control costs are highly variable and dependent on many diverse factors. The spatial inter- and intradependence of many facets of water pollution control are critical. Effluents of one geographic area affect the influents of downstream river reaches and receptors. Attempts to modify effluent loads through pollution abatement activities directly impacts the controlled region and also indirectly all downstream receptors. For example, pollution abatement in headwater regions may result in favorable externalities in downstream areas by way of reduced influent loads. The actions in one segment of a basin thereby influence water pollution control costs in downstream segments of the same basin (but not influent loads nor water pollution control costs in upstream river reaches or in other independent drainage basins). The thrust of the discussion is that water pollution control costs within a basin are typically spatially interdependent and may not be additive nor easily generalized to accurately represent national water pollution control cost estimates or functions.

The benefit side of the analysis encounters the same complications. Location-preserved analyses are necessary. These conclusions indicate the need for an aggregation framework to reflect source-receptor orientations.

An Operational Hydrologic Framework

The above mentioned physical intrabasin relationships and the desirability of tracing or tracking specific pollutants through the hydrologic basin suggest that the most realistic approach to benefit and cost aggregation is on a hydrological basis. Other political, economic and geographic aggregation schemes fail to capture the 'location-dependent' aspects of pollution control costs and benefits.

Such a framework has been suggested and partially implemented on a hydrologic-geographic basis by the Water Resources Council. The Water Resources Council is charged with maintaining a continuing study and preparing an assessment of the adequacy of supplies of water necessary to meet the water requirements in each water resource region of the United States (Exhibit VI-1). As a part of this responsibility, the Water Resources Council has developed a National Assessment of Water and Related Land Resources. A system for definition of water resource regions and subregions according to various geographic units is contained in their Assessment.

The twenty major U. S. water resource regions are further broken into subregions on hydrologic bases (Exhibit VI-2); and, furthermore, into subareas on a county basis (Exhibit VI-3). The latter breakdown/aggregation system is proposed as the key to integrating much of the existing benefit/cost data available. Thus, it is possible to aggregate from a county basis to subareas, which in turn approximate subregions. (Subregions may be aggregated to water resource regions to a national basis. This aggregation system is most logical in terms of assessing benefits of pollution control because benefits/damage-reductions typically occur within hydrologic oriented areas.) Since the Assessment breaks down to a county basis it is compatible with many available sources of economic and other secondary data.

As a final note concerning the proposed suitability and general completeness of the Assessment framework for cross-classification of various geographic units, a sample table is shown in Exhibit VI-4. This Exhibit and the results of the first National Assessment were published July, 1970 by the Water Resources Council under the title "Water Resources Regions and

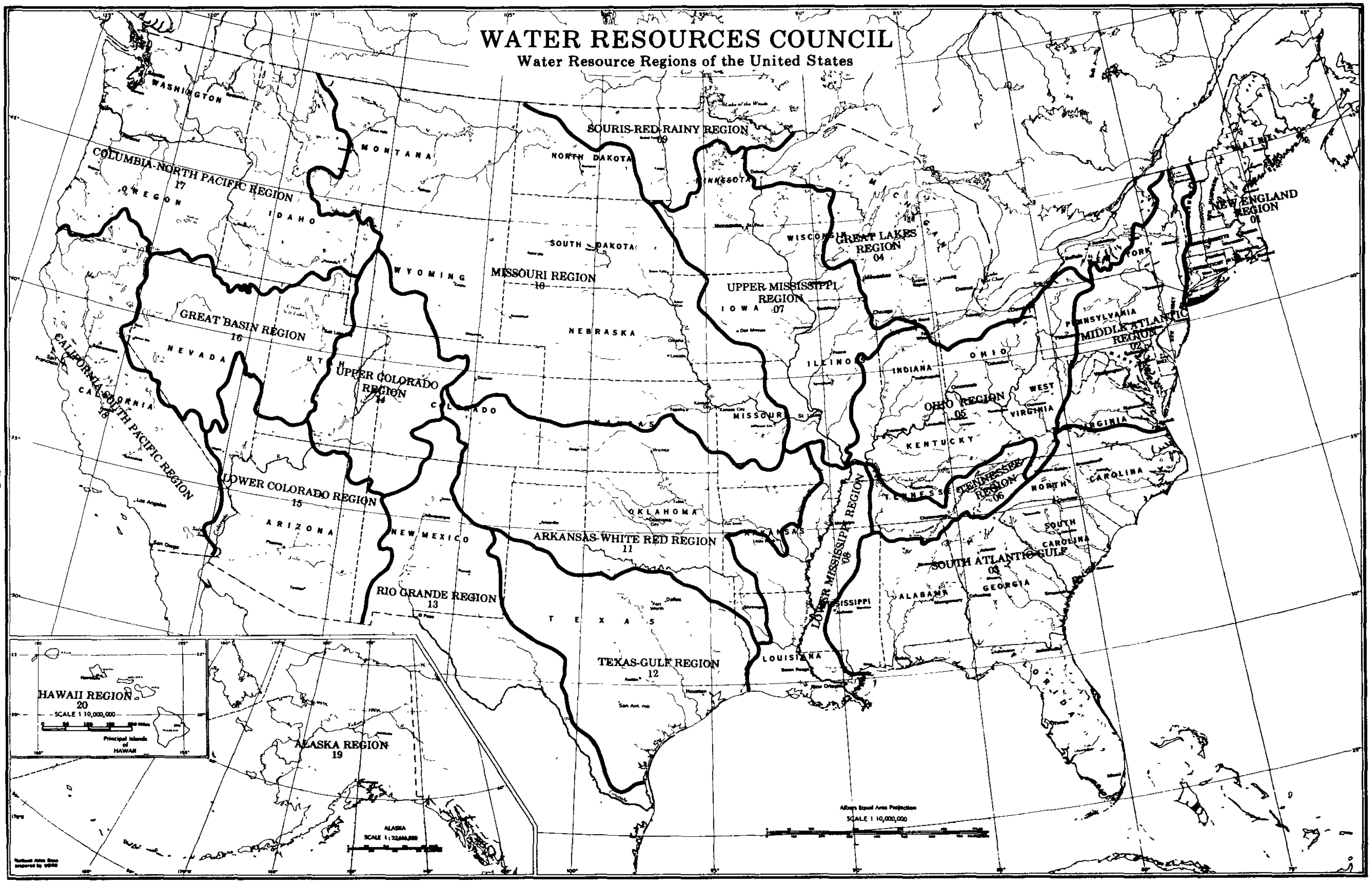

WATER RESOURCES COUNCIL
Water Resource Regions of the United States
NEW ENGLAND REGION 01
MIDDLE ATLANTIC REGION 02
SOUTH ATLANTIC-GULF REGION 03
GREAT LAKES REGION 04
OHIO REGION 05
TENNESSEE REGION 06
UPPER MISSISSIPPI REGION 07
LOWER MISSISSIPPI REGION 08
SOURIS-RED-RAINY REGION 09
MISSOURI REGION 10
ARKANSAS-WHITE RED REGION 11
TEXAS-GULF REGION 12
RIO GRANDE REGION 13
UPPER COLORADO REGION 14
LOWER COLORADO REGION 15
GREAT BASIN REGION 16
COLUMBIA-NORTH PACIFIC REGION 17
CALIFORNIA-SOUTH PACIFIC REGION 18
ALASKA REGION 19
HAWAII REGION 20
WASHINGTON
OREGON
IDAHO
MONTANA
WYOMING
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
NEVADA
UTAH
CALIFORNIA
ARIZONA
NEW MEXICO
TEXAS
OKLAHOMA
IOWA
ILLINOIS
INDIANA
OHIO
KENTUCKY
WEST VIRGINIA
PENNSYLVANIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
ALABAMA
LOUISIANA
SCALE 1:10,000,000
Albers Equal Area Projection

Exhibit VI-1

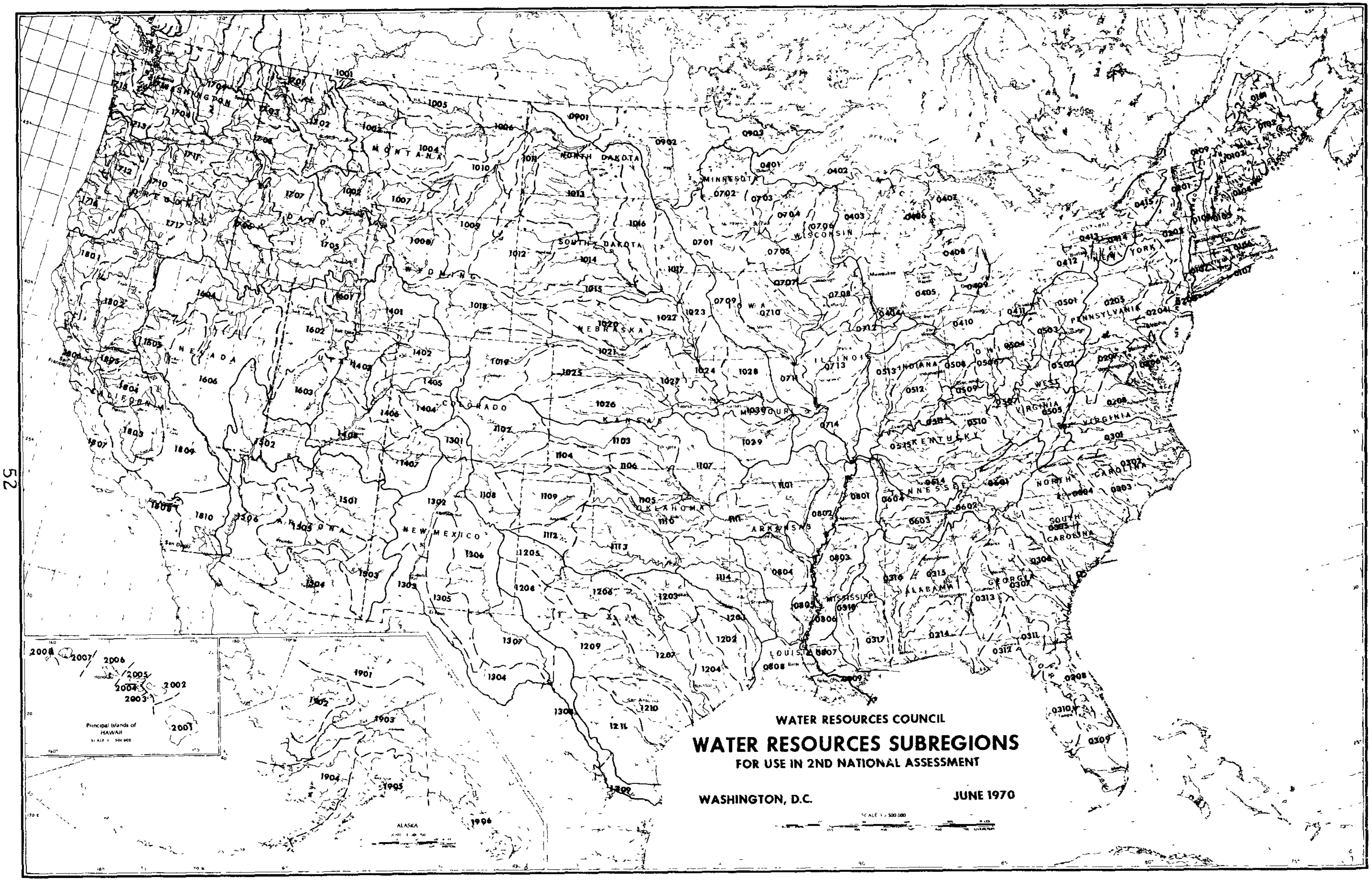

WATER RESOURCES COUNCIL
WATER RESOURCES SUBREGIONS
FOR USE IN 2ND NATIONAL ASSESSMENT
WASHINGTON, D.C.
JUNE 1970

Exhibit VI-2


There is no sub-area 1001
Water Resources Council
WATER RESOURCES SUBAREAS
For Use in National Assessment
Washington, D.C.
July 1970
Scale 1:5,000,000
Scale 1:10,000,000
ALBERS EQUAL AREA PROJECTION

Exhibit VI-3

06.--TENNESSEE REGION--The drainage of the Tennessee River

Subregions

0601.--Upper Tennessee: The Tennessee River above Watts Bar Dam, which includes the Clinch, Holston, French Broad, and Little Tennessee Rivers

Region	Sub-area	Name		State	County	Economic area	Land Resource		SMSA
		County	State				Group	Area	
06	01	Avery	North Carolina	37	011	027	58	130	
		Buncombe	North Carolina	37	021	027	58	130	0480
		Graham	North Carolina	37	075	027	58	130	
		Haywood	North Carolina	37	087	027	58	130	
		Henderson	North Carolina	37	089	027	58	130	
		Jackson	North Carolina	37	099	027	58	130	
		Macon	North Carolina	37	113	027	58	130	
		Madison	North Carolina	37	115	027	58	130	
		Mitchell	North Carolina	37	121	027	58	130	
		Swain	North Carolina	37	173	027	58	130	
		Transylvania	North Carolina	37	175	027	58	130	
		Yancey	North Carolina	37	199	027	58	130	
		Anderson	Tennessee	47	001	050	59	128	3840
		Blount	Tennessee	47	009	050	59	128	3840
		Campbell	Tennessee	47	013	050	58	125	
		Carter	Tennessee	47	019	051	58	130	
		Claiborne	Tennessee	47	025	050	59	128	
		Cocke	Tennessee	47	029	050	58	130	
		Cumberland	Tennessee	47	035	050	58	125	
		Grainger	Tennessee	47	057	050	59	128	
		Greene	Tennessee	47	059	051	59	128	
		Hamblen	Tennessee	47	063	050	59	128	
		Hancock	Tennessee	47	067	051	59	128	
		Hawkins	Tennessee	47	073	051	59	128	
		Jefferson	Tennessee	47	089	050	59	128	

Exhibit VI-4. Sample data, National Assessment of Water and Related Land Resources.

Source: Water Resources Regions and Subregions for the National Assessment of Water and Related Land Resources, Water Resources Council, Wash., D. C., July 1970.

Subregions for the National Assessment of Water and Related Land Resources." The National Assessment provides a general appraisal of the overall water supply and requirements situation, including environmental quality aspects, and of the future national needs for water-related goods and services based upon correlated projections of population and economic activity in each region of the Nation. The National Assessment process is a continuing study reported every five years and will be based upon and serve as a national constraint to regional framework studies.

Benefit and Cost Aggregation Schemata

To further indicate the proposed aggregation framework in terms of this study, two preliminary framework schemata are shown in Exhibit VI-5 and VI-6 for (1) Cost Aggregation and (2) Benefit Aggregation, respectively.

As implied in Exhibit VI-5, pollution control cost data, by major type of pollutant, are largely available on a sub-county basis, e.g., from the original 1962 inventory of municipal and industrial wastes and subsequent updates carried out by the Federal Water Pollution Control Administration (now the Water Quality Office of EPA). This may be aggregated to a county-level and subsequently aggregated in various ways to eventually derive a national aggregate. In particular, given the Water Resources Council National Assessment Areas framework, it is noted that the cost aggregation may be displayed by water subregions and regions (approximate).

In Exhibit VI-6, pollution control benefit data is also shown in relation to the various ways of achieving a national aggregate. However, it is proposed that county data, if derived, will necessarily be related to basin and subbasin factors within each specific county. Hence, county estimates will involve hydrologic-area considerations as appropriate. It is noted, however, that the county level aggregation could be by-passed in terms of benefit aggregations in some cases if desired. The level-of-aggregation specified when estimating benefit cost relationships will be important in actual implementation efforts. The generalized framework shown is proposed as one which could fulfill various needs (as yet not fully specified) implicit in the proposed study.

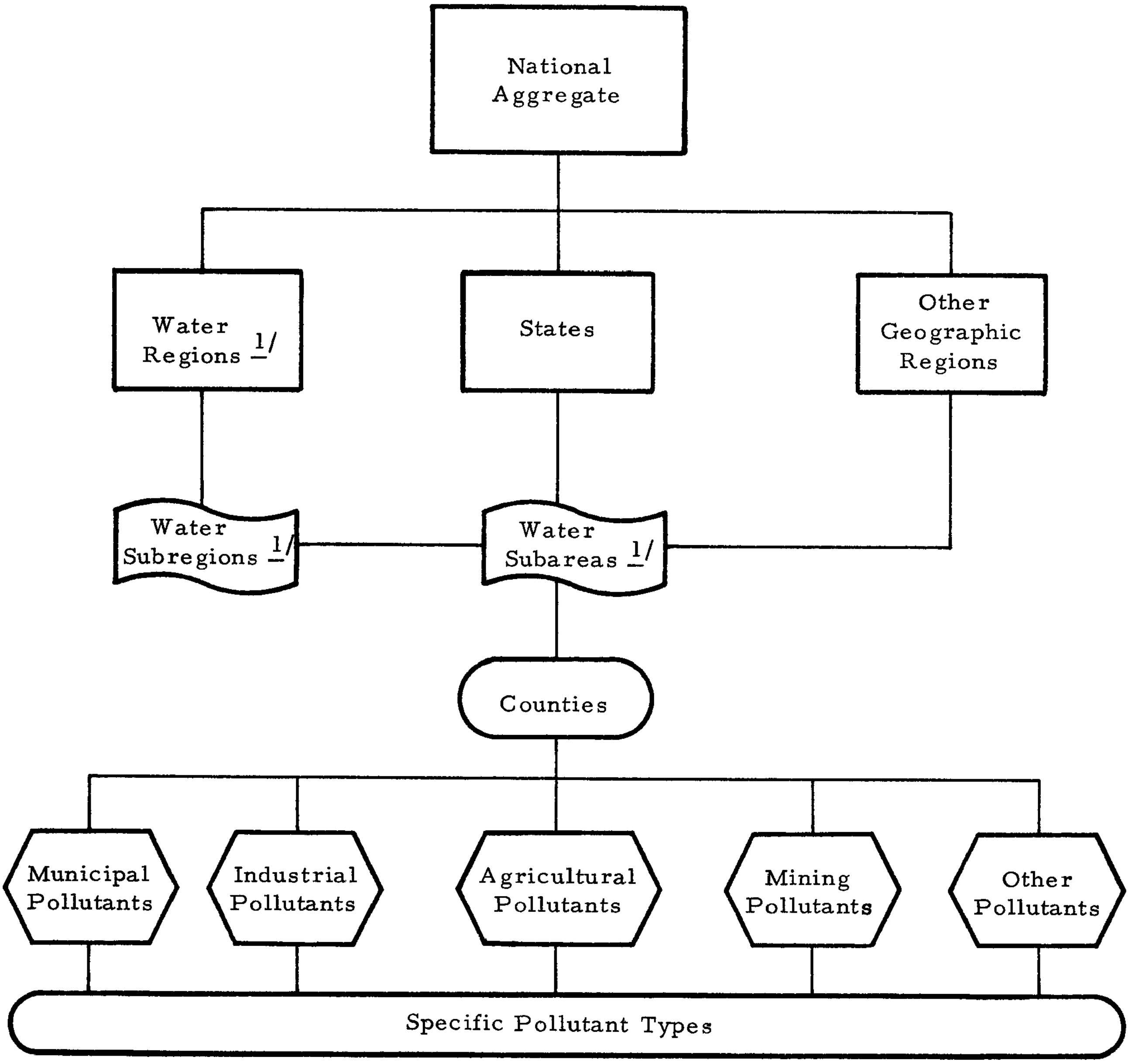


Exhibit VI-5. Water Pollution Control, Cost Aggregation Schema

1/ Based on Water Resources Council National Assessment Areas.

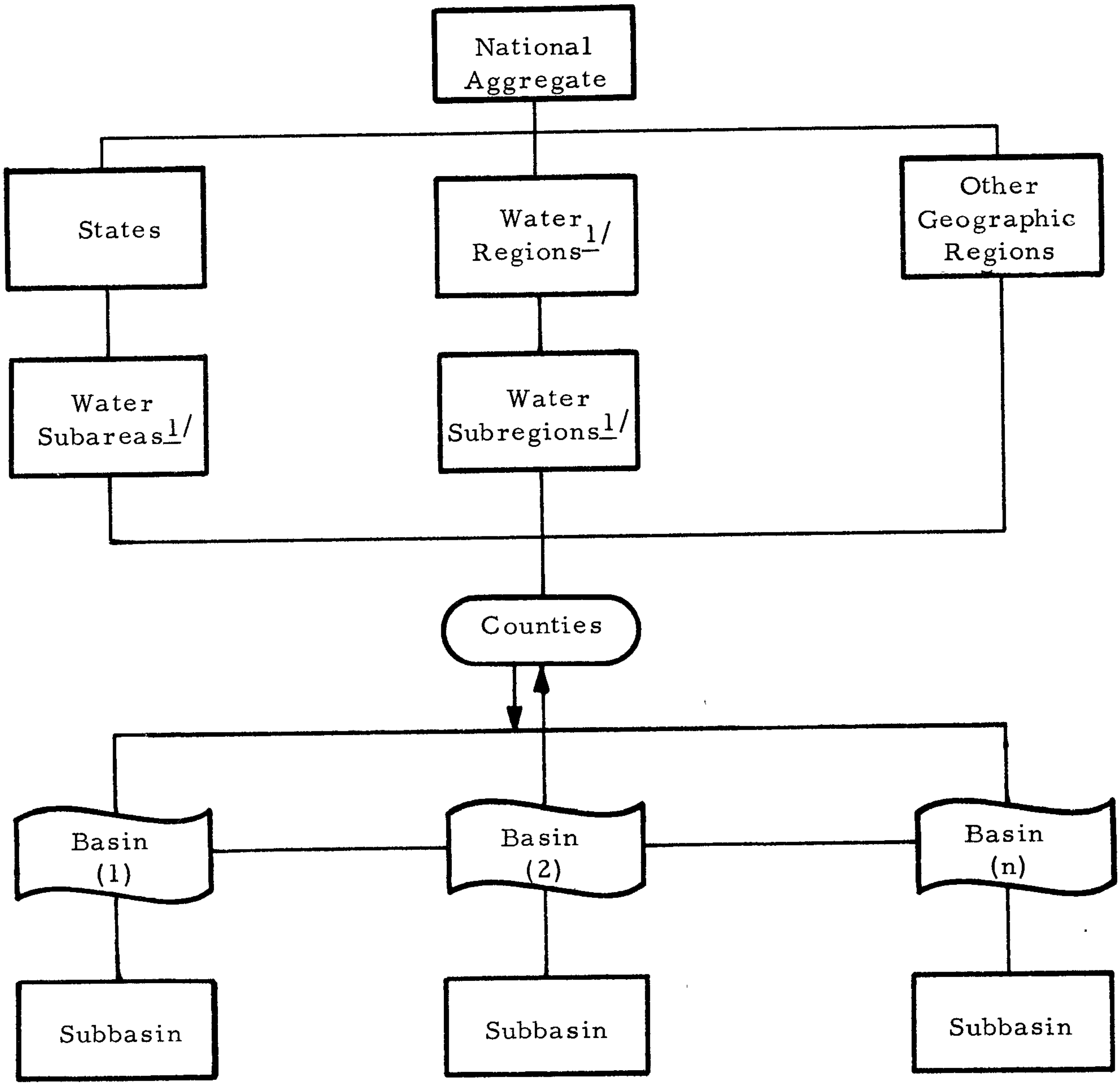


Exhibit VI-6. Water Pollution Control, Benefit Aggregation Schema

1/ Based on Water Resources Council National Assessment Areas

Procedural Implications

If the above procedure were implemented and the interrelationships within and among hydrological basins assessed, the inter- and intrabasin effects of alternative pollution control practices could be simulated to observe specific benefit and cost impacts. The above procedure further establishes a method whereby the differential impacts of various pollution abatement policies could be assessed. As long as subbasin boundaries, including exogenous and endogenous water flows, were properly specified, any subset of the hydrologic basin might be considered as a separate operational-analytical entity.

Knowledge of interbasin boundaries and water flows facilitates quantification and simulation of interbasin dependencies and relationships. Subsequent relationships among regions could be determined and a method of arriving at national water pollution control estimates or functions would be achievable.

SECTION VII

GENERAL EQUILIBRIUM MODELS

Because of the complexities of a more satisfactory framework for benefit cost analysis, a variety of general equilibrium models have been developed. Ayres, Kneese, Isard and Leontief have pioneered recent contributions in this area.

Benefit cost analysis effectively becomes a supplementary analysis of alternative general equilibrium solutions or simulations. This is compatible, however, with welfare economic concepts involving social (public) choices.

A Materials-Process-Product Model

For the purpose of forecasting residuals and to facilitate other kinds of analysis needed for environmental management purposes, a new sort of model is developed by Ayres (1972) which combines economic and technological elements. Since existing economic measures or models do not take into consideration social costs resulting from the production process, it is suggested that a model must be designed to deal with quantity itself. However, this emphasis on physical materials flow rather than dollar flow imposes a new set of requirements on the form of the model.

According to the author, the typical input-output model which utilizes the Standard Industrial Classification (SIC) code, does not allow one to observe the relationship between a product and its process. Consequently, forecasts of economic growth or residual production as a function of technological change can only be accomplished by interindustry coefficient trend extrapolation. Since this data is almost nonexistent, the author suggests that the interrelationship between technological change and the economy would appear to be far more tractable in a context that takes advantage of the production process.

In particular, a model based on three fundamental classifications is proposed: (a) materials, based on physico-chemical composition and a model of utilization; (b) processes, based on the relations between the number and the type of material output; and (c) final products, which is grouped in accordance with the SIC code so that the results can be used in conjunction with the typical input-output models.

The proposed model is a generalization of the well-known Walras-Cassel general equilibrium model, extended to include intermediate consumption by process and also including unpriced material inputs such as air and water, and unpriced outputs (residuals) such as combustion products and solids. The mathematical formalism of the model represents an elaborate attempt by the author to show how mass or material can be conserved-extended; and, if desired, the model could include conservation of energy. Defining unit prices, or unit value-added, introduces the possibility of describing a dynamic system, with one (or more) equilibrium solutions.

One problem that is dealt with by the author in reference to the materials-process-product model is the nomenclautre or taxonomy required for such a framework. Just how much stress should be put on disaggregation in terms of the classification of materials and processes is an important question. For the purpose of this paper, the author has chosen to select an industry (defined by a SIC code) and to apply the materials-process taxonomy and formulation within the confines of the industry. This is done in an attempt to make the data acquisition problem more manageable. Examples are given to show how this type of classification can be used to form a matrix for micro-processes which are compatible with both simple materials and composite materials.

It should be noted that the objective of the model is to focus upon forecasts of industrial residuals and other environmental problems by examining the prevailing technology or the processes and materials used for final products. The author notes, however, that materials flow relationships may also be affected by factors other than changes in material processing technology. For instance, changes in raw material characteristics as well as changes in end-product demand may also have obvious effects on material-flow relationships. As a result of this complication, the author suggests that residual forecasting should proceed as follows: (1) identify major elements of demand; (2) identify major sources of raw materials; (3) identify major existing processes; (4) project one or more (e.g., high, medium, low) future trends for each of the above. Process trends will be given in terms of relevant figures-of-merit such as energy requirement, etc.; and (5) look for possibilities of major changes in demand pattern, raw material supplies, policy, or technological breakthroughs that could lead to accelerated rates of substitutes of one material or process for another. Finally, according to the author, a more interesting application of the model for economists would be to examine the impact of changes in the incentive structure, e.g., shifts in taxes, subsidies, etc.

An Ecologic-Economic Model

The purpose of Isard's (1972) book is to develop a conceptual framework which takes into consideration both the ecologic and economic interrelations in regional development. By extending and reformulating techniques employed in economic and regional science, it is suggested that such critical problems as air pollution, water pollution, and erosion can be analyzed more effectively when decisions concerning resource development are required.

A considerable amount of progress is made in developing a more appropriate methodology for economic-ecologic analysis by extending four basic analytic tools: the comparative cost approach, the input-output technique, industrial complex analysis and the gravity model. Each one of these techniques represents an important part in the methodology developed in the remainder of the book.

A modified version of the input-output technique, which can be adapted for programming, is employed for a description of the data and relationships of an ecologic system. Three food chains are incorporated into this format, as well as the basic photosynthesis process and certain sub-cycles in the phosphorous cycle. While this methodology deals with systematic ecologic analysis, it is not very useful for the evaluation of development alternatives. As it stands, it does not translate ecologic magnitudes into dollars and cents, or any other common unit useful in welfare and planning analysis. Theoretically, however, this type of methodology can be fused with the economic sector to provide the framework for evaluating various alternatives relating to repercussions on the environment in general. As a result, the authors proceed to develop a fused framework for an input-output, activity analysis approach to the combined economic-ecologic system. It is suggested that such an interrelation table is useful for systematic description, for comprehensive planning and programming, and for thorough study of the direct and indirect impacts of major developments.

The importance of the conceptual framework is demonstrated when it is employed in a very limited manner to examine the problem of the proper development of a marina complex in the Kingston Bay area. Since no mineral deposits of any significance occurs in the Shelf of this area, and since it lacks potential for fishing and industrial development, only its recreational possibilities are examined at some depth. Several sites for recreational development are identified. Through a comparative cost analysis of the several sites, covering both ecologic and economic costs, a least-cost site is determined. In the process, a recreational complex following the traditional industrial complex approach is developed. Although the recreational complex does not encompass the full range of relevant ecological processes and their relationships, it is suggested how such a complex approach could be applied more extensively to the ecologic system.

In order to estimate the benefit or demand side of the proposed recreation project, a gravity model is employed. It is determined that the market demand is the same at all the sites and thus the least-cost site is the most profitable site for the development project.

In summary, the methodology for the synthesis of economic and ecologic analysis developed in this book is based upon the modification of existing analytical tools in regional science. Through a comparative cost analysis of the several sites, covering both ecologic and economic costs, an optimal site is determined. For this site a recreational complex is developed. In addition, a gravity model is employed to esimate demand, an input-output model is utilized to check for consistency of total input requirements and to estimate total capital investment, and a standard cost and revenue procedure is outlined to calculate profitability. Finally, the industrial complex and comparative cost procedures are employed to determine the relative profitability of complexes of different sizes at the several sites.

The Kneese Approach

Kneese et al. (1970) see pollution as a physical phenomena associated with production of goods or services. Production is basically the transformation of physical raw materials into real physical products. During the transformation of raw materials to final products quantities of the physical raw materials are transformed to undesirable materials to be discarded of, these undesirables are seen as pollutants. Thus, pollution is a function of final output (Y).

$$\text{Pollution} = f(Y)$$

Kneese takes a total approach to the environment. There are three types of pollution, dependent on the receptor of the pollution: water, air, and solid pollution There are also two sectors of pollution, pollution associated with the production sector and pollution associated with final consumption. The first distinction indicates that pollution in any one receptor can be reduced only at the increase of pollution in one of the other two receptors if final output is to remain constant. The second distinction shows the inevitability of pollution. First, there are pollutants associated with the transformation of raw materials into final products. Further there is the pollution associated with the use of the final product up to its final discarding as trash. Thus the majority of all resources used in production ends up as a form of undesirable discard or pollutant. There are then two ways of attacking this pollution, without the transformation from one form of pollutant to another type of pollutant: (1) to increase the efficiency of the transformation of raw materials to final product, i.e., less industrial pollution; and (2) to recycle the final product after it has served its useful life.

Kneese sees the world as the natural receptor of discharge. The natural environment operates to dispose of these discharges. It is generally assumed that nature has three times the capacity to clean itself of its discharge than it produces. Industrial man has begun to use that natural capacity. The problem is when man exceeds the natural capacity limits or introduces materials that are impenetrable to natural organic processes. Both of the above are being accomplished by modern industrial society. Kneese envisions a systems approach where nature takes care of its own discharge and part of mans. But because man's is so large and complex he must design a system to reduce and reuse his discharges for nature cannot cope with the quantity and types of discharges man is capable of creating.

Input-Output and Environmental Repercussions

Leontief (1970) uses his traditional input-output framework to analyze pollution by including a pollution row and an anti-pollution column. This is a straight-forward extension of the usual I-0 framework.

Inclusion of the pollution row indicates the level of pollution generated per dollar of delivery to final demand. The function is, of course, linear. Pollution is considered an integral part of the economic process.

The proposed anti-pollution activity is viewed as a separate industry requiring the usual type of inputs.

The net result is that the effects of both the generation and elimination of pollutants can be analyzed in the usual I-0 manner including the resulting changes in prices.

Systems Analysis

During the first half of the 1960's the systems analysis reached a fad stage of development. The systems approach gained wide appeal for its ability to integrate numerous components into a single framework.

An excellent study by Hamilton et. al. (1969) of the Susquehannah River Basin illustrates the systems analysis approach. The selected diagrams below are illustrative of various components of a systems model. A cursory examination of the format will indicate that a system of this type has a very large data requirement because of the resources necessary to implement a systems framework such as that designed by Hamilton. It is rarely feasible to utilize that type of systems analysis.

However, systems analysis in general is simply an orderly way of thinking through and integrating the various components that relate to resource development. The major contribution of the approach is to facilitate an orderly presentation of the factors influencing factors such as the benefits and costs of pollution control. (See Exhibits VII-1, VII-2, VII-3, VII-4.)

Exhibit VII-1. A Flow Chart of a Simplified Subregional Model.

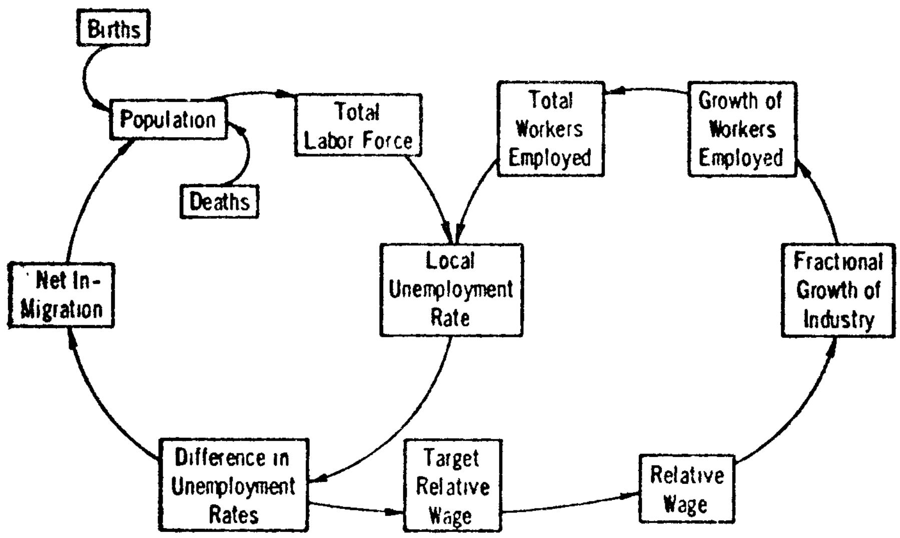
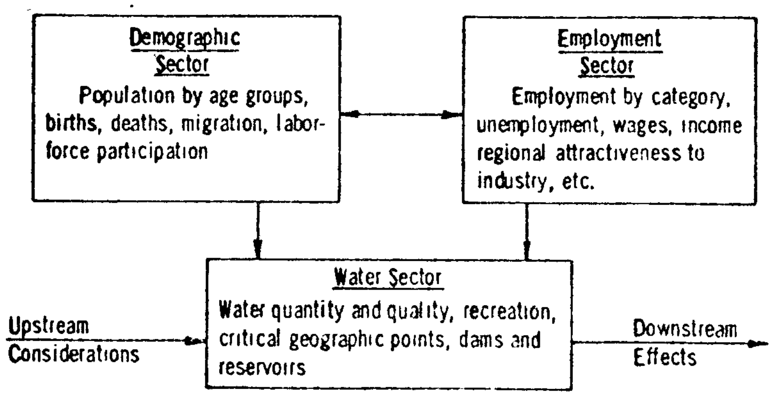


Exhibit VII-2. The Three Major Sectors of a Subregional Model.



Source: H. R. Hamilton, et al, Systems Simulation for Regional Analysis, An Application to River-Basin Planning, The M.I.T. Press, 1969.

Exhibit VII-3. Two Submodels Forming the Regional Model

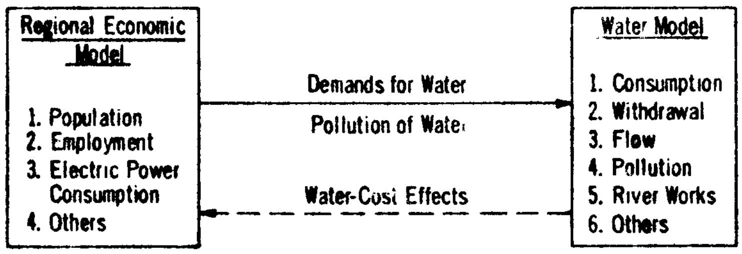
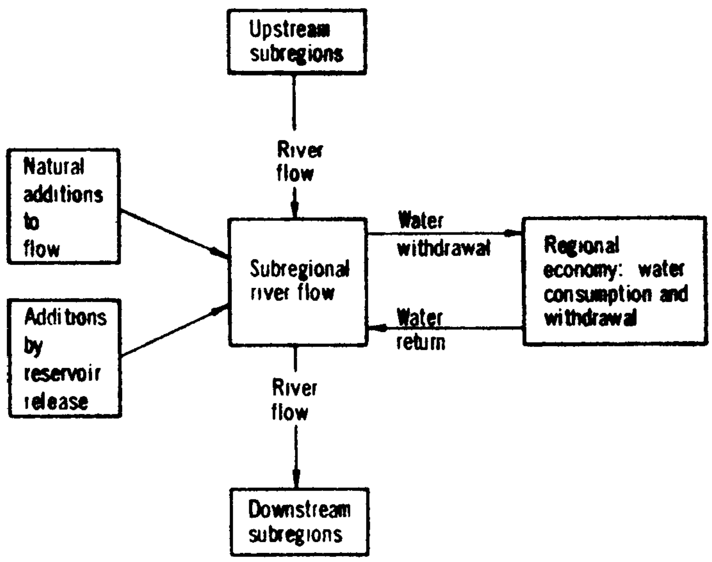


Exhibit VII-4. Diagram of the Water-Flow Submodel



Source: H. R. Hamilton, et al, Systems Simulation for Regional Analysis, An Application to River-Basin Planning, The M. I. T. Press, 1969.

SECTION VIII

SUMMARY OBSERVATIONS

The state-of-the-arts in identifying and measuring benefits and costs from pollution control is in an embryonic stage of development as the foregoing review suggests. Only in the past few years has significant attention been directed to evaluating pollution control mechanisms in response to shifting public priorities in the direction of environmental quality.

The conceptual and empirical base upon which benefit and cost analysis of environmental policies could build has been oriented primarily toward development objectives. The metrics of traditional benefit cost analysis included income, output and employment. But with regard to pollution, it was recognized that policies designed to increase economic activity generally resulted in an increase in pollution. The sources of pollution stem from various types of activity. Likewise the receptors of both pollution damage and benefits from pollution reduction may be considered to be similar activities. Consequently, traditional benefit cost analysis has been of limited value as a building block in evaluating policies designed to improve the environment.

Conceptual Problems

Three major difficulties exist with the type of methodologies used to evaluate pollution control policies. First, they are unable to consider several alternatives and often the most elementary trade-offs are neglected. Second, the approaches are more rules of thumb than economic analyses. Third, the framework used to evaluate development projects has been an inadequate base upon which to build an analytical framework for evaluating the benefits and costs of pollution abatement.

On the other hand, progress has been made toward more general model development which takes account of environmental repercussions of development (and other) activities. From these more general studies, new possibilities arise for benefit cost analysis.

Data Problems

Regardless of the conceptual framework, the most glaring void for economic analysis of anti-pollution policies is costs of pollution damages, or conversely, the benefits from a reduction in pollution. But water quality damages and/or cost implications depend on the uses or users involved. Even water of drinking quality may be damaging to steel rolling mills because of excessive chlorides. Likewise water used as feed water in high pressure boilers must be of high quality to prevent corrosion, scale formation and biological slimes. Water used in the paper industry may be of considerably lower quality but even then should not contain much iron, mangenese or carbon dioxide. Thus, water quality has no single standard for determining damages but a multiplicity of standards that are linked via the users of water. 'Users' also include affected ecological systems.

The trade-offs become even more numerous when domestic uses are considered. For instance, cool water desirable as an industrial coolant requires greater energy to heat for some domestic uses. Soft water requires less soap but increases the sodium level which may be harmful to certain individuals.

Some General Problems Involving Water Quality

Past research and study has resulted in rather fragmentary results. Problems (damages) are most frequently recognized at various major water user-levels, but underlying cause-effect knowledge and understanding has only recently become a serious concern. Trade-offs among affected users are not generally known.

For the purpose of this review, it can only be indicated that water quality problems are now widely recognized. In summary, a brief description of how various 'users' of water have been affected is presented below. Pertinent cause-effect relationships and consequent feasible and economical problem solutions have not been identified.

Municipal Water Supply Users. Municipal water supplies are distributed to a wide variety of different users. A considerable array of quality standards are involved, but they may, in numerous cases, be conflicting. Considerable data exist on water quality standards for different industries along with recent cost estimates for accomplishing these objectives in particular situations. However, the intake water varies significantly in quality from place to place so that treatment costs are spatially variable.

Industrial Water Users. Industrial water use is about double that of municipalities with the heaviest use in cooling. Because of a wide spectrum of differences in production processes, it is difficult to generalize about industrial pollution costs or damages. Although a significant number of fixed cost estimates for particular treatment strategies exist, not enough is known about the firm's response of internalizing the cost of waste disposal. The cost data for specific treatment strategies may be most relevant in that it is something that firms may try to escape by shifts in production techniques. This flexibility and adaptability poses serious problems for predicting or even identifying the social costs of pollution control.

Water-Based Commercial Users. Commercial fishing damages from water pollution have been discussed for sometime but frequently in an isolated framework where trade-offs are neglected. A variety of studies of the Great Lakes have suggested that large losses have occurred from water pollution; but the exact biological links have not been rigorously specified.

Agricultural Water Users. Agricultural pollution has attracted several intensive studies in recent years. The Colorado river, a relatively unpolluted river by most standards, was the focus of attention a few years ago, partly because of the pollution of the river by agricultural chemicals. Aside from this effort, relatively little is known about the trade-offs between agriculture and industry water quality requirements.

Water-based Recreation Users. From a benefit analysis standpoint, more is known about the value of cleaner water for recreation than any other area. A variety of approaches have been employed to get at the elusive intangible benefits associated with recreation.

General Public Users. Public health problems associated with water quality have the longest legacy of attention. Integrative information relating various cause-effect situations is lacking however. Bacteriological contamination has been the leading subject of surveilance by public health officials with resulting standards based on empirically derived tolerances. Other pollutants are less well documented; although recent information suggests that serious contamination/toxicity induced health affects from water pollution are occurring and/or can be expected.

In order to improve the state of knowledge of water pollution damages, both intensive and integrative approaches are recommended. Heavy water users, including municipal, industrial and agricultural, could be selected and thoroughly studied for the cause-effect damages that may result. Few studies of this nature exist. By far the most benefit analysis of cleaner water has focused on recreation. As implied, this area of focus by economists leaves most environmental quality management issues unanswered.

SECTION IX

IMPLICATIONS FOR PLANNING AND RESEARCH

The above state-of-art survey indicates that water pollution control problems are both diverse and complex. Both intensive and extensive efforts are needed to better understand the scope and ramifications of these problems.

A variety of implications for research and planning are apparent. Some of these implications are pursued in this report. Also, however, a systematic procedure for developing research needs and priorities has been planned as described first in this concluding section of the Phase I report.

Procedure for Establishing Needs

Concern for environmental quality management involves numerous factors and variables which have heretofore been inadequately considered in economic and other analyses. Consequently, there exists an implicit need for further research and planning efforts which incorporates pertinent additional environmental variables.

A statement such as: "More research is needed," fails, however, to come-to-grips with this rather obvious conclusion. Attention must be given to specific needs and establishment of priorities among the needs defined.

Reflection upon processes which might be used to identify specific needs involving water-based aspects of environmental quality management (or similar concerns) leads to various means-ends schema which might be used. A particular such framework proposed here is as follows:

Step	Description
1. Define Basic Problem	Without immediate regard to problem solution, it is usually possible to define a problem in terms of (1) desired outputs or results and (2) types of needed inputs which affect the outputs desired.
2. Place Problem in Perspective	Each problem identified has its 'environmental setting' and a visual-descriptive understanding of this setting is needed in order to assess whether the basic problem definition has validity. Realistic problem-solution methods and approaches must account for presumed exogenous factors which can affect problem solution efforts.
3. Refine Problem Definition	A concerted effort to place a problem in realistic perspective can generally result in refinement of the problem definition. Affected audiences can be exposed to aspects of the problem and feedback inputs can further alter problem definition.
4. Determine Directions of Study Needed	Different types of results, or components of a given type of result, may require alternative directions and approaches of study. Diverse directions may be required, but each can contribute to the desired whole. Care must be taken to project expected results or findings and how they relate to the whole, however.

Step	Description
5. Establish Criteria for Defining Needs and Priorities	A judgemental framework for ranking and ordering sub-problems within the basic problem needs to be established. Also, preferences as to the ordering of desired outputs can affect the statement and ranking of needs. Input needs and priorities are subsequently affected. In reverse, evaluation of input needs can result in re-ordering of needs and priorities.
6. Subsequent Steps	Further processes and specifications include (a) Development of approaches and methods of analysis, (b) Determination of specific inputs, (c) Establishment of priorities given time/budget constraints, and (d) Project scheduling and operation.

At the outset of this report, an attempt was made to define the basic problem of water pollution control independent of a physical-social-political-economic setting. The survey of state-of-art benefit cost analyses dealing primarily with water pollution control indicates indirectly much of the setting in which this problem is to be solved.

To pursue further the process for establishing research needs (and subsequently the development of priority needs), a brief overview of some broad perspective viewpoints available in the literature is presented in the next section.

The intended stopping-point of this report is development of ideas through step 4 as outlined above. Development of steps 5 and 6 are presented in a separate report.

Some Perspective Viewpoints

At the outset of this report, an introductory perspective was presented to suggest that water quality management problems can realistically neither be separated from other environmental quality management nor other critical national issues. Attention was not given to how one might proceed to integrate, either analytically or operationally, the multiple or joint concerns, however. Given the state-of-art survey above, it is better realized how some of the major issues are interrelated. For example, from the Materials-Process-Product general equilibrium model approach described, it is more easily conceived how raw material (energy source) substitutions could significantly affect both the quantity and quality of residual waste flows. Hence, energy resource use and water quality management concerns may be significantly interrelated.

Attention has and is increasingly being given to multiple-problem modelling and analysis in a general systems theory setting. A variety of relatively recent publications have dealt with environmental quality problems in a global framework. Examples include the following:

(1) Albertson, P. and M. Barnett (ed.) Managing the Planet, 1972.
(2) Boulding, K. The Economics of the Coming Spaceship Earth, in Jarrett (1966).
(3) Ecologist. A Blueprint for Survival, 1972.
(4) Forrester, J. W., World Dynamics, 1971.
(5) Fuller, R. B., Operating Manual for Spaceship Earth, 1969.
(6) Kellermann, Henry J., Ecology: A World Concern, 1971.
(7) Kneese, A.V., & B. T. Bower (ed.), Environmental Quality Analysis, 1972.
(8) Kneese, A.V., S. E. Rolfe and J. W. Harned, Managing the Environment: International Economic Cooperation for Pollution Control, 1971.
(9) Meadows, D. H., et al., The Limits of Growth, 1972
(10) Ramsay, W. and C. Anderson. Managing the Environment, 1972.
(11) Report of the National Goals Research Staff, Toward Balanced Growth: Quantity with Quality, 1970.

(12) Spilhaus, A., Ecolibrium, 1972.
(13) Train, R. E., The Quest for Environmental Indicies, 1972.

Concepts and ideas presented in the above type of publications provide much more complete perspective viewpoints of dealing with environmental quality management problems. Some of the ideas developed in these more general viewpoints can and should affect the manner in which water pollution control problems are modelled and analyzed. Without some attention to world-views involving environmental quality problems, it is predicted that partial-studies may be not only incomplete but misleading or incorrect. Hence, the following summaries are presented as a pertinent step in establishing directions of needed study.

Five specific references from the above listing are briefly summarized in this report. They help provide a broader perspective toward understanding of pollution and pollution control problems. Also, suggestions are given of how we might collectively approach the complex task of environmental quality management.

The selected references do not effectively deal with all facets of the general problem, but various levels of concern and some additional relevant perspectives are indicated. The following brief general citing and categorical description of each is an attempt to explain why these selections are included herein:

Reference	Categorical Description
1. Operating Manual for Spaceship Earth, by R. Buckminister Fuller (Fuller is a University Professor at Southern Illinois University. He is the inventor of the geodesic dome.)	This statement by Fuller is philosophical and comprehensive at this level. Long-term perspectives are introduced and the 'irrationality' of current activities and behaviors are pointedly stated. Fuller indicates well what we need to do, but detailed implementation plans are yet to be developed.

Reference	Categorical Description
2. An interview (see Wheeler, 1972) with Alexander King, a spokesman for the Club of Rome. (King, a scientist, is director-general for Scientific Affairs of the Organization for Economic Cooperation and Development)	King, a founder of the Club of Rome, discusses the alledged dooms-day publication by Meadows, D.H., et al., The Limits of Growth and other Club of Rome activities. "Trajectory' consequences of extrapolated traditional human activities are indicated. The need for changes in current-types of activity and human behavior are made clear with this type of perspective. Again no detailed implementation plans are yet agreed upon.
3. "Ecolibrium," by Athelstan Spilhaus, --an address as retiring president of AAAS. (Spilhaus is a fellow of the Woodrow Wilson International Center for Scholars, Smithsonian Institution)	This article presents major issues surrounding environmental quality management and suggests kinds of long-range planning efforts which need to be pursued. Ideas presented are part of the needed bridge-work to pragmatically deal with environmental management problems given current socio-economic-political-legal structures.
4. Environmental Quality Analysis, by A. V. Kneese and B. T. Bower (ed). (Kneese is director and Bower is associate director of the 'Quality of the Environment Program' at RFF)	This book is a collection of selected state-of-art papers by Resources for the Future staff members and other scholars involved in a current environmental quality program. Emphasis has been primarily theoretical and methodological. The authors have attempted to meaningfully segment and classify both current and needed research areas. While progress is being made, it is clear that 'answers' are still not available.

Reference	Categorical Description
5. "The Quest for Environmental Indices" by Russel E. Train--an editorial opinion. (Train is chairman of the Council on Environmental Quality)	A specific item of general and political concern are broad indicators of environmental quality. Train explains the need for such indicators both in terms of policy formulation and dialogue. Most of this concise statement is presented. It reflects many of the specific problems currently being faced to improve understanding and assessment of environmental quality.

These five references are briefly summarized next. They represent the type of general thinking and the kinds of developments which place water quality management problems in realistic perspective.

Selected Reference No. 1

In a lucid, philosophic statement: Operating Manual for Spaceship Earth, R. Buckminister Fuller systematically and skillfully builds ideas to yield an experimentally-defined concept of the universe. He then proceeds to systematically 'subdivide progressively' that which he built-up into its most relevant physical and metaphysical bi-sected 'bits', including spaceship earth.

To bring into perspective how one might consider operating this spaceship, Fuller, by analogy, likens spaceship earth to an automobile:

> One of the interesting things to me about our spaceship is that it is a mechanical vehicle, just as is an automobile. If you own an automobile, you realize that you must put oil and gas into it, and you must put water in the radiator and take care of the car as a whole. You begin to develop quite a little thermodynamic sense. You know that you're either going to have to keep the machine in

> order or it's going to be in trouble and fail to function. We have not been seeing our Spaceship Earth as an integrally-designed machine which to be persistently successful must be comprehended and serviced in total.
>
> Now there is one outstandingly important fact regarding Spaceship Earth, and that is that no instruction book came with it. (p. 47)

Fuller suggests that the 'instruction book' was purposely not provided, and continues in the following manner:

> The designed omission of the instruction book on how to operate and maintain Spaceship Earth and its complex life-supporting and regenerating systems has forced man to discover retrospectively just what his most important forward capabilities are. His intellect had to discover itself. Intellect in turn had to compound the facts of his experience. Comprehensive reviews of the compounded facts of experiences by intellect brought forth awareness of the generalized principles underlying all special and only superfically-sensed experiences. Objective employment of those generalized principles in rearranging the physical resources of environment seems to be leading to humanity's eventually total success and readiness to cope with far faster problems of universe. (p. 49)

In order to tackle present world problems, Fuller proceeds with his operating manual theme using a variety of "powerful thought tools": topology, geodesics, synergetics, general systems theory and operational 'bitting' (with reference to computers). Using a general systems analysis framework, he progressively subdivides the universe into ordered relevant 'bits' which he summarized as follows:

> Our first isolated bit is the system, which at maximum is the starry macrocosmic and at minimum the atomic nucleus; the second bit reduces the macrocosmic limit to that of the galactic nebula; the third bit separates out cosmic radiation, gravity and the solar system; and the fourth bit isolates the cosmic radiation, gravity, sun, its energized, life-bearing Spaceship Earth, together WITH the Earth's Moon as the most prominent components of the life regeneration on Spaceship Earth.
>
> I would like to inventory rapidly the system variables which I find to be by far the most powerful in the consideration of our present life-regenerating evolution aboard our spaceship as it is continually refueled radiationally by the Sun and other cosmic radiation. Thus we may, by due process, suddenly and excitingly discover why we are here alive in universe and identify ourselves as presently operating here, aboard our spaceship, ... thinking effectively regarding the relevant contemporary and local experiences germane to the solution of humanity's successful and happy survival aboard our planet. We may thus discover not only what needs to be done in a fundamental way but also we may discover how it may be accomplished by our own directly-seized initiative, undertaken and sustained without any further authority than that of our function in universe, where the most ideal is the most realistically practical. (p. 69-70).

At this point in the discussion, Fuller is ready to-take-to-task the general problem of human survival, a problem to which all others are subsidiary as indicated next:

> Typical of the subsidiary problems within the whole human survival problem, whose ramifications now go beyond the prerogatives of planners and must be solved, is the problem of pollution in general--pollution not only of our air and water but also of the information stored in our brains.

> We will soon have to rename our planet "Poluto." In respect to our planet's life sustaining atmosphere we find that, yes, we do have technically feasible ways of precipitating the fumes, and after this we say, "But it costs too much." There are also ways of desalinating sea water, and we say, "But it costs too much." This too narrow treatment of the problem never faces the inexorably-evolving and solution-insistent problem of what it will cost when we don't have the air and water with which to survive. (p. 70)

Rather obviously Fuller does not agree with our traditional benefit cost approaches of problem solving. He subsequently elaborates on his viewpoints as follows:

> The adequately macro-comprehensive and micro-incisive solutions to any and all vital problems never cost too much. The production of heretofore nonexistent production tools and industrial networks of harnessed energy to do more work does not cost anything but human time which is refunded in time gained minutes after the inanimate machinery goes to work. Nothing is spent. Potential wealth has become real wealth. As it is cliched "in the end" problem solutions always cost the least if paid for adequately at outset of the vital problem's recognition. Being vital, the problems are evolutionary, inexorable, and ultimately unavoidable by humanity. The constantly put-off or under-met costs and society's official bumbling of them clearly prove that man does not know at present what wealth is nor how much of whatever it may be is progressively available to him.
>
> We have now flushed out a major variable in our general systems problem of man aboard Earth. The question "What is wealth?" commands our prime consideration. (p.72-73)

To conclude this brief perspective summarization of Fuller's book, three final parts of his book are presented. These sections are both forward thinking and perhaps provacative. They directly relate to this study however in terms of pollution (generation) control and our economic accounting systems (benefits and costs):

> Inasmuch as we now are learning more intimately about our Spaceship Earth and its radiation supply ship Sun on the one hand and on the other its Moon acting as the Earth's gravitationally pulsing "alternator" which together constitute the prime generator and regenerator of our life supporting system, I must observe also that we're not going to sustain life at all except by our successful impoundment of more of the Sun's radiant energy aboard our spaceship than we are losing from Earth in the energies of radiation or outwardly rocketed physical matter. We could burn up the Spaceship Earth itself to provide energy, but that would give us very little future. Our space vehicle is similar to a human child. It is an increasing aggregate of physical and metaphysical processes in contradistinction to a withering, decomposing corpse.
>
> It is obvious that the real wealth of life aboard our planet is a forwardly-operative, metabolic, and intellectual regenerating system. Quite clearly we have vast amounts of income wealth as Sun radiation and Moon gravity to implement our forward success. Wherefore living only on our energy savings by burning up the fossil fuels which took billions of years to impound from the Sun or living on our capital by burning up our Earth's atoms is lethally ignorant and also utterly irresponsible to our coming generations and their forward days. Our children and their children are our future days. If we do not comprehend and realize our potential ability to support all life forever we are cosmically bankrupt. (p. 78-79)

Given the above viewpoints of how to better operate spaceship earth plus an outline description of other topics which he develops, attention is now turned to his viewpoints on our economic accounting systems:

> ... Our economic accounting systems are unrealistically identifying wealth only as matter and are entering know-how on the books only as salary liabilities; therefore, all that we are discovering mutually here regarding the true nature of wealth comes as a complete surprise to world society--to both communism and to capitalism alike. Both social co-operation and individual enterprise interact to produce increasing wealth, all unrecognized by ignorantly assumed lethally competitive systems. All our formal accounting is antisynergetic, depreciative, and entropic mortgagization, meaning death by inversally compounding interest. Wealth as anti-entropy develops compound interest through synergy, which growth is as yet entirely unaccounted anywhere around Earth in any of its political economic systems. We give an intrinsic value to the material. To this we add the costs of manufacturing which include energy, labor, overhead, and profit. We then start depreciating this figure assuming swift obsolescence of the value of the product. With the exception of small royalties, which are usually avoided, no value is given for the inventiveness or for the synergistic value given by one product to another by virtue of their complementarity ... (p. 86-87)
>
> Our common wealth is also multiplied in further degree by experimentally-derived information which is both multiplying and integrating the wealth advantage at an exponential rate. The synergetic effect upon the rate of growth of our incipient world common wealth augmentation has been entirely overlooked throughout all the accounting systems of all the ideologically-divergent political systems. Our wealth is inherently common wealth and our common wealth can only increase, and it is increasing at a constantly self-accelerating synergetic rate.

> However, we inadvertently dip into our real, unaccountedly fabulous wealth in a very meager way only when our political leaders become scared enough by the challenges of an impressively threatening enemy. Then only do socialism and capitalism alike find that they have to afford whatever they need. (p. 89)

And, finally, Fuller offers the following operating rules or procedures for survival. He returns to his automobile analogy to advise of some of these rules:

> We have learned that only and exclusively through use of his mind can man inventively employ the generalized principles further to conserve the locally available physical energy of the only universally unlimited supply. Only thus can man put to orderly advantage the various, local, and otherwise disorderly behaviors of the entropic, physical universe. Man can and may metaphysically comprehend, anticipate, shunt, and meteringly introduce the evolutionarily organized environment events in the magnitudes and frequencies that best synchronize with the patterns of his successful and metaphysical metabolic regeneration while ever increasing the degrees of humanity's space and time freedoms from yesterday's ignorance sustaining survival procedure chores and their personal time capital wasting. (p. 110) ...
>
> We have thus discovered also that we can make all of humanity succesful through science's world-engulfing industrial evolution provided that we are not so foolish as to continue to exhaust in a split second of astronomical history the orderly energy savings of billions of years' energy conservation aboard our Spaceship Earth. These energy savings have been put into our Spaceship's life--regeneration-guaranteeing bank account for use only in self-starter functions.

The fossil fuel deposits of our Spaceship Earth correspond to our automobile's storage battery which must be conserved to turn over our main engine's self-starter. Thereafter, our "main engine," the life regenerating processes, must operate exclusively on our vast daily energy income from the powers of wind, tide, water, and the direct Sun radiation energy. The fossil-fuel savings account has been put aboard Spaceship Earth for the exclusive function of getting the new machinery built with which to support life and humanity at ever more effective standards of vital physical energy and reinspiring metaphysical sustenance to be sustained exclusively on our Sun radiation's and Moon pull gravity's tidal, wind, and rainfall generated pulsating and therefore harnessable energies. (p. 111)

We have discovered that it is highly feasible for all the human passengers aboard Spaceship Earth to enjoy the whole ship without any individual interfering with another and without any individual being advanced at the expense of another, provided that we are not so foolish as to burn up our ship and its operating equipment by powering our prime operations exclusively on atomic reactor generated energy. The too-shortsighted and debilitating exploitation of fossil fuels and atomic energy are similar to running our automobiles only on the self-starters and batteries and as the latter become exhausted replenishing the batteries only by starting the chain reaction consumption of the atoms with which the automobiles are constituted. (p. 112)

Selected Reference No. 2

In 1970, The Club of Rome (an ad hoc group of worldwide influential persons, founded by Alexander King and Aurelio Peccei commissioned Jay Forrester and Dennis Meadows of M.I.T. to undertake a projection of the world in the early two thousands as it would look if present trends and policies continued. The results of this study were published under the title: The Limits to Growth, (Meadows, et al., 1972). In essence the report indicated major calamities would occur within about fifty years.

Six major aggregate variables were considered in the projection model (ninety equations with many feedback loops): (1) world population, (2) food required (by an increasing population), (3) the agricultural potential to supply food, (4) industrial and economic growth, (5) depletion of raw materials, and (6) pollution. Despite a variety of assumptions in projecting, major collapses were expected by about the middle of the next century. (A sample computer print-out picture is shown in Exhibit IX-1).

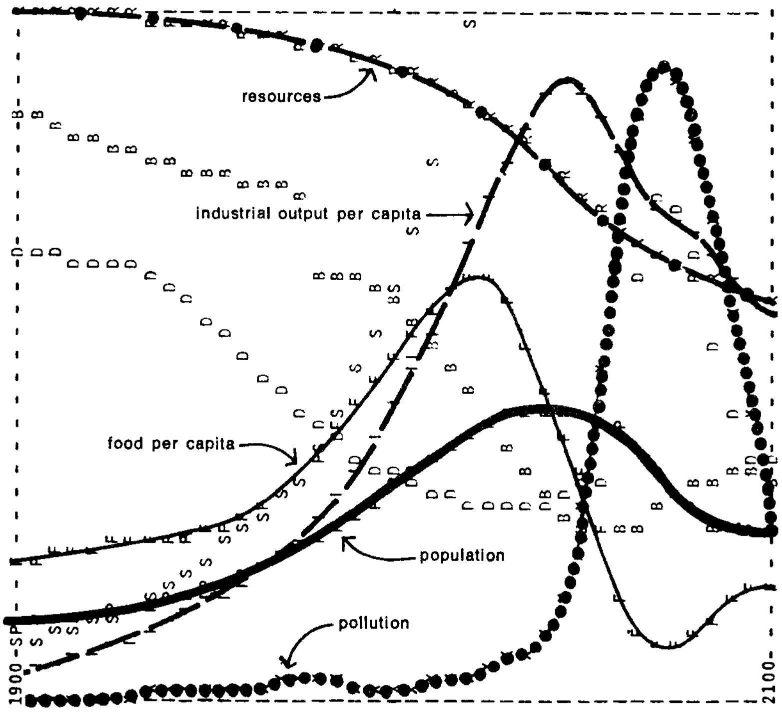
This publication has been the subject of rather intense international debate and discussion. In an interview by Wheeler (1972), Alexander King explained some of the background for this study and reflected on the basic issues involved. In a summary statement, King believed the value of the study and publication was as follows:

> We think it's a magnificent first attempt, that it's unfair to reproach it for not having given all the answers. It has started an international dialogue which is urgently needed. This first work should not be regarded as a basis for policy--it's far too tentative, too general. But it's a precursor of perspectives for the reorientation of world research and development efforts in relation to real problems. (p.27)

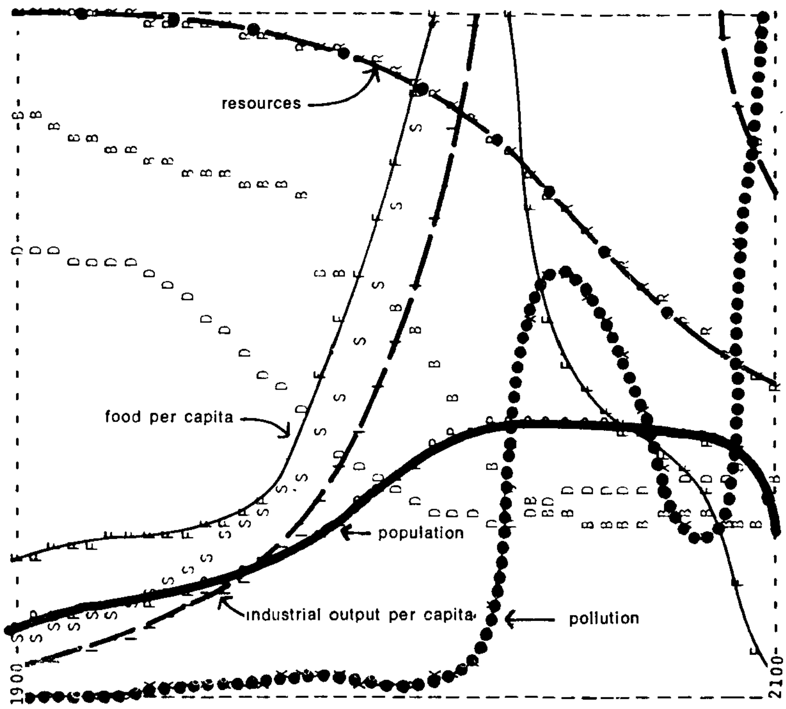
King went on to outline some additional steps and projects being supported or pursued under the auspices of the Club of Rome. Three such new projects outlined were: (1) An alternative methodological approach (a new method of model-making which starts

Exhibit IX-1

WORLD MODEL WITH "UNLIMITED" RESOURCES, POLLUTION CONTROLS, AND "PERFECT" BIRTH CONTROL



WORLD MODEL WITH "UNLIMITED" RESOURCES, POLLUTION CONTROLS, INCREASED AGRICULTURAL PRODUCTIVITY, AND "PERFECT" BIRTH CONTROL



Source: Center Report, Center for the Study of Democratic Institutions, Oct., 1972.

with a highly disaggregated system and attempts integration after looking at various levels, including policy levels; (2) Creation of a model to represent the less developed portions of the world (this model is to reflect human resources, energy resources, and material resources in dynamic terms, including entropy considerations); and, (3) A study to consider how in the next twenty to forty years the world might accommodate the next doubling of world population. (The next doubling is assumed as inevitable in the next thirty years or so.) Hence, what will be the required infrastructure changes; the needed resources; the economic, capital and trade-consequences; and the East-West and North-South consequences.

Also, King indicated beginning of work towards a political World Forum concept where continued dialogue is possible among all people of the world.

Selected Reference No. 3

Spilhaus (1972) coined a word: "Ecolibrium," which he defined to mean "balance in our earthly home." He then presented a plea for careful and continuous long-range planning to achieve ecolibrium. The type of planning needed was indicated in general as follows:

> ...planning not only to supply the basic physical needs of shelter, water, food, air, and fire (which is energy), but planning which is also sensitive to people's "wants". These often may be ill-defined psychological needs in mobility, communications, recreation, culture, and beauty which keep us intellectually well and humanly alive. (p. 711)

As a basic guide or index to planning, Spilhaus believes it is important for government to consider how to: "...multiply choices for each individual in such a way as to impinge least on the choices of other individuals." His reasoning in support of this recommendation was as follows:

> Vague phrases such as the quality of life, progress, standard of living, and so forth are ill-defined; one measure, however, is the kind and number of choices that individuals may make. To increase choices is to increase freedom. Increasing choices is democratic. Increasing choices enables individuals to make combinations for themselves which most closely fit their own views of "quality of life." Increasing choices, therefore, preserves individuality. (p. 711)

In relation to environmental quality, Spilhaus believes that pollution in general reduces the choices of a clean environment. He further indicates:

> The solution here is not to limit the choices of things and services that people want to ease their lives, but to rebuild the industries and works of man that provide these things and change them so that they are saving and clean. ...
>
> The great challenge is how to continue providing for people's needs and wants and yet, at the same time, to manage the environment by containing wastes in the manufacturing plants--by recycling, reprocessing, and reuse--and by rebuilding industry to be saving of both materials and energy. ... all the efforts to maintain and increase choices use energy. Hence, if we are to continue to provide choice or increase choices, we must expect and plan to increase energy per capita in saving and clean ways.
>
> But to come full circle, when we accomplish these intermediate steps and increase energy per capita, if, at the same time, there is a continual increase in population, we will eventually arrive at a point where getting rid of the nonequilibrium heat generated on earth will become a problem. Inescapably, therefore, population limits which will maintain choice with no additional expenditure of energy are fundamental and most urgent. (p. 711)

Based on some ideas attributed to Professor Solow, Spilhaus reflects also on an economic approach to pollution and its control. He develops a theme of "Free costs everybody more" (with special reference to air and water "commodities") as follows:

> "Free" is a word loosely used for things we pay for without knowing it. We have necessities which traditionally were free and now are partially free in the sense that their cost to the user is kept below the real cost. Such unrealistically low costs promote waste which in turn raises real cost by increasing scarcity.
>
> Water was free in the past. It was free before there were so many of us. Clean air, clean water, and even natural foods were free for the taking before our numbers made it necessary to produce them faster than nature can supply them. Water is still almost always priced far below its true cost, even where it is in short supply. Yet food, equally fundamental to our bodies, is priced according to its scarcity. We can no longer think of water and air as free, inexhaustible supplies. Nor can we think of fouled air and water as natural bounties which can be cleaned up at a price once and for all. As we continue to use them we'll continue to dirty them and must continue to clean them for reuse at a continuing cost of energy. (p. 713)

An additional concept which Spilhaus develops is his belief as to what is meant by a steady-state world. He discusses this concept in view of his ideas concerning ecolibrium as explained above. He says:

> In environment, steady state does not mean and cannot mean conservation of nature as it was 100 or 1000 years ago. Ecologies will continue to be "engineered" as they have been since the beginning of agriculture. We must learn to change them in accord with the changing needs of people, but maintain steadily the desired qualities.

> Steady state does not mean that things for living would not continually be improved or changed as people's choices dictate. Neither does it mean a static number of choices. There can be exciting change, continual improvement, without escalation of the amount of things. A steady-state world should not inhibit experimentation. On the contrary, it should open up a great new field of scientific and technological experimentation and discovery to develop the "saving" industries to produce things to satisfy new wants with less materials, using energy more efficiently. In a steady state, there must be continual invention to increase choices and give variety to life.
>
> Ideally, the steady-state world should remove the day-by-day crises of human physical needs. Then we will more clearly recognize that welfare is not merely the provision of these needs, but that to fare well is to have rewarding work and continual learning and, relieved of the chore of keeping physically alive, time for the important business of being human.
>
> All this requires the wisest, broadest, long-term planning with its continuity ensured. (p. 714)

In a final section, Spilhaus emphasized the need for long-range planning efforts and made the following suggestions:

> We should set up a permanent United States Planning Board now to formulate long-range directions for our society. Otherwise the future serious realities will be lost in the noise of immediacies and solutions by crises. New initiatives, technological assessment, and research applied to national needs can then be meshed with the preservation of environment, of beauty, and of the texture of cultures in long range living design. ...

Short-range planning tactics for living are appropriately in the hands of the Executive branch. But long-range planning, the strategy of living, should be set up to have greater detachment and continuity while still being responsible to the Executive and Congress. This board would not remove the prerogatives of existing agencies. Neither would it federalize the private long-range thinking that goes on in industry, business, universities, and other institutions. It would use all of these and provide a pathway to national policy where they could be woven into the long-range plans for man on earth.

While one thinks naturally of the parallel with the Supreme Court, this permanent planning board would probably not need a constitutional amendment to give it its status. It would be funded by Congress so that no removal of Congress' control of appropriations would be involved.

The board should represent not only economics, industry and natural and social sciences, but, equally importantly, the arts, architecture, and the humanities.

Only by ensuring a continuity of long-term planning in our government can we hope to build toward the harmony of a bountiful economy with a beautiful environment.

The guideline would be that of preserving and multiplying choices for people. To the old statement "to govern is to choose" we may add that to govern well is to provide people with the opportunity to choose. (p. 715)

Selected Reference No. 4

Kneese and Bower, in Environmental Quality Analysis, classify theoretical and empirical projects dealing with the quality of the environment into three broad areas:

(1) Environment and Economic Growth

The declining quality of the natural environment--which is viewed by the authors to include the air mantel, watercourses and oceans, landscapes, the electromagnetic spectrum, complex ecosystems, climate, and rare geomorphological features of the earth--is shown to be essentially due to the impact of economic growth. More to the point, the impact of prior methods of handling residuals (wastes) has resulted in degradation of environmental quality.

A fundamental law, known as "Conservation of Mass" is recalled to stress that resource inputs used in production and consumption processes "do not disappear into the void after they are burned and processed, but that a residual mass about equal to that initially extracted from nature must eventually be accommodated. Kneese and Bower further stress that: "Unless economical and carefully designed control of residuals generation and recycling processes (emphasis added) is undertaken, the common 'dumps' of air and water must suffer spectacular quality degradation with grave effects on ecology and in due course on man." Some attention is now being given to environmental quality problems in this 'materials-balance' setting.

(2) Management Programs

The need for comprehensive management programs to deal with environmental quality management problem has resulted in more emphasis toward developing management programs which embody environmental impacts of mans' activities.

Rather formal mathematical modeling is generally required to aid in understanding the complex interrelationships between human activities and environmental systems. Also, various approaches might be taken to achieve improved environmental quality; and, comprehensive planning implies analysis of "salient public policy alternatives."

To outline the types of considerations required in such modeling and analysis a 'master model' which contains the following 'submodels' was suggested: (a) submodels of production and consumption activities, (b) submodels to represent modification of residuals after generation in such activities, (c) submodels to trace discharge of residuals (with locations preserved), (d) submodels of dispersion and degradation of residuals in the environment, (e) submodels of effects on receptors, and (f) submodels of mechanisms as required for feeding back information for decisions in the production-consumption-residuals modification segment. Because of the complexity and scope of such modeling and analysis, regional applications only are currently plausible. Aggregations are then required.

(3) Political and Legal Institutions

Special kinds of 'collective-choices' are required when dealing with 'common property resources' (such as the environment) of a society. Unlike traditional resources, such as land and minerals, which are usually valued in a market system, the environmental resources will require new or special kinds of decision-making procedures. Here, concerns of leadership and institution building (with responsibility, authority and power to act on behalf of society) become involved.

Designing of political and legal institutions to effectively deal with environmental quality issues has thus become a matter of general concern and a distinct area of study. Development and analysis of public choice mechanisms are needed as a basis for designing (and/or redesigning) the requisite public institutions.

Selected Reference No. 5

Russell Train concisely presents in the following statement the need for indicator measurements of environmental quality as one practical means for making practical use of scientific evidence which is available:

> Our indicators of gross national product, cost of living, and unemployment are based on somewhat arbitrary definitions that can produce quite misleading results if their assumptions and limitations are not fully recognized. And yet these measures of the economy are critical factors in both formulating and evaluating economic policy. Despite their shortcomings, they are adequate for their purpose, and their use has improved both policy formulation and the level of political dialogue.
>
> Is it possible to provide a similar set of indices for environmental quality? The Council on Environmental Quality and other organizations concerned with the environment have been grappling with this question. I am convinced that we not only can develop such indices, but that we must if the level of environmental policy and planning is to be improved.
>
> A limited number of environmental indices, obtained by aggregating and summarizing available data, could be used to illustrate major trends and highlight the existence of significant environmental conditions. These indices could provide measures of the success of federal, state, local, and private programs in coping with environmental problems that must be solved.

Many obstacles lie in the path of developing environmental indices. For some aspects of the environment there are conceptual questions that must be answered. For example, we know that land use is a basic component of environmental quality, but at this point it is not clear what aspects of land use we should be measuring.

Good indices depend upon good data, but the environmental data now being collected are deficient in many respects. Inadequate sampling is probably the most pervasive problem. ... water pollution readings are only rarely adjusted to take into account the location of the stations collecting the data. Another major problem is the excessive length of time between collections of data. Unsatisfactory systems for data storage and dissemination are often notable deficiencies.

Finally, in many cases the scientific knowledge necessary to properly weight the components of an index is lacking. How important is dissolved oxygen compared to turbidity in estimating the quality of our nation's water? How much park space does a typical urban dweller need or want? Until sound standards are set for the major aspects of the environment, a number of somewhat arbitrary assumptions will have to be made in the computation of indices.

Although there are formidable obstacles to the development of environmental indices, real progress has been made in this direction. There has been a marked increase in interest in the subject among federal, state, and local agencies and also within the academic community. The dialogue concerning environmental problems has increasingly been based on empirical evidence instead of on intuitive assumptions or political interests.

Policy-making neither can nor should become totally "scientific." Vital decisions will always depend ultimately on the values we hold and on the way we express these values through the political system. But we must also strive to make maximum use of the scientific evidence available to us, and the development of environmental indices is one important way of doing this.

Summary of the Problem in Perspective

Up to this point we have tried to accomplish two of the outlined procedural steps toward establishing planning and research needs. That is, the procedural steps taken have been:

Step 1 - Define Basic Problem
Step 2 - Place Problem in Perspective

We are now ready to consider:

Step 3 - Refine Problem Definition

We believe the basic problem definition presented in the first section is still applicable, but a variety of interdependent factors (and other problems) necessitate that water quality management be considered in a general systems analysis framework. Water quality management is not strictly isolatable or independent from other environmental management problems.

Based upon the state-of-art survey and the selected perspective viewpoints, we believe the following 'types-of-refinements' in problem definition are required: (Note--Further efforts are needed to adequately reflect these considerations in a comprehensive definition of the problem.)

Factors Affecting Problem Definition	Type-of-Refinement Required in Problem Definition
1. Hydrologic Basis	Water is both a dispersed and mobile resource. Location-preserved analyses are required to link and assess water quality in affected receptors. (Sources of effluents are also location-dependent.)

Factors Affecting Problem Definition	Type-of-Refinement Required in Problem Definition
2. World-wide Scope	Oceans are the final receptors and hence water quality management becomes a world-wide concern.
3. Aggregation Framework	Interdependency of impacts (benefits and costs) among receptors necessitates a systematic aggregation framework to generalize management needs and results.
4. Social Welfare Setting • Efficiency • Equity • Externalities	Social welfare maximization is an implicit goal. Problems of efficiency and equity are involved. Externalities of pollution result in the need for a social setting.
5. Other Environmental Quality Management Problems • Air • Land • Other Eco-systems	All environmental quality problems are shown to be intertwined; and, therefore, water quality management is not an isolatable problem.
6. Other Related Problems • Economic Growth • Natural Resource Use • Materials Balance • Energy Sources and Use • Technology/Industrialization • Population	The cited factors are also integrally related to water quality management and must be considered in a comprehensive analysis.
7. Types of Pollution and Pollution Control Impacts • Health • Esthetics • Production (Activity) Changes • Ecological	As outlined in Exhibit I-1, a vast array of consequences are involved in dealing with water quality management. Comprehensive efforts are called-for and need to be included.

Factors Affecting Problem Definition	Type-of-Refinement Required in Problem Definition
8. Dynamic Setting	The entire water quality management problem is cast in an ongoing and dynamic setting. This affects the types of analysis needed.
9. Thermodynamic Setting (Entropy)	Especially in a global long-term framework, thermodynamic laws related to entropy must be considered. Water quality is involved.
10. Management Approaches • Regulation • Taxes/Subsidies • Licensing • Others	A broad range of policy, program and pollution abatement management alternatives exist. Different economic and social consequences are involved.
11. Quantification/Measurement Techniques	Analytical and data requirements will vary in relation to approaches considered.
12. Value Systems • Physical/Metaphysical • Tangible/Intangible • Economic/Metaeconomic • Known/Unknown • Quantity/Quality	Environmental quality management problems in general have caused reconsideration of numerous types of implicit, underlying value systems. Management embodies values in terms target criteria and objectives.
13. Institutional Setting and Legal Structures	Social choice mechanisms (socially and culturally dependent) involve institutions and legal structures. Changes are occurring in this regard and such changes affect management strategies.
14. National and International Goals and Priorities	Water quality management is one of many concerns.
15. Management Framework	The sum-total of the above (plus other factors) affect the needed water quality management framework.

One can hardly consider the above listing of factors affecting water quality management to be a useful analytical refinement of the basic problem. However, perhaps we are ready to "turn-the-corner" and get on with our principal concern of identifying and quantifying relevant 'costs' and 'benefits' of water pollution control.

Directions of Needed Study

From an economic point-of-view there appear to be four major inadequately developed concepts which inter-link most, if not all, of the identified factors of the water quality management problem: (1) Externalities, (2) Value, (3) Time Profile, and (4) Equity. The most needed directions of study stem from these concepts as will be briefly described below.

First, however, it is taken as given that agreement can be reached with the economists' contention that:

> Maximization of social (public and private) welfare is the implicit goal of a society.

Also, it is believed agreeable that society seeks the most efficient means to achieve a given level of social welfare.

Benefit measurement is the dominant problem to be faced as we proceed from the current state-of-the-art. Current approaches to benefit measurement are derived from an economic development orientation which 'flies-in-the-face' of environmental quality. In other words, it is the objective function (social welfare) which requires the most additional attention. What is it that we are attempting to optimize? This leads us to basic concepts such as externalities, value, time profile and equity.

Externalities

We believe that the single most critical problem which needs further study relative to assessing benefits and costs of water quality management is to identify, measure and quantify externalities, i.e., the spillover effects of controllable activity.

Direct cost enumerations of pollution control are relatively straightforward and not the main concern toward determining maximum social welfare.

The enumeration and evaluation of benefits (including damage reduction) are much more complex. The existence of externalities means that not all 'beneficiaries' may be enumerated by observing market transactions. Benefits, as measured by market prices, will therefore tend to be incorrectly estimated since not all beneficiaries are included in the observed market demand price. Buyers will falsify their true demand price if a public good externality is involved.

For this reason, economists contend that maximization of social (public and private) welfare is the implicit goal of a society.

If we restrict our thinking to a nation, then it is noted that the potential for additional externalities still exists and should be taken into account. Further, then, economists (generally) say that our implicit objective as a nation is to maximize Net Social Benefit which is a function (i.e., the social welfare function):

Net Social Benefit = Total Social Benefit -
Total Social Costs

In this function, externalities are 'conceptually' included. A rather macrocosmic gap or void exists however in empirical economic analyses to date to actually measure and quantify the conceptual variable called externality.

If only one direction of needed study were mentioned, the need for measurement and quantification of externalities of water resource use would be it.

Values

Even if externalities were adequately defined, a problem remains in that all externalities are not included in our market-exchange systems. Many externalities include intangible qualities which have value.

A need exists to assign a 'value' to intangibles which are associated with environmental quality. Our market-exchange system fails to capture intangible benefits. Numerous esthetic qualities of clean water have expressed but intangible value to citizens. Net social benefits as described above inherently include 'value' which may not be readily expressed in common-denominator terms.

One notion expressed by some to include economic value for intangibles is embodied in a new term: metaeconomics. Briefly, by inference, this term would relate to other concepts as follows:

Physical/Metaphysical
Tangible/Intangible
Economics/Metaeconomics

Until the 'value' of intangibles (and non-market based tangibles) is adequately developed in comparable terms with tangibles, then we cannot really estimate the social welfare function as described.

Time Profile

Efficient resource use depends on its relative scarcity on one hand, but also temporal allocations must be more adequately considered to assure social efficiency through time. Natural resource use and their depletion is a case in point.

In terms of water quality management, any predictable deterioration of water quality should be projected and evaluated. Otherwise we can expect to spend relatively more time, effort and money in treating consequence of pollution rather than its control. The long term aspects water quality management need to be studied much more completely.

A major factor in this area is the discount rate which is used in benefit cost types of studies. A high rate of interest rapidly discounts future net benefit streams.

Equity

The final major area which we conclude needs further study deals with equity. In brief, environmental quality management in general, with the recent shift toward greater protection, has and will cause various disruptions of past behaviors and activities. Equity issues are involved both in terms of cost burdens and benefit distributions.

From welfare economics we learn some things about compensation principles to account for inequities. There is need to consider this area further.

Four major categories of benefit cost impacts of water pollution and its control were outlined in Exhibit I-1: (1) Health, (2) Esthetics, (3) Production (Activity) Impacts, and (4) Uncertain Ecological Disruptions. We believe the above inadequately developed concepts must be cross-examined in terms of each of these categories.

In this final section we have briefly sketched some of the major directions of needed study based upon the review and perspectives presented. We admit that our own value judgements affected our final conclusions; but, also, we tried to view the problem from the point-of-view of 'society-at-large'. We propose to reserve further, more specific judgements to the Phase II: Research Needs and Priorities report as originally planned. A final visual-descriptive exhibit (Exhibit IX-2) is attached to help convey some of the concerns and concepts (as only briefly sketched) which are involved and which we believe need further study.

Most assuredly, the needed further studies will not be completed for some time. The implied benefits and costs continue however in their dynamic setting. Therefore, we close this report with the following (Davidson, Garnsey and Hibbs, 1967):

> "There is no acceptable substitute for informed value judgements in the evaluation of benefits of public goods. In fact, the only substitute is uninformed value judgements."

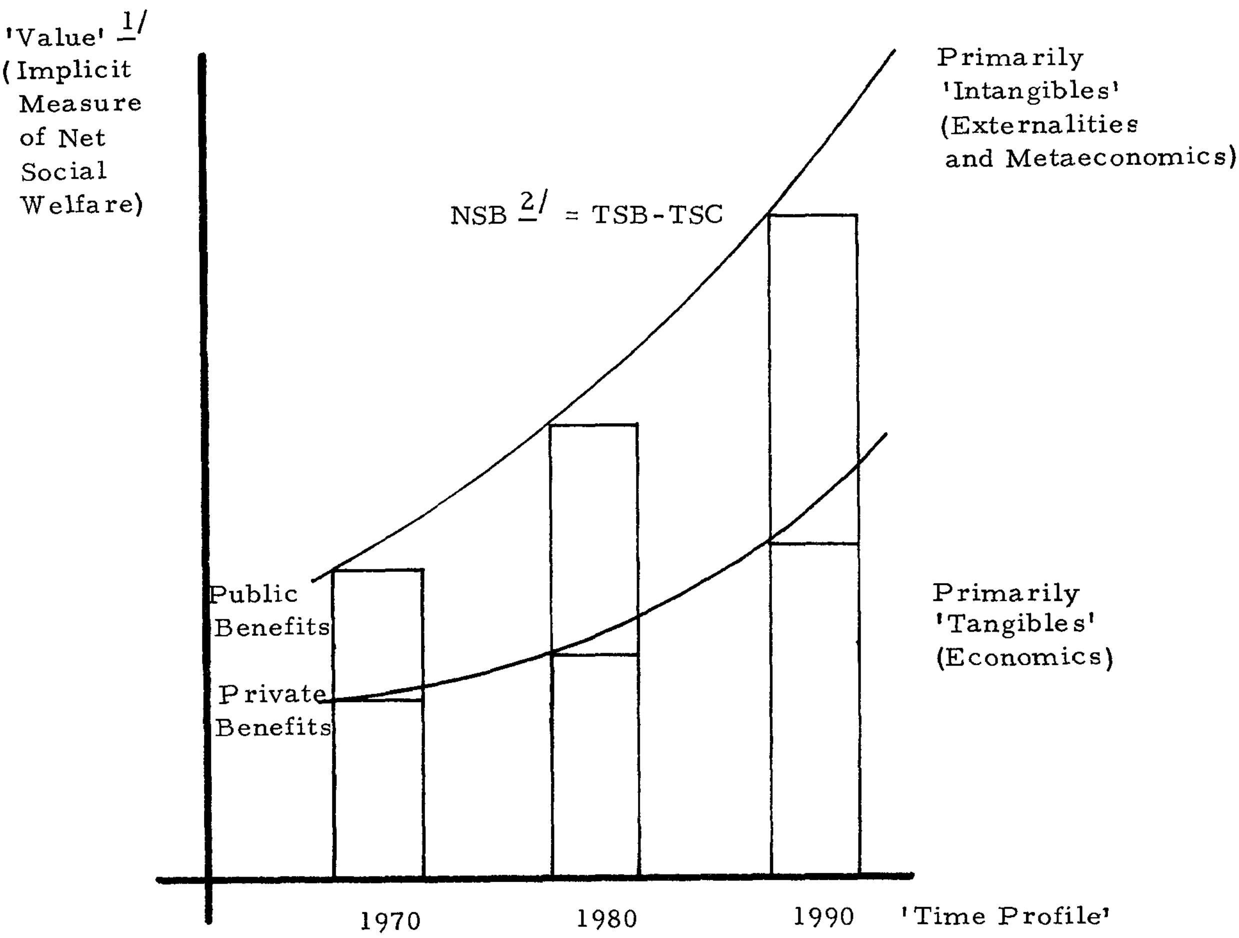


Exhibit IX-2. Hypothetical Net Social Benefits Over Time

1/ Value in common-denominator terms, e.g. dollar-based. In welfare economic terms a non-dollar concept of utility is generally used. The term, 'Utils', has been introduced to imply units of utility, but this leaves the concept abstract.

2/ Net Social Benefit = Total Social Benefit - Total Social Costs

SECTION X

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NOTE: An extended Bibliography was prepared for this project under a separate cover.

SECTION XI

APPENDICES

APPENDIX A

A GENERALIZED WATER QUALITY MANAGEMENT FRAMEWORK

As a framework for establishing national water quality management planning and research needs, it is instructive to first identify a logical series of action-oriented tasks which are typically associated with any on-going general management problem. For this purpose, we propose the following general tasks be considered:

General Management-Problem Tasks

1. Establish Target
2. Estimate Trajectory
3. Determine Required Change(s)
4. Evaluate Methods to Accomplish Required Changes
5. Select a Management Strategy
6. Implement Strategy
7. Monitor Results
8. Feedback Results for Assessment

Compositely these tasks make-up or form a continuous process required in a dynamic setting.

The development of a dynamic management framework to assist and give direction in the realization and evaluation of the desired management objective is an implicit need. To translate the water quality management problem of this study into the above framework, a series of comparable task descriptions were developed. These are outlined in Exhibit A-1.

Exhibit A-1. Outline Description of Tasks Involved in National Water Quality Management

General Task	Water Quality Management Task (By Receptor)
1. Establish Target	Specify water quality criteria
2. Estimate Trajectory	Estimate current and projected water quality
3. Determine Required Change(s)	Establish required effluent-level changes
4. Evaluate Methods to Accomplish Required Change(s)	Determine and evaluate alternative methods for achieving required pollution control
5. Select a Management Strategy	Select a pollution abatement strategy(s)
6. Implement Strategy	Develop, administer and execute the pollution abatement strategy
7. Monitor Results	Develop, administer and execute a survelliance/monitoring system
8. Feedback Results for Assessment	Develop, administer and execute a water quality control feedback information system

APPENDIX B

HEALTH IMPACTS OF WATER QUALITY

Pollutants in each of five broad categories (physical, microbiological, inorganic chemicals, organic chemicals, and radioactivity) may in certain doses lead to undesirable human health effects. The general categories of effects are: (1) acute illnesses, (2) chronic illnesses (including shortening of life or impairment of growth), (3) alteration of important physiological functions, (4) sensory irritations or other symptoms which might lead people to seek medical attention, and (5) possible psychological effects.

The methods of transmission of the pollutants to the population maybe categorized as:

1. Pollutants which enter through the public water supply.
   a. Chemical impurities
   b. Bacteria, viruses, etc.

2. Pollutants which enter through the food supply (where the food is polluted by water, such as a buildup of chemicals in fish which will be consumed by humans).
   a. Chemicals in water supplies
   b. Bacteria and viruses in water supplies

3. Effects of polluted water on transmission of communicable diseases by
   a. Natural populations (such as mosquitoes)
   b. Domesticated animals
   c. Humans

4. Pollutants which enter the body through direct (bodily) contact with the water.

5. Pollutants which lead to ecological changes which affect human physical and/or psychological health.

This discussion presents some representative health impacts which are based on water quality. In Exhibit B-1 these impacts and a number of additional diseases or undesirable effects are described. Also, specific pollutants which are implicated in each effect and the method of transmission of the pollutants involved from water to the population are presented.

Representative Health Effects Due to Water Pollution

The first health impact given is an alteration of the liver function, which is an example of the alteration of an important physiological function (effect category 3). The pollutants involved are polychlorinated biphenyls (PCBs) which are transmitted through the food chain (method of transmission 2). The largest amounts of PCBs reach the environment through industrial and municipal discharges to inland and coastal waters. The water environment is probably the principal sink and transport mechanism for PCBs. PCBs are fat soluble and are stored in the fat of fish and animals. Levels of PCBs 75,000 times the water concentration have been found in fish. Other human health impacts resulting from PCBs are chloracne (skin eruptions-category 4) and hydropericardium (accumulation of fluid in the sac surrounding the heart).

Another health impact based on water quality is eye irritation, which is an example of sensory irritations (effect category 4). Eye irritations can be caused by a pH range (hydrogen ion concentration) which is too high or too low to be tolerated by the lacrimal fluid of the eye. The specific range of pH levels tolerated without pain depends also on the buffering capacity of the water. pH of water is affected when strong acids or bases are added. In this case the undesirable effect is transmitted by direct contact of the body with the water (transmission method 4). The pH of the lacrimal fluid is 7.4 and ideally the pH of the water should be about the same. However since the lacrimal fluid has a high buffering capacity a range of pH values from 6.5 to 8.3 can be tolerated under average conditions.

Another important health impact is hepatitis (inflamation of the liver) which is in effect category 1 (acute illness). The specific cause is a virus which grows in polluted water and is spread through contaminated water or food (transmission methods 1 and 2). It is often carried to man when he eats raw oysters or clams which live in polluted water. Oysters and clams are scavengers which prefer to live where there is a combination of salt and fresh water, such as at the mouths of rivers which are increasingly polluted. Thus they are particularly subject to infection. If they are thoroughly cooked there is little danger, however many people eat them raw. Hepatitis can also be spread from person to person and is one of the most common communicable diseases.

Leptospirosis is caused by microscopic parasites (leptospira) which enter the victim through scratches, wounds or the mucous membranes of the nose, eyes or mouth. The effects are fever, muscular pain and nausea, which are in effect category 1 (acute illness). The method of transmission is 4 (bodily contact with water). These parasites are shed in the urine of infected animals, they contaminate the soil and waterand then enter the victim. Most cases of leptospirosis are relatively mild but some involve inflammation of the brain or the covering of the brain, causing encephalitic or meningitic symptoms. In some cases the disease also affects the kidneys and liver. More victims are infected by swimming in contaminated ponds or streams than by any other source.

The four health impacts discussed are representative of the many undesirable effects which may result from lack of control of water quality.

Acknowledgment:

The Health Impacts of Water Quality summary of representative impacts was prepared for this report by Linda G. Erickson and Larry E. Erickson.

Exhibit B-1: Effects of Water Pollution on Health

Type of Health Impact	Type of Effect	Method of Transmission	Pollutants Involved
Alteration of liver function	3-physiological function	2-through food chain as PCB	Polychlorinated Biphenyls
Chloracne	4-skin eruptions	same	same
Eye Irritation	4-eye irritation	4-through bodily contact with water	Too high or low a pH range and buffer capacity of water
Cholera	1-diarrhea, vomiting muscle cramps, low blood pressure	1b.-through water supply or 2b.-food supply, ingestion orally of food or water contaminated with V. cholarae	Contamination of supply with V. cholarae (through fecal contamination)
Malaria	1-2-fever, chills back pain	3-transmitted by Anopheles mosquitoes	Mosquitoes breeding in swampy areas
Schistosomiasis	1-rash, stomach pain, dizziness 2,3-damage to internal organs, stunt growth anemia, cancer of the liver	1-b. enter through the intestine when person drinks contaminated water and 4-enter through the skin of swimmers or waders in contaminated water	The schistosomiasis eggs in feces from infected humans develop into larvae in streams or ponds and seek an Australorbis glabratus snail. They burrow into the snail and emerge as fee-swimming organisms which can infect man if a victim is found within 30 to 36 hours
Hepatitis	1-inflammation of the liver	1,2 a virus which is spread through contamined water or food esp. raw oysters or clams	A virus which grows in polluted water (raw sewage)

Exhibit B-1 (continued)

Type of Health Impact	Type of Effect	Method of Transmission	Pollutants Involved
Leptospirosis	1-fever, muscular pain, nausea	4-bodily contact with water	Microscopic parasites-leptospira. Shed in the urine of infected animals, they contaminate soil and water and enter victim through scratches, wounds or mucus membranes of the nose, eyes or mouth
Salmonellosis	1-stomach, upsets, diarrhea, chills, fever	1,2-contamined water or food supply	Salmonellae bacteria which breed in food or water
Minamata disease-mercury poisoning	1-weakening of muscles, loss of vision, paralysis coma, death	2-food chain such as in fish. Methyl mercury is concentrated in food chains because it is fat soluble.	Mercury (primarily in the form of methyl mercury).
(Cadmium effects) Cancer, renal effects, itai-itai, hyper-tension	1,2-both acute and chronic effects	2-through food chain	Cadmium
Methemoglobinemia	3-reduces blood's ability to transport oxygen	1-chemical in water supply	Nitrites and nitrates
<u>Endemic fluorosis</u> dental	2-chronic toxic effects on tooth enamel and on bones	1-through water supply (fluoride also enters body through food)	Fluoride-large doses over time (the total fluoride intake must be considered, including water intake)
skeletal (secondary involvement of the nervous system)	increased density of bone, stiffness of spine, limitation of movement		

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APPENDIX C

SUMMARY OF TYPES OF ECONOMIC IMPACTS EXPECTED WITH INTERNALIZED WASTE TREATMENT COSTS

The Council on Environmental Quality, Environmental Protection Agency and the Department of Commerce have jointly sponsored and prepared reports of expected economic impacts of pollution controls on various selected industries. A summary report of eleven industries was published, i.e.,: The Economic Impact of Pollution Control, A Summary of Recent Studies, Prepared for the Council on Environmental Quality, Department of Commerce and Environmental Protection Agency, March, 1972.

The Council provided a general outline of factors to be investigated as a minimum. The consequences, including economic dislocations, which might result from pollution control activities being planned and/or in process needed to be assessed. Disruption impacts of the means used to control pollution were of major concern.

The main means of control being pursued was via application of pollution abatement standards at industrial plant sources. The following list of impacts (Exhibit C-1) outlines the various types of effects which are typically involved assuming waste treatment costs are to be internalized at the plant level. Most of these were specifically noted prior to the studies by the Council. The classification categories were implicit.

A general concern by economists relates to alternative policy, program and other pollution control management activities which might provide a more efficient means for achieving comparable control (at the receptor level). Various policy and program alternatives for control should also be evaluated in terms of the effects cited.

APPENDIX C

Exhibit C-1. Summary of Types of Economic Impacts Expected with Internalized Waste Treatment Costs

Representative Firm Effects

Differential Costs of Production (W&W/O Treatment)
- Small Size Plants
- Medium Size Plants
- Large Size Plants

Plant Closures
Profitability
'Lesser-Cost Alternatives'
- Municipal Systems
- Lagoons (Simple, Activated Sludge, etc.)
- Ponds/Irrigation
- Other, e.g. Regional Treatment

Industry Effects

Structure
Regional Impacts
Prices
Profits
Employment

Associated Industry Effects

Basic Raw Material Suppliers
Other Input Suppliers
Wholesale and Retail Customers
Waste Treatment Facilities Suppliers

National and International Effects

Consumer Prices
National Employment
National Income
Aggregate Demand/Supply Balance
International Trade
Balance of Payments
Long-term Impacts

Source: Unger, Samuel G. and Donald J. Wissman (Development Planning and Research Associates, Inc.) Economic Implications of Waste Treatment Costs and Control Standards on Agricultural Processors: A Case Study of the Fruit and Vegetable Processing Industry, AAEA Ann. Meeting, Gainesville, Fla., Aug. 1972.

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SELECTED WATER RESOURCES ABSTRACTS INPUT TRANSACTION FORM	*1. Report No.*	2.	**W**

STATE-OF-ART REVIEW:
WATER POLLUTION CONTROL BENEFITS AND COSTS **Vol. I**

5. Report Date

6.

8. Performing Organization Report No.

Samuel G. Unger, M. Jarvin Emerson and David L. Jordening

21-AQJ-05

Development Planning and Research Associates, Inc.
200 Research Drive
Manhattan, KS 66502

68-01-0744

13. Type of Report and Period Covered

12. Sponsoring Organization

Environmental Protection Agency report number,
EPA-600/5-73-008a, October 1973.

This report presents a survey and assessment of the state-of-art of economic analyses dealing with water pollution control benefits and costs. The investigation includes the extension of traditional benefit cost analysis into the area of pollution control. Implications for planning and research plus some directions of needed study are also developed. A conceptual basis for benefit cost analysis involving water quality management is suggested. An economic concept of a social welfare function is presented as the most widely accepted public criterion which embodies environmental quality concerns. Problems of efficiency, equity, externalities and social discount rates are outlined. Also, the adequacy of such information is assessed. Benefit measurements of water quality factors are meager and underdevelo ed. A variety of parial-equilibrium approaches to benefit measurement are outlined and some problems, including the planning horizon (time profile), are described. To assess benefit cost impacts of water pollution control, location-preserved analyses are necessary. An aggregation framework which also proposed. General systems analysis approaches are implicitly required to measure benefits and costs of pollution control. Recent developments in the literature have begun to directly assess impacts of environmental quality management. In thif setting, benefit cost analysis effectively becomes a supplementary analysis of alternative sets of simulated general equilibrium types of economic solutions.

17a. Descriptors

Water Quality, Benefits, Costs, Benefit-Cost Analysis, Bibliographies, Literature, Economics

17b. Identifiers

19. Security Class. (Report)	*21. No. of Pages*	*Send To:*
20. Security Class. (Page)	*22. Price*	WATER RESOURCES SCIENTIFIC INFORMATION CENTER U S DEPARTMENT OF THE INTERIOR WASHINGTON, D C 20240

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