METHODS DEVELOPMENT FOR ENVIRONMENTAL
CONTROL BENEFITS ASSESSMENT
Volume I
MEASURING THE BENEFITS OF CLEAN AIR AND WATER

by

Allen V. Kneese
Resources for the Future, Inc.
Washington, D.C. 20036

Based on Research Reports Whose Principal Authors Are:

Richard Adams - University of Wyoming
Ralph d'Arge - University of Wyoming
Shaul Ben-David - University of New Mexico
David Boldt - SRI International
David Brookshire - University of Wyoming
Richard Carson - Resources for the Future
Ronald Cummings - University of New Mexico
Thomas Crocker - University of Wyoming
Maureen Cropper - University of Maryland
Shelby Gerking - University of Wyoming
Leonard Gianessi - Resources for the Future
Michael Hazilla - Resources for the Future
Raymond Kopp - Resources for the Future
Edna Loehman - SRI International
Robert Mitchell - Resources for the Future
John Mullahy - Resources for the Future
Henry Peskin - Resources for the Future
Paul Portney - Resources for the Future
Clifford Russell - Resources for the Future
William Schulze - University of Wyoming
Mark Sharefkin - Resources for the Future
Mark Thayer - San Diego State University
William Vaughan - Resources for the Future

Project officer

Dr. Alan Carlin
Office of Policy, Planning and Evaluation
U.S. Environmental Protection Agency
Washington, D.C. 20460

OFFICE OF POLICY ANALYSIS
OFFICE OF POLICY, PLANNING AND EVALUATION
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OTHER VOLUMES IN THIS SERIES

Volume 2, <u>Six Studies of Health Benefits from Air Pollution Control</u> , EPA-23012-85-020.

This volume contains six statistical epidemiology studies. They show that large associations between health and current levels of air pollution are not robust with respect to the statistical model specification either for mortality or morbidity. They also find that significant relationships, mostly small, occasionally appear.

Volume 3, <u>Five Studies on Non-Market Valuation Techniques</u>, EPA-230-12-85-021.

This volume presents analytical and empirical comparisons of alternative techniques for the valuation of non-market goods. The methodological base of the survey approach - directly asking individuals to reveal their preference in a structured hypothetical market - is examined for bias, replication, and validation characteristics.

Volume 4, <u>Measuring the Benefits of Air Quality Changes in the San Francisco</u> <u>Bay Area: Property Value and Contingent Valuation Studies</u>, EPA-230-12-85-022.

This volume replicates a property value study conducted in the Los Angeles Basin for the San Francisco Bay area. A taxonomy series of air quality types and socioeconomic typologies are defined for cities in the area to examine how property values vary with pollution levels. The contingent valuation method surveys individuals, directly asking their willingness to pay for changes in air quality. The survey method yields benefit values that are about half the property value benefits in both the Bay area and Los Angeles.

Volume 5, <u>Measuring Household Soiling Damages from Suspended Particulates:</u> <u>A Methodological Inquiry</u>, EPA 230-12-85-023.

This volume estimates the benefits of reducing particulate matter levels by examining the reduced costs of household cleaning. The analysis considers the reduced frequency of cleaning for households that clean themselves or hire a cleaning service. These estimates were compared with willingness to pay estimates for total elimination of air pollutants in several U.S. cities. The report concludes that the willingness-to-pay approach to estimate particulate-related household soiling damages is not feasible.

Volume 6, <u>The Value of Air Pollution Damages to Agricultural Activities in</u> <u>Southern California</u>, EPA-230-12-85-024.

This volume contains three papers that address the economic implications of air pollution-induced output, input pricing, cropping, and location pattern adjustments for Southern California agriculture. The first paper estimates the economic losses to fourteen highly valued vegetable and field crops due to pollution. The second estimates earnings losses to field workers exposed to oxidants. The last uses an econometric model to measure the reduction of economic surpluses in Southern California due to oxidants.

Volume 7, <u>Methods Development for Assessing Acid Deposition Control Benefits</u>, EPA-230-12-85-025.

     This volume suggests types of natural science research that would be most useful to the economist faced with the task of assessing the economic benefits of controlling acid precipitation. Part of the report is devoted to development of a resource allocation process framework for explaining the behavior of ecosystems that can be integrated into a benefit/cost analysis, addressing diversity and stability.

Volume 8, <u>The Benefits of Preserving Visibility in the National Parklands of the</u> <u>Southwest</u>, EPA-230-12-85-026.

This volume examines the willingness-to-pay responses of individuals surveyed in several U.S. cities for visibility improvements or preservation in several National Parks. The respondents were asked to state their willingness to pay in the form of higher utility bills to prevent visibility deterioration. The sampled responses were extrapolated to the entire U.S. to estimate the national benefits of visibility preservation.

Volume 9, <u>Evaluation of Decision Models for Environmental Management</u>, EPA-23012-85-0@7.

This volume discusses how EPA can use decision models to achieve the proper role of the government in a market economy. The report recommends three models useful for environmental management with a focus on those that allow for a consideration of all tradeoffs.

Volume 10, <u>Executive Summary</u>, EPA-230-12-85-028.

     This volume summarizes the methodological and empirical findings of the series. The consensus of the empirical reports is the benefits of air pollution control appear to be sufficient to warrant current ambient air quality standards. The report indicates the greatest proportion of benefits from control resides, not in health benefits, but in aesthetic improvements, maintenance of the ecosystem for recreation, and the reduction of damages to artifacts and materials.

FOREWORD

This volume is one of the reports prepared by research institutions under cooperative agreements with the Economic Research Program of the United States Environmental Protection Agency (EPA). The purpose of the Program is to carry out economic research that will assist EPA in carrying out its mission. Until very recently, most research sponsored by the Program @t to improve the methods and data available for determining the economic benefits of pollution control, thereby assisting EPA and other Federal Agencies responsible for preparing benefit-cost analyses of programs and regulations. Such benefit-cost analyses are required as part of the Regulatory Impact Analyses mandated for most major Federal regulations by Executive Order 12291. The availability of improved methods and data will make it possible for EPA and other Agencies to determine more accurately the economic efficiency of their regulations and programs. Very recently, the scope of the Program has been expanded to include a broader range of research on increasing the economic efficiency of pollution control.

The Economic Research Program was a part of the office of Research and Development (ORD) until early 1983, when it was transferred to what is now the Office of Policy, Planning and Evaluation. The cooperative agreements under which this volume was prepared were concluded while the Program was still in ORD; accordingly, ORD's important contribution should be recognized.

This volume is one of a series under the title Methods Development for Environmental Control Benefits Assessment prepared mainly under cooperative agreement R805059 with the University of Wyoming, although several of the individual volumes were completed under later cooperative agreements or under subagreements with other institutions. Each of the other volumes in the series is listed on the front and back inside covers of this volume. The overall purpose of the series is to report significant research results achieved under the cooperative agreement. The purpose of the agreement was to develop improved methods for assessing environmental benefits, with emphasis on air pollution benefits. An earlier series of interim reports prepared under the same cooperative agreement was published by EPA in 1979 under the series title of Methods Development for Assessing Air Pollution Control Benefits with report numbers EPA-600/5-79-001a through 001e.

This volume is a nontechnical summary of most of the economic benefits research funded by EPA at the Universities of Wyoming and New Mexico and at Resources for the Future over the period 1976-83. As such, it represents an overview of much of the research funded under the Economic Research during this period, as well as of a few studies funded by the Office of Air Quality Planning and Standards. Although originally prepared under cooperative agreement R805059, this summary was extended under R810466 with Resources for the Future. A number of the research studies summarized in this volume (and listed in the Bibliography) are part of this same series.

Alan Carlin
Office of Policy, Planning
and Evaluation (PM-220)
Washington, D.C.

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ABSTRACT

This volume is a nontechnical discussion of the work of a number of scholars located at Resources for the Future, the University of Wyoming, the University of New Mexico, and the University of Chicago. The focus of these efforts was to develop improved methods for the economic evaluation of environmental improvements or maintenance. The work was sponsored by the U.S. Environmental Protection Agency by a sustained program in this area of research. The studies centered on two broad approaches. The first involves methods based on actual behavior with respect to environmental goods. These include travel to recreational opportunities of varying quality, prices paid for houses in environments of different quality, decisions about farm crops depending upon how they are affected by air pollution. While a certain confidence adheres to methods based on actual decisions because of their nonhypothetical nature, these methods are not applicable to all environmental benefits. For example, they are not suitable for evaluating visibility effects of air pollution in large landscapes or to a category of benefits termed nonuser or intrinsic. The latter are benefits to people who have a preference for environmental quality in situations in which they do not actually participate. For example, people may value good water quality for the nation as a whole even though they do not recreate in natural waters. Accordingly, resort is made to a set of methods called contingent valuation. These methods rely on questioning respondents about their willingness to pay for various hypothetical changes in environmental quality. While doubts about the accuracy of these methods necessarily arise because of their hypothetical nature, the research reported in this volume suggests that the identified sources of possible bias can be controlled for by careful questionnaire design. There remain, however, some questions for future research. In particular, the matter of how to get respondents to evaluate their replies in terms of their overall budgetary situations invites further inquiry. While the central focus of the research reported in this volume was methods development, some broad insights concerning the quantitative benefits from environmental maintenance or improvement also emerged.

CONTENTS

PART I: BASICS

CHAPTER 1

INTRODUCTION TO BENEFIT-COST ANALYSIS

In the 1960s, the people of the United States became increasingly aware that the fruits of economic development were infected by the rot of environmental deterioration. Late in the decade and early in the 1970s, concern grew to such an extent that a number of laws were passed by the Congress aimed at not only stemming the deterioration of the environment, but improving its quality as well. As we move into the 1980s, environmental concerns, as attested by public opinion polls, are still vividly alive, but are being increasingly balanced by economic considerations. In this atmosphere, there has been heightened interest in the question of whether the costly environmental regulations that have been put in place are, in fact, worthwhile.   To try to shed some light on this question, appeal is often made to an economic evaluation method called benefit-cost analysis.

Benefit-cost analysis was developed initially to evaluate water resources investments by the federal water agencies in the United States, principally the United States Bureau of Reclamation and the United States Corps of Engineers. The general objective of the method in this application was to provide a useful picture of the costs and gains associated with investments in water development projects.   The intellectual "father" of benefit-cost analysis was the nineteenth century Frenchman, Jules Dupuit, who in 1844 wrote an often cited study "On the Measure of the Utility of Public Works." In this remarkable article, he recognized the concept of consumers' surplus (which is explained in the next chapter) and saw that as a result, the benefits of public works usually are not the same thing as the direct revenues that the public works projects will generate.

In the United States, the first contributions to development of benefit-cost analysis did not come from the academic or research communities, but rather from government agencies. Water resources development officials and agencies in this country have from the very beginning of the nation been aware of the need for economic evaluation of public works projects. In 1808, Albert Gallatin, President Jefferson's Secretary of the Treasury, produced a report on transportation programs for the new nation in which he stressed the need for comparing the benefits with the costs of proposed water improvements. Later the Federal Reclamation Act of 1902, which created the Bureau of Reclamation and was aimed at opening western lands to irrigation, required economic analysis of projects. The Flood Control Act

of 1936 proposed a feasibility test for flood control projects which requires that the benefits "to whomsoever they accrue" must exceed costs.

In 1946, the Federal Interagency River Basin Committee appointed a subcommittee on benefits and costs to coordinate the practices of federal agencies in making benefit-cost analysis. In 1950, the subcommittee issued a landmark report entitled "Proposed Practices for Economic Analysis of River Basin Projects." This document was fondly known by a generation of water, project analysts as the "Green Book." While never fully accepted either by the parent committee or the pertinent federal agencies, this report was remarkably sophisticated in its use of economic analysis and laid an intellectual foundation for research and debate in the water resources area which made it unique among other major reports in the realm of public expenditures. It also provided general guidance for the routine development of benefit-cost analysis of water projects which persists until now, even though a successor report does presently exist which is more adapted to the conditions of the present day.

Following the "Green Book" came some outstanding publications from the research and academic communities. Several volumes which appeared over the past two-and-a-half decades have gone much further than ever before in clarifying the basic ideas underlying benefit-cost analysis and the methods for quantifying them. Otto Eckstein's <u>Water Resource Development: The Economics of Project Evaluation</u> (Harvard University Press), which appeared in 1958, is particularly outstanding for its careful review and critique of federal agency practice with respect to benefit-cost analysis. A clear exposition of principles together with applications to several important cases was prepared by Jack Hirshleifer, James DeHaven, and Jerome W. Milliman in <u>Water Supply: Economics and Policy</u> (University of Chicago Press, 1960). A later study which was especially notable for its deep probing into applications of systems analysis and computer technology within the framework of benefit-cost analysis was produced by a group of economists, engineers, and hydrologists at Harvard and published under the title <u>Design of Water Resource Systems</u> in 1962 (Harvard University Press). The intervening years have seen considerable further work on the technique and a gradual expansion of it to areas outside the water resources field, some of them more or less natural extensions of the work on water resources. For example, the last two decades have seen many attempts to evaluate the benefits of outdoor recreation--both water-related and otherwise. A relatively recent book which looks at some applications other than water-related ones, but which is in the mainline of the traditional benefit-cost analysis, is Ezra Mishan, <u>Cost-Benefit Analysis</u> (Praeger Publishers, 1976).

But the most striking development in benefit-cost analysis in recent years has been its application to the economic and environmental consequences of new technologies and scientific and regulatory programs. For example, the Atomic Energy Commission (before the Energy Resources and Development Administration and then the Department of Energy were created) used the technique to evaluate the fast breeder reactor program. A report on this study is found in U.S. Atomic Energy Commission, Division of Reactor Development and Technology, <u>Updated (1970) Cost-Benefit Analysis of</u>

the U.S. Breeder Reactor Program, Washington 1184 (January 1972). The technique has also been applied to other potential sources of environmental pollution and hazard. Two studies which come to quite contrary conclusions have been made of the Automotive Emissions Control. Volume 4, The Costs of Benefits of Automotive Emissions Control Series No. 19-24, Washington GPO (September 1974) was prepared by a committee of the National Academy of Sciences. The other study from a major automotive producer is reported in Clement J. Jackson, et al., "Benefit-Cost Analysis of Automotive Emissions Reductions," Research Laboratory, General Motors Corporation, Warren, Michigan, CMR 2265 (October 15, 1976). Other studies have been or are being conducted in the area of water quality improvement policies, emissions control from stationary and mobile air pollution sources, and regulation of toxic substances.

Even while the technique was limited largely to the relatively straightforward problem of evaluating public works, there was much debate among the economists about appropriate underlying concepts and methods of making quantitative estimates of benefits and costs--especially of benefits. Some of the discussion surrounded primarily technical issues, e.g., ways of computing consumer surplus (the idea referred to earlier and explained later) and how best to estimate demand functions (also explained later) for various outputs of projects. Others were more clearly value and equity issues, e.g., whether the distribution of benefits and costs among individuals or regions needed to be accounted for or whether it was proper to consider only the sums over all affected parties. Another central issue was what the proper weighting of benefits and costs occurring at different points in time was to be. This is known as the "discounting" issue. The term refers to the question of how to take into account the fact that normally the further into the future gains or losses accrue, the less heavily they are weighted by those who stand to do the gaining or losing.

Application of benefit-cost analysis to issues such as nuclear radiation, the storage of atomic waste, and the regulation of toxic substances in the various environmental media (both those substances which are immediately toxic to man and those which affect his life support or value systems) aggravate both the conceptual and quantification problems which existed in water resource applications. There are several reasons for this.

Firstly, while water resource applications often involved the evaluation of public goods (in the technical economic sense which is explained in the next chapter), the bulk of outputs from such projects are irrigation water, navigation enhancement, flood control, and municipal and industrial water supplies. These outputs can usually be reasonably evaluated on the basis of some type of market price information because often private developments produce similar or closely related outputs. In the new application, we are dealing entirely with situations in which useful information from existing markets is difficult, if not impossible, to establish.

Secondly, such matters as nuclear radiation and toxic materials relate to exposure of the whole population or large subpopulations to very subtle

influences of which they may be entirely unaware. It is difficult to know what normative value individual preferences have under these

circumstances, and clever methods of quantifying damages (negative benefits) have to be evolved.

Thirdly, the distributional issues involved in these applications concern not only monetary benefits and costs, but the distribution of actual physical hazard. For example, residents of an industrial city may suffer ill health resulting from pollution associated with the production of goods consumed in another locality. While it is not out of the question that monetary equivalents to these risks could be developed, the ethical value issues involved appear to be deeper than just the associated economic returns. This is especially so if compensation is not actually paid to damaged parties as in practice it is usually not.

Fourthly, we are in some cases dealing with long-lived effects of a policy decision which could extend to hundreds of thousands of years and many, many human generations. This situation raises the question of how the rights and preferences of future generations can be represented in this decision process. Realistically, the preferences of the existing generation must govern. The question is whether the simple direct desires of existing persons are to count exclusively or whether justice demands that the present generation adopt some ethical rule or rules of a constitutional nature in considering questions of future generations.

Thus the new application of benefit-cost analysis bristle with ethical, value, and quantification issues. A group of researchers located principally at Resources for the Future and the Universities of Wyoming, New Mexico, and Chicago have, for the last several years, been working on a research program aimed at making progress in the basic understanding and analysis of these issues. In the present book, a nontechnical summary of results from one of the most substantial thrusts of this research--methods development and quantitative estimation of benefits from air and water pollution control (air and water quality maintenance or improvement) is presented. This program of research has received sustained support from the U.S. Environmental Protection Agency. A person wishing to study the details and technicalities of the research studies underlying this brief nontechnical volume describing these studies is referred to the bibliography at the end of this book. For simplicity, references are held to a minimum in the exposition itself.

Before proceeding specifically to a discussion of the methods and results of the research, it will be useful to describe, in general terms, some of the basic ideas from the discipline of economics which were central to this research enterprise. Also the next few chapters display its inherently interdisciplinary character.

But before doing so, I wish to underline what this book is and what it is not. It is not an effort to provide a comprehensive review of environmental benefits studies in general. The case material in it comes from EPA-sponsored studies of air quality and water quality, conducted in a coordinated way over the course of a number of years primarily at the

University of Wyoming, the University of New Mexico, and Resources for the Future. While this therefore is not an entirely comprehensive review of research in the area, some bounds had to be set, and the one chosen seems reasonable on three grounds: (1) I have had some personal involvement in nearly all of the projects discussed and therefore feel more qualified to write about them than if I had only read about them; (2) these projects span the range of methodologies that have been developed for benefits assessment work including bidding games, surveys, property value studies, wage differentials, risk reduction evaluation, and mortality and morbidity cost estimation (all of these will be explained subsequently); and (3) they represent the results of a reasonably coherently planned program of research. Accordingly, the book contains a relatively complete picture of the state of the art of benefits measurement for environmental improvements as of 1983. However, a further point should be made, and that is that these studies are deliberately at the frontiers of the benefit measurement craft. Their chief intent was methodological improvement, and the reader should give primary attention to that aspect. Quantitative estimates of benefits are given but they should be regarded as preliminary and experimental in character, and at best an order of magnitude indication of the actual numbers. For this reason, I have not adjusted results for inflation even though they accrued over several years. They are in the dollars of the late seventies and early eighties. To refine them further would confer on them an unfounded aura of accuracy.

CHAPTER 2

WHAT ARE ECONOMIC BENEFITS

INTRODUCTION

        While this book is intended to be a nontechnical presentation of
our research on air and water quality benefits, some knowledge about a
few key concepts from economic theory is essential to understanding both
the research approaches taken and the results attained.   The most
central of these concepts is that of an economic demand for a good (a
material object which is valued by people), or for a service.
When economists speak of demand, they are referring to the relationship
between the real or hypothetical price of a good or service and the
amount of it consumers actually buy or would wish to buy per unit time
at that price. Except in very unusual cases, one of which actually
occurs in chapter 13, the amount consumers will want to take will be
less the higher the price. The discussion here of economic demand is
simple and straightforward, but very compact.

        It is important to keep one distinction clearly in mind when
discussing economic demand. That is, the distinction between the demand
of one individual or household--individual demand--and the "added up"
demand of all individuals or households demanding that good or Service--
aggregate demand. The latter is sought in doing benefit analysis but it
is logically derived from the former.

INDIVIDUAL DEMAND

        Let us start with a look at individual demand. Consider the
following numerical example of an individual's price quantity
relationship for the fictitious commodity widgets.

        At a price of eight dollars, the consumer will buy no widgets, at
six dollars, he will buy two, and so on. If, for whatever number he
does wind up buying, he is charged the same amount for each one (this is
the usual practice in actually existing markets) then the third column,
in which the price is multiplied by the number taken, will indicate how
much he actually does pay. But if we could figure out a way to make him
pay the maximum he

        ==

        1 . There is also the pertinent concept of derived demand.
On the theory that "enough is too much," we will postpone discussion of
this idea until we need it in connection with the case study presented
in chapter 8.

Price of Widgets	Quantity Taken by Consumer	Price Times Quantity	Price Times Incremental Quantity	Accumulated Price Times Incremental Quantity
8	0	$ 0	0	$ 0
7	1	7	7	7 (7)
6	*2*	*12*	6	13 (7+6)
5	3	15	5	18 (7+6+5)
4	4	16	4	*22* (etc.)
3	5	15	3	25
2	6	*12*	2	27
1	7	7	1	28
0	8	0	0	28

is willing to pay for each individual unit (column four) or be deprived of having any widgets at all, then the accumulated price times incremental quantity shown in the last column would reflect his <u>total willingness to pay</u> for widgets. This is the amount he would pay in an "all or nothing"' situation where he either pays everything he would be willing to pay or he is deprived of widgets altogether.

Now suppose that our consumer decides he wishes to buy 5 widgets because the going price for widgets is $3 per item. He then actually pays $15, but if he had no alternative but to pay the maximum he would have been <u>willing to pay</u>, then he would have paid $25 for the three.   The difference between what he did pay and what he would have been willing to pay, $10, may be thought to be some extra benefit which the consumer gets because there are such things as widgets available in the market. But because they are uniformly priced at a level less than his maximum willingness to pay, he gets this extra benefit. This additional value is called <u>consumer's surplus</u> by economists. If it were to be the case that the consumer is not required to pay anything for the widgets, he takes eight and his consumer's surplus will be equal to his total willingness to pay--$28. In all cases where there is a positive price, his total willingness to pay will be greater than what he actually does pay because it will include what he actually does pay and his consumer's surplus. For example, if he buys four widgets his willingness to pay equals what he actually does pay plus his consumer's surplus (i.e., $16 + $6).

It is usual in expositions of consumer demand theory to express these ideas graphically by plotting a demand curve for the individual. Below is a plot of the numerical example just reviewed. In the simple example, the
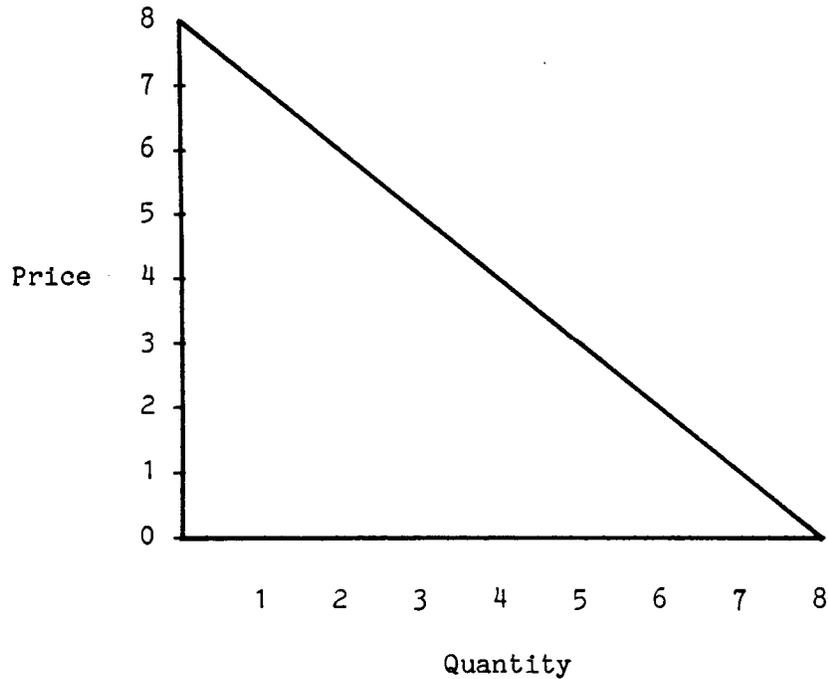
demand curve is a straight line. We generate this line by plotting a price quantity pair point for each of the pairs shown in the numerical example, with interpolation between the points. It is pretty apparent that the accumulated price times incremental quantity column (willingness to pay) is the accumulated area under the demand curve. To see this, observe that every individual price times quantity pair makes a box on the graph as is shown more abstractly below.

P x Q = area of this box, e.g., ⟶
amount actually paid
for this Q
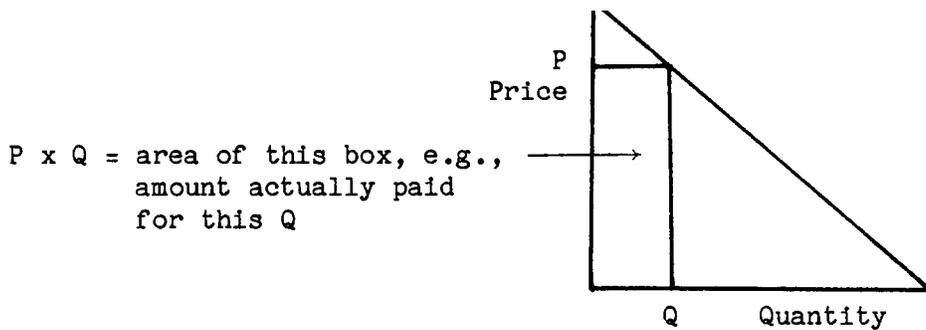
Since the curve represents every possible combination of such Ps and Qs (all possible boxes--imagine their width to be vanishingly small), it follows that the area under the whole curve is equal to the consumer's willingness to pay at zero price for Q.

Again, then, more abstractly than in the numerical example above, let us use a graph to review all the main ideas we have defined so far.

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```
                              ←——————  Demand curve
       (a)
       consumer                   Area (a) + (b) + (c) = total
       surplus                       willingness to pay for the
actual price                           good at zero price
of the good
       (b) P x Q
       amount actu-                    Area (a) + (b) =
       ally paid by      (c)             willingness to pay
       consumer                            for quantity Q


                         Q      Quantity
                         ↑
                  Quantity taken at
                     that price
```
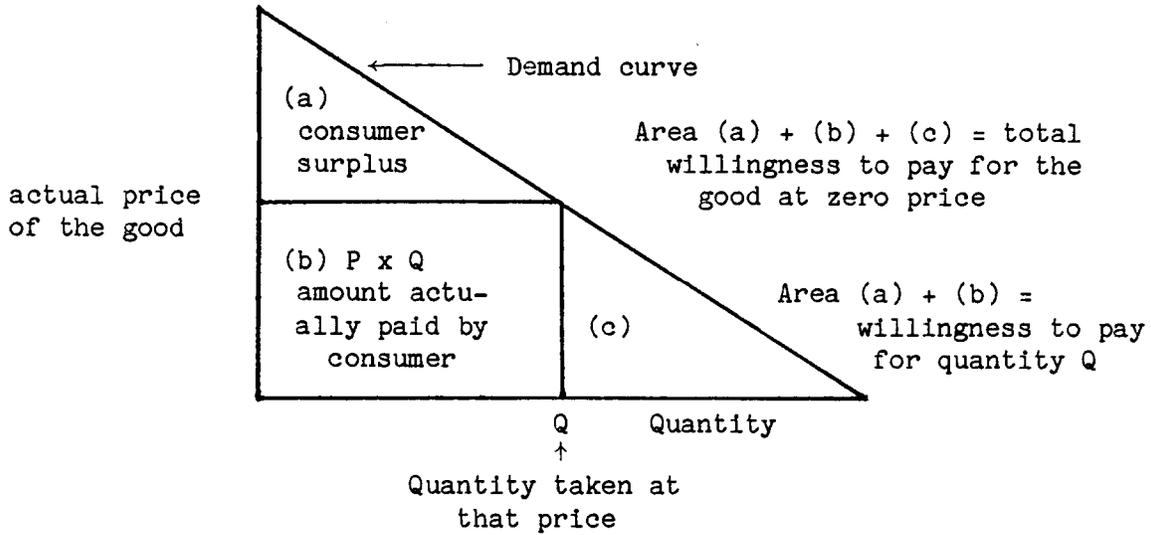
AGGREGATE DEMAND

So much for the individual consumer. But for many purposes (some of which will become clear later) we are interested in the total demand by all consumers for a good or service (in this case, widgets). How, then, do we add up the demands of all consumers in this market? If we are willing to make the assumption that all persons in the market for widgets should be treated equally, that is to say, everyone's demand counts the same in making up the sum, the answer is very easy--we just add up the quantities demanded at every price. For example, let us assume that there are two individuals in the widget market and both are just alike--let's say both are like the one in the numerical example. In this case, the aggregate demand would be just double the individual demand at any given price. For example, at the price of $5, aggregate Q would be 6, P x incremental Q would be $30, and P x Q accumulated would be $36.

Again I illustrate this adding up process a little more abstractly and generally with a graph.


```
Distance A =
Distance B
                 Price
A + B = 2A
   ΣQ = 2A
```

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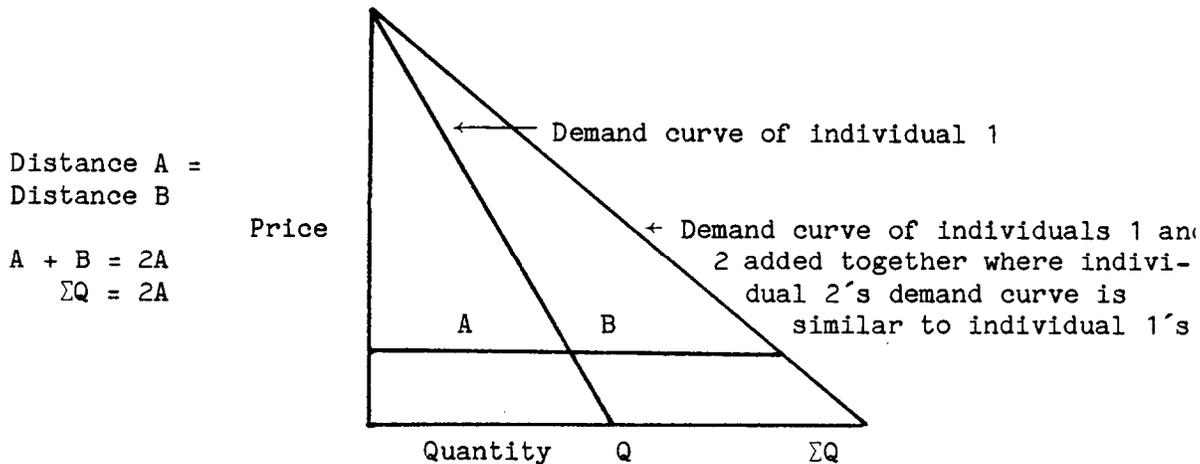
There is no reason why individuals would need to be similar to make the adding up work. Everything is done the same way if they are not, only the numbers are different. Once an aggregate demand curve has been calculated, the concepts of willingness to pay and consumer's surplus apply to it in the same way as to the individual demand curve (still assuming we are willing to treat everyone equally for this purpose).

Stated in its broadest terms, the objective of the research described in this document is to develop methods to derive estimates of the demand (willingness to pay) for cleaner air and water which would then be at least loosely comparable to the demand for other goods and services. This is to permit, at least roughly because of the uncertainties involved, comparison of the value consumers place on cleaner air relative to other goods and services they buy. In practice, this is a very hard problem. But, unfortunately, even from the standpoint of ideas and concepts, we are not yet ready to proceed to quantitative economic analysis. In fact, cleaner air or water are not goods similar to widgets or the many real goods and services, ranging from houses to pins, that can readily be bought and sold in markets. Economists refer to goods like widgets as <u>private</u> goods, and goods like cleaner environments as <u>public goods</u>.

PRIVATE GOODS AND PUBLIC GOODS
In the economist's lexicon, widgets are private goods because they are divisible and separable. If you buy a widget and use it, that same widget does not at the same time render a service to me. If I buy and eat a banana, you cannot buy and eat that same banana. Such goods are easy for the private sector to produce and market because they come in distinct, divisible units and can be sold to distinct, divisible buyers. Should you, however, go and buy cleaner air, for example, in the city where you and I reside, say by paying industries to clean up, the services of that cleaner air are at the same time available to me, even though I didn't pay anything for them. Such goods are called public goods because their units are not divisible and distinct. Their services are available to many persons at the same time, including those who don't pay for them, and unlike private goods the use of their services by one person does not diminish their availability to others. Private markets are very bad at producing such goods; indeed, there usually is no private economic incentive to produce them at all because while many people could benefit from them, no single individual has a sufficient incentive to pay for them.

Two chief implications for the research reported in this book flow from this situation. First, while in principle it is possible to think of an individual demand curve for cleaner air or water just like a demand curve for widgets, there usually will not be market price information which will help directly in defining such a curve. Sometimes, as we will see further on, such information is helpful indirectly. This means further that development of methods for obtaining information on how consumers value or would value cleaner air or water if they had more information, is a very important and difficult task. To develop such methods was, as already stated, the chief objective of our research.

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A second implication is that even if we have individual demand curves for public goods, we cannot properly add them up in just the same way as for a private good. The way we added up for the private goods is called <u>summing</u> horizontally. Individual demands for public goods must be summed <u>vertically</u>.

To see this, refer back to our widgets example. Assume that instead of demand for widgets, the columns refer to successively lower prices for air quality improvements for an individual consumer and the quantities of improvement the consumer would want at those prices. P x Q and P x Q accumulated have the same interpretation as for private goods for this one individual. But now let us add a second consumer as we did in the private goods case. With the second consumer added in, it does not mean that more units of quantity of cleaner air will be taken at a given price, as was the case with the private good. The same units of quantity are available to both consumers. Thus, the willingness to pay for up to three units of cleaner air is $18 for the first individual plus $18 for those same three units, or a total of $36. As noted, the kind of <u>summing</u> done here is called <u>vertical</u> summing in contrast to the <u>horizontal</u> summing for private goods. Again, we can illustrate this graphically. It is easier to show the procedure when demand curves for the two individuals are not equal, so our illustration assumes they are not. In the graph below, individual demand curves are designated D1 and D2' For any given level of air quality, say Q, the willingness to pay for that level (the cross-hatched area) is the willingness to pay of. D, plus the willingness to pay of D2 for the same quantity of air quality improvement.
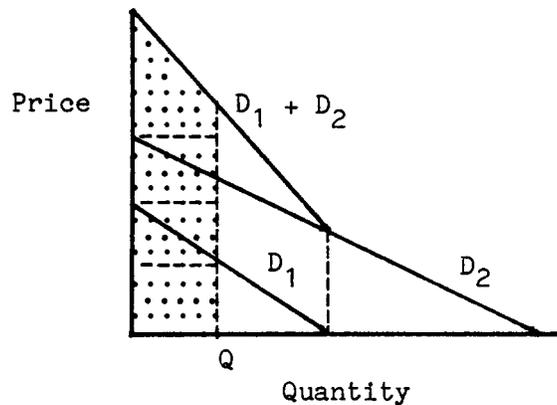
This total willingness to pay for q units of clean air is in economic terminology the "benefit" of q units of clean air. Since no price is charged for these q units it is also the consumers surplus associated with the provision of q units of clean air.

COMPENSATION

A final note on concepts of demand; economic reasoning indicates that when we are considering a situation in which persons are deprived of something they otherwise would have had, as when previously clean air is polluted, willingness to pay for the clean air is not the fundamental test of its value to them. Rather, if they are to be as well off as before the change, one must ask how much they would have had to be compensated to be as well off as before. Generally speaking, <u>willingness to pay</u> is easier (although usually not easy) to estimate than required <u>compensation</u>. Economic theory indicates that the former will be equal to or smaller than the latter. In most of what follows, we will concentrate on willingness to pay as a conservative and usually more measurable quantity.

The aspiration in the quantitative studies reported here was to estimate willingness to pay, but we shall see that we must often be satisfied with results that resemble more the price times quantity value. But we do have the advantage of knowing in which direction the error lies in such an instance. We know from the earlier discussion that P x Q will never be larger than willingness to pay and that usually it will be smaller.

This completes the general discussion of economic benefits. More specific topics in the area will arise in connection with the case studies presented in Part II of this volume.

The next chapter in this part treats briefly an essential element in the complete analysis of benefits from air and water quality improvement. This is the matter of establishing the link between a change in emissions of pollutants to the atmosphere or a water course on the one hand, and the ambient environmental conditions on the other, which, in some manner, adversely affect human beings.

There are two steps or linkages in the analysis of benefits from reducing emissions, the one just mentioned, and, the other, once that link of emissions to human effect is established, what economic value is to be placed on that effect. The latter is the subject, in abstract terms, of chapter 4. The case studies presented in the following chapters concentrate primarily on quantifying the value to be placed on various pollution effects. But in the next chapter, as mentioned, I discuss the linkages between emissions and effects on humans. While this is not strictly an economic problem, the economist endeavoring to estimate benefits must often study these linkages as well because there is in many cases no pre-existing information about them.

CHAPTER 3

LINKS BETWEEN ACTIONS THAT AFFECT THE
ENVIRONMENT AND EFFECT ON HUMANS

INTRODUCTION

As just stated, an essential element in estimating the benefits from air and water pollution control programs is an understanding of how emissions control affects the environmental conditions which humans value. Such effects can be rather direct and easy to perceive, as when visibility is impaired, or quite indirect and difficult to perceive, as when air pollution produces chronic illness or when agricultural productivity is reduced by air contamination. This chapter briefly discusses the various linkages, and methods of estimating them, between emissions and ambient conditions that directly or indirectly affect humans. Understanding these linkages is central to the various illustrative cases of economic evaluation discussed later.

HEALTH LINKAGES

Concern about health effects has been the basis for most of our air pollution legislation in the United States. Linkages between emissions and health are subtle and difficult to establish, especially when one wishes to link changes in emissions to health states (as is necessary if we wish to estimate the demand for improved air quality or the demand for air quality maintenance). Four kinds of information are needed: emissions, translation of those emissions to concentrations in the environment, dose-response relationships (i.e., how are specific concentrations of an air pollutant related to health), and the population at risk. The latter three of these items are hard to estimate. Translations of emissions into concentrations in the environment (e.g., tons of sulfur oxide emitted into parts per million of sulfates at various points in the surrounding air) is best accomplished by means of special computer models called <u>dispersion</u> models. These are imperfect at best, and it is usually not possible to verify them against observed conditions. The linkage between concentration in the environment and health effects is also hard to establish, especially if we are concerned with chronic as opposed to acute effects.

For example, there has been much concern about possible links of air pollution to cancer. But cancer is a disease that usually appears many years after there has been exposure to carcinogenic substances-- often fifteen or twenty years later. Therefore, it is very hard to sort out Possible causes. Essentially, there are two ways of trying to make the

link--epidemiology and animal studies with subsequent extrapolation to human beings. The latter have well-known deficiencies, especially with respect to something as complex and subtle as air pollution, and we made only limited use of them in our research. Epidemiology observes conditions as they exist in actual environment, and, trying to control for other factors which might be related to health, endeavors to isolate the effect of air pollution. Our effort to develop improved methods for quantifying the benefits of air quality improvement involved several epidemiological experiments which are reported in connection with cases reviewed in Part II. Almost needless to say, efforts to establish the link between air pollution and health are afflicted by great uncertainty.

VISUAL QUALITY

An emerging air quality issue of central importance, especially in the West, is the impairment of visibility due to air quality deterioration. In this case, the linkage between emissions and effects on humans is by direct perception of the degraded conditions. However, we are not interested only in how some fixed condition is perceived, but, in accordance with our discussion of economic demand in the previous chapter, we wish to know what persons would be willing to pay for alternative, increasingly better, levels of air quality. Therefore, even though a person can perceive conditions directly, we must find ways of simulating situations other than those that exist at any given time. While I reserve deeper discussion of how values can be attached to such conditions until the next chapter, we can say here that the main method employed is asking people, with carefully structured questions, how much they would be willing to pay for improved conditions. To solicit such information, simulated conditions are presented in visual form to the interviewee. Generally, this is done by means of photographs which have been taken during actual episodes of clean and dirty air that, at one point in time or another, have actually existed in the particular area being viewed. A technique which potentially is an advancement over this procedure is computer simulation of changed conditions. In this technology, a slide of a particular scene is put in digital (numerical) form so that it can be replicated by a computer on a high resolution television screen. Then computations are made about the effect which a hypothetical change in emissions, associated, say, with a projected new power plant at some specified distance and direction from the scene, would have on visibility. Since this calculation is also numerical, the computer can then simulate in pictorial form, on the television screen, the changed conditions of visibility. Development of this latter technique has been part of the projects reported here (although not funded by EPA), but efforts made to get consumer values for visibility, because of the then existing state of the art, had to be based on actual pictures.

LINKS TO AGRICULTURAL PRODUCTIVITY

Agriculture may be adversely affected by air pollution. Plants may suffer from leaf burn due to acid rain resulting from sulfur or nitrogen compounds emissions or may be weakened and made more subject to disease by

exposure to ozone. Since vegetation may be influenced by many factors, only one of which is pollution, isolating this effect is not so straight-forward as it might appear. However, that such damage does exist is well documented. Associations between monitored levels of air pollution and crop production are reasonable well established, especially in Southern California, the locale for the study reviewed in chapter 9. But as in the case of visual impacts and health, we are interested not only in what effect existing levels of pollution have on production, but also in what impact changes in pollution levels would have. This once again means that, at least in principle, estimates of real or hypothetical emissions changes must be translated into ambient conditions with dispersion models, crops that may be especially sensitive identified, and exposed acreage calculated. Estimating the effects on consumer welfare via their derived demand (explained in chapter 9) for cleaner air for agriculture presents a particularly subtle and difficult problem. But that is a subject for the next chapter.

LINKS IN WATERCOURSES

I have repeatedly emphasized the need for having a linkage between pollution discharge and effects on things in the environment that man values or on man himself. Unfortunately, in the air, the needed dispersion models are only available in some places--no nationwide model is available or, for that matter, feasible in the present state of the art. Accordingly, often various simplifications must be made in actually doing air quality benefits studies--especially ones that are aimed at estimating national benefits. These short cuts will be described in connection with the cases as the need arises. Fortunately we are in somewhat better shape in the water quality area where impacts of changes in effluent discharges on the aquatic environment must similarly be forecast. Resources for the Future has built, maintains, and is steadily improving a National Water Quality Network Model. Constructing the model was not part of the EPA-sponsored research, but its results were incorporated into that research. This model simulates in a computer water quality changes associated with changes in effluent discharge in the main water courses of the nation as shown in the map below.

The network of water bodies contains 304 rivers, 175 lakes and reservoirs, 37 bays, 10 segments of Great Lakes shorelines, and 26 ocean shoreline segments. Pollutants can be injected into the system at the nodes (municipal and industrial discharges) and uniformly between them (nonurban runoff). The computer model then simulates the transport, degradation, and transformation processes that occur in the water body and calculates a number of water quality characteristics at any point in the system taking account of all of the points of discharge that affect that location. This capability, when translated further into areas of water rendered suitable for various recreational activities by pollution control policies, proved very useful in the benefits from recreational fishing project described in chapter 12. Unfortunately the model presently can handle only a few of the more conventional better understood types of pollution--biochemical oxygen demand and suspended sediment, for example.

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Map of rivers, lakes, and reservoirs included in the National Water Quality Network model.

Subtler influences on water quality, such as the effects on aquatic ecosystems of the introduction of acid from environmental sources presently elude it.

AQUATIC ECOSYSTEM LINKAGES

Over time, it has become increasingly apparent that rainout and other types of deposition of materials from the atmosphere are major sources of contamination of water courses. Special interest and concern has come to focus on acid deposition. When fossil fuels, especially coal, are burned, compounds of sulfur and nitrogen are released along with the other flue gases. Automobiles are also an important source of nitrogen emissions. Through chemical transformation processes in the atmosphere, these substances are partly converted to sulfuric and nitric acid. When this acid rains out of the atmosphere or is otherwise deposited in water courses, especially lakes, they may become so acid that they cannot continue to support fish life. Also, increasingly acid soils can affect plant life adversely. Understanding the link between emissions at particular sources and such ecological effects is difficult, and research on the question is in its infancy. In principle, we need again to understand quantitatively the processes of dispersion in the atmosphere (in this case, for very long distances-- possibly thousands of miles), deposition processes, effects on acidity of the stream and related

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phenomena (for example, increased acidity may cause toxic heavy metals to dissolve and become a problem), and finally, the ways in which aquatic life is affected by the acidity. In practice, as we will see in chapter 14, we must make do with much less knowledge than this in our quest for the benefits of controlling acids from the atmosphere. Moreover, what we do know about the linkage between increasing acidity and fish life suggests that it is quite complex. For instance, it seems that as a certain critical level of acid in the water body is reached, damage to aquatic life mounts drastically with small further increases, but that damage then increases much more slowly, if at all, with further increases. Also, once damage has occurred, it may not be reversible by any practically available technology. Both these characteristics have substantial implications, as we will see in chapter 14, for the economic evaluation of benefits from controlling acidity in water bodies.

MATERIALS DAMAGE

As well as having adverse aquatic ecosystem effects, the deposition of acid or its precursors is the major cause of materials damage from air pollution. Again, dispersion and deposition processes must be understood, but the actual damaging effects are chemical rather than biological in nature. For example, sulfuric acid reacts with the carbonate in limestone and destroys the stone. In addition, acids etch metals and cause corrosion. Similarly, fabrics and plastics can be damaged. Unfortunately, quantitative understanding and predictability of these phenomena is extremely primitive so that, once again, radical assumptions must be employed if damages, especially damages associated with changed conditions, are to be estimated.

GROUNDWATER LINKAGES

One of the most difficult to simulate linkages between pollution discharge and changed conditions in the environment is in the case of groundwater. This is so because (1) far fewer resources have gone into developing such an understanding than is true of surface waters and the air, (2) ground- water flow is often highly complicated, and (3) it is very difficult and expensive to make measurements (holes must be bored). Because it is a highly specialized area and because establishing the needed linkages was such an integral part of the benefits study of controlling groundwater contamination, further discussion will be deferred until I turn directly to that study in chapter 15.

The discussion of the present chapter, unfortunately, illustrates that, even though it is in the domain of "hard" sciences, understanding of exactly how natural systems are affected by man's discharge of polluting substances is still very limited. The uncertainties of knowledge about these linkages are fully as great as the uncertainties about how to do the actual economic evaluations. Thus we are studying, in the experiments reported in this volume, something more akin to a craft than an exact science.

The next chapter discusses, again in very general terms, some methodological aspects of placing an economic value on air and water pollution effects on the environment once they are identified and quantitatively estimated. Each of the methods discussed is employed and further explained in one or more of the case studies in Part II.

CHAPTER 4

PROBLEMS OF ASSIGNING ECONOMIC VALUES

INTRODUCTION

     Once links have been established between humanly controllable
actions that affect the environment and the associated direct and
indirect effects on humans, then the central problem addressed by the
research reported here arises--how to measure the economic demand for
cleaner air and water. That is to say, what is the economic value to be
attached to a given or successively higher levels of improvements to air
or water quality or to protect the existing level of quality from
deterioration? The methods used to make estimates of these values
necessarily differ as among the different types of effects associated
with air and water quality deterioration. This is partly inherent in
the different situations, for example, whether the effect is directly or
indirectly on consumers, and partly a matter of the types of data it is
practical to acquire. As further background for discussion of case
studies in the following chapters, I briefly review some central issues
in the economic evaluation of cleaner air and water.

VALUING RISK TO HEALTH

     The studies of health effects reported in the next two chapters
focus on the possibility that air pollution and contamination of
groundwater may cause chronic disease, which in turn may contribute to
higher death rates (mortality) or nonfatal sickness (morbidity). One
central question, if one is to calculate a benefit in monetary terms, is
what value to place on reduced mortality. How much would people be
willing to pay for a reduction in their risk of earlier death or how
much would they have to be compensated to voluntarily accept an increase
in this risk?

     Economists in the past have attempted to value human life as the
future earnings over an individual's lifetime. This approach, however,
is now no longer viewed as acceptable. In the first place, it assumes
that the value of life can, in fact, be measured in economic terms--a
point certainly open to debate. Second, it implies that the lives of
children, housewives, retired, and other unemployed individuals are
worth less than

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     2.   For those familiar with the concept of present value, it
should be explained that the value used is actually the discounted
present value of expected future earnings.

the lives of employed heads of households. Nearly everyone would find these implications ethically unacceptable.

An American economist named Thomas C. Shelling was, nearly twenty years ago, apparently the first to distinguish between the concept of the cost of statistical risk and efforts to value human life based on lost earnings. The cost of risk idea is ethically more appealing than attempts to value a particular human life. The effort here is to put a value on a small increase or decrease in the probability of death for anonymous, statistical persons. Implementation of this approach has usually involved a search for information about how much people have to be compensated to voluntarily accept a small increase in risk in occupations differing in riskiness--say the risk of additional death per thousand persons. Thaler and Rosen (N.E. Terleckyj, ed., <u>Household Production and Consumption</u>, 1976, Columbia University Press), using wage differences between jobs varying in the level of job-associated risk of death, were apparently the first to estimate explicitly the value of changes in safety. They observed that workers in high risk jobs receive higher wages, and a value of safety can be imputed by examining these risk-related wage differences. Other factors that influence wages were statistically held constant by use of a technique called regression analysis (this method is briefly explained in the following chapter). Unfortunately, however, the Thaler and Rosen study dealt with a class of individuals who, because they are engaged in risky occupations may be more willing to accept risk than the rest of the population. Even so, the estimate they make suggests that a small reduction in risk over a large number of individuals which saves one life is worth about $340,000 (in mid 1970's dollars). This is far higher than the numbers obtained in lost earnings studies. Another study, Blomquist <u>(Journal of Political Economy</u>, June 1977), which examines seat belt use, suggests that the figure for a lost life might be $260,000. This study first estimates how people value their own time and then imputes a value of safety from the amount of time a sample of individuals spent in buckling up seat belts. It may be noted that unlike the Thaler and Rosen result, this is a "willingness to pay" rather than a "compensation" measure. The result may, however, also be biased downward because individuals seem to perceive risks differently when an element of personal control, such as driving an automobile, exists rather than when an involuntary, individually uncontrollable risk is at issue, as is the case with environmental risk. Finally, Smith <u>(Law and Contemporary Problems</u>, Summer-Autumn 1974) in a study similar to Thaler and Rosen-s, but for a more typical population, found that the needed compensation to save one life may exceed $1,000,000. Numbers even higher than this have been reported in the literature.

Clearly, the cost of risk is not precisely known, and perhaps will never be, since attitudes--in particular, risk averseness--presumably can change over time, between groups, and can even vary in different situations. But, we at least have a range of values with which to make order of magnitude estimates of the costs of environmental risks. Likely values lie between a quarter of a million and a million dollars per life, valued in mid-1970s dollars.

There are some additional observations to be made about valuing mortality risk by a particular number derived from observed behavior of people concerning risks.

First, no distinction is made with respect to age, sex, employment, or other personal variables. To paraphrase Gertrude Stein, "a life is a life is a life." This seems ethically acceptable, but might well be the subject for debate.

Second, this analysis does not give attention to the pains and suffering associated with different causes of mortality or to the cost of nonfatal diseases (morbidity).

Third, the value obtained from existing studies does not vary with the degree of risk. To put the matter in terms of the discussion of economic demand in chapter 2, this means that the demand curve for mortality reduction vis-à-vis pollution looks like that depicted in the following figure.

Number of lives saved
because of cleaner air

x_1 = number of lives saved because degree of clean air achieved
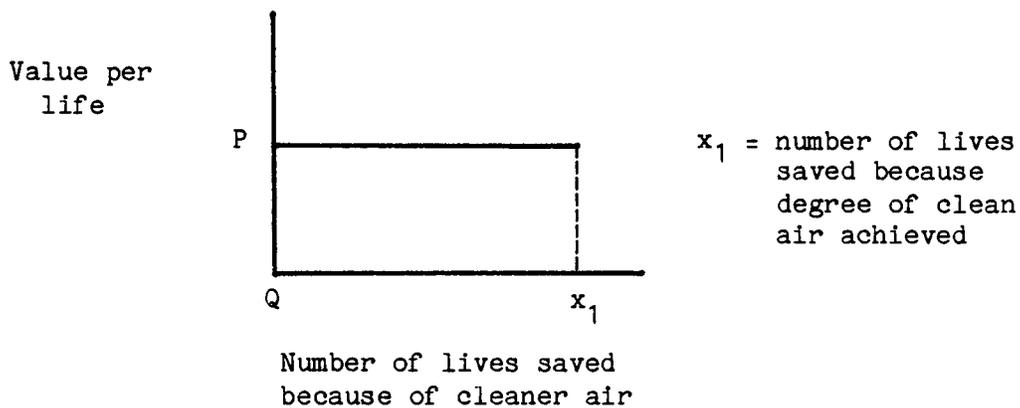
While as stated in chapter 2, one generally expects price to decline as quantity increases, this constant value may be defensible within the present context because in the case of air pollution we are, at most, speaking about small changes in the general risk to health. Over such a small range, it is not unreasonable to think that the value of risk reduction would remain about constant.

MORBIDITY

Pollutants can, of course, do much harm to health without actually killing. A number of studies have tried to evaluate this harm by estimating the number of days lost from work because of such pollution and then, to get an economic value, multiplying those numbers of days by the average wage rate. This procedure is incomplete for several reasons: it does not value the cost of sickness for persons who are not in the labor force, i.e., it neglects the disutility of the sickness itself. Also it does not recognize that people can protect themselves to some extent, and

at some cost (say by installing an air filter), against sickness. Approaches that recognize and account for these factors are sorely needed.

VISUAL PERCEPTION

Introduction

As pointed out in the last chapter, questions about the value of visibility impacts have become highly significant in air quality policy, especially as it applies to conditions in the mountainous West, where unusually clean air and the associated large, bright landscapes are highly prized by many people. The question of how to value such effects is a very difficult one. In an urban area, one might consider using differences in housing property values as an indication of aesthetic values people attach to air clarity--this approach is discussed further on. But in scenic rural areas such as national parks, this is clearly not feasible. Thus, it was necessary to develop and use alternative methods.

The method chosen for our research used questions posed to recreationists and others affected by visibility impacts in an effort to discover their preferences and values. In all cases studied, the respondent was confronted with an image of possible changes in air quality at a particular site, in the form of carefully prepared photographs, and asked to state a value for it. The respondent was also asked to reveal other pertinent characteristics about himself or herself. This approach is referred to in the trade as a "bidding game." Respondents can be queried as to willingness to pay for the cleaner air conditions, minimum compensation to accept a change, potential site or activity substitutions for the one in question, income, age, sex, etc. As is explained in connection with discussions of cases in Part **II,** responses to these types of questions can be used to estimate demand curves for cleaner air.

The major concern in using bidding games, or other survey questionnaire techniques (such as the one discussed with respect to water quality in chapter 12), to construct demand curves is that the reply to questions may be biased either because the interviewee wishes to deceive or because of problems in the **way** questions are posed. Possible biases which could well exist in theory have been a major preoccupation of researchers pursuing the bidding game and other survey approaches. The main types of bias which have been identified in our work as possibilities are: (1) strategic bias, which means that the respondent may attempt to influence the outcome or result by not responding truthfully; (2) information bias, which is bias resulting from lack of complete information on the part of the respondent; (3) starting point bias, where the respondent may be influenced by the opening bid which is usually suggested by the interviewer; and (4) hypothetical bias, which could result from inability to confront the respondent with an actual situation, for example, using a photograph rather than an actual scene.

The bidding game and other survey techniques are sufficiently central to the research in several of the case studies reported in the following

chapters, and possible biases in results are sufficiently important, that they merit a bit of special attention.

Strategic Bias

Most economists have long supposed that direct revelation of consumer preferences for public goods (defined in chapter 2) would be impossible. In particular, the so-called "free-rider problem" would arise because the public goods situation gives individuals incentives to misstate their preferences. For example, if nearby residents were asked how much they were willing to pay to clean up the air near a power plant, and if they suspected that control costs would be borne by consumers and owners elsewhere, local residents might well have an incentive to greatly overstate their actual willingness to pay since they would, in fact, not have to pay anything. On the other hand, if residents believed that they would be taxed an amount equal to their own individual willingness to pay, then a clear incentive would exist to understate their own true value, since their individual bid would have a negligible effect on the outcome in any case.

It is thus apparent that different techniques aimed at eliciting willingness to pay may generate their own variety of bias. For example, if respondents are told that the average of their bids to prevent construction of a power plant near a national park will be used to set an entrance fee to the park, those individuals who suspect their bid to be greater than the average bid will have an incentive to overstate their willingness to pay. They, in fact, in principle have an incentive to raise the average bid as close as possible to their own true bid. In other words, individuals will, again in principle, have incentives to misstate their own preferences in an attempt to impose their true preferences on others.

Information Bias

Since bidding games are hypothetical, answers obtained through these surveys will not be based on information or perceptions as complete as would apply if consumers based answers on real experiences which, unfortunately, is usually not possible. Typically, consumers do reevaluate actual decisions on the basis of experience. Thus, a recreator might respond to a hypothetical decrease in air quality at one location with a low bid, thinking that other nearby sites would make good substitutes. However, in a real situation, the recreator might have found that other sites involved more travel costs and were less satisfactory than imagined. Clearly, then, the information presented to the respondent in a questionnaire situation relating to substitution possibilities and alternative costs may well bias the stated willingness to pay. On the other hand, there may be no amount of verbally conveyed or written information that can fully substitute for actual experience.

Starting Point Bias

Central to the bidding game approach are questions on willingness to pay (and/or compensation) for hypothetical changes in air quality. It may

be that it is better to ask the interviewee a question with a "yes" or "no" answer rather than a question requiring independent quantitative estimation on his part. Assuming that yes/no responses are desirable, it is necessary to suggest a starting bid or minimal level of compensation. Here the potential bias arises because the interviewee's final reply may be influenced by the opening bid.   This possible bias comes from at least two possible sources. First, the bid itself may suggest to the respondent the approximate range of appropriate bids. Accordingly, he may respond differently depending on the amount of the starting bid. Second, if the respondent values time highly, he may become "bored" or irritated with going through a lengthy bidding process. In consequence, if the suggested starting bid is substantially different from his actual willingness to pay, the bidding process may yield inaccurate results. The effect of these two types of starting point biases may substantially influence the accuracy of bidding game valuation and therefore the usefulness of this approach for assessment of references with respect to air pollution.

Hypothetical Bias

The bidding game requires suggesting, by way of pictures, a change in air quality such that it is believable to the respondent and accurately depicts a possible potential change. In addition, the change must be fully understandable to the respondent, i.e., he must be able to understand Most, if not all, of its ramifications for him.   Finally, he must believe that the change might occur and that his bid might have an effect on both the possibility and magnitude of change in air quality. If these conditions are not fulfilled, the hypothetical nature of bidding approaches will make their application to air quality issues dubious and may bias the respondent's answers up or down. However, unlike other types of biases identified, it is extremely difficult to measure the extent of hypothetical bias since it depends not only on how well structured the interview is, but also on uncontrollable factors such as attitudes, style of presentation by interviewer, the recreationist's "mood," etc.

Conclusions About Bidding Game Bias

To test for the presence and importance of bias and to assist in developing methods in controlling for it, the research team ran a number of "experiments" using bidding games and surveys. The experiments show that all forms of bias can definitely exist. But it appears that problems of strategic, information, and starting point bias are all surmountable with proper questionnaire design and statistical analysis. This, plus the comparison with an alternative valuation method in chapter 7, and a technique developed in the National Water Quality Survey reported in chapter 12, suggest that well-designed survey techniques can produce reasonably reliable information about the value of air and water quality and other public goods.

WATER-BASED RECREATION

Much work has been done by economists on the problem of evaluating water-based recreation and aesthetic values, and many methods have been applied to the problem. These include bidding games, other types of surveys, inferences from the value of waterfront properties, and a method based on travel costs to particular sites. In the two studies reported in this volume, a survey method was used in one and the travel cost method in the other. For present purposes we distinguish between bidding games and surveys, as hinted in the previous section, even though they both ask respondents questions about willingness to pay. The bidding games reported in this volume all pertain to the evaluation of quality changes at particular sites, and the sample population may or may not be, but usually is not, randomly selected from the general population. For example, if the technique involves interviews at the site, the sample population consists of those who happen to be at the site during the interviewing, and there is no reason to believe that those questioned actually are a random representation of the population at large. Surveys, as the term is used here, always choose their respondents randomly from the national population. This is an important feature for the study reported in chapter 12 because it was explicitly designed to provide national benefit estimates, and randomness permits an extrapolation of the sample results to the whole population by statistically acceptable procedures. In addition, this study endeavored to measure benefits of water quality improvement that may accrue to people even though they may not be direct users of these water bodies. These benefits are variously called nonuser, intrinsic, or existence benefits. They are explained in later chapters.

The other benefits study reported in chapter 11 also had national level benefits estimation as its objective, but was "site-specific" if site is interpreted to be a rather large geographical area and focused only on actual or potential users of water bodies for recreational purposes, specifically, sport fishing. However, it used neither a bidding game nor a survey method. Rather, it employed the travel cost method to evaluate benefits to recreational fishing. This method was developed at RFF many years ago and is a well-established technique of recreational benefits evaluation that has been used many times by economists, planners, and others to evaluate specific recreation sites. The novelty of the study reported in chapter 11 is its ingenious application of the methods to the particular problem of obtaining a national benefit estimate for recreational fishing associated with water quality improvement. Actual applications of the travel cost technique are often quite complicated. Here I wish only to convey to the reader the general concept of how the method is used to construct a demand curve for a recreation site. The basic idea is that increased access cost associated with user distance from a desirable recreation site will tend to affect recreation visits in the same manner as an increase in access cost resulting from a hypothetical rise in an admission fee. If it were feasible to experiment with the fee, hypothetically setting it from zero to increasingly higher levels, it would of course be possible to define a relationship between demand and price (a demand function as discussed in chapter 2). The basic principle of the procedure can be clarified by a simple numerical example.

Assume that we have divided the "market area" for a recreation site into four zones at different distances from it, and we have the information shown in the table about them.

Zone	Population	Access (travel) cost to site	Number of visitors	Visits per 1,000 population
1	1,000	$1	500	500
2	2,000	$2	400	200
3	3,000	$3	300	100
4	4,000	$4	0	0

Total visits at zero entrance fee   1,200

If there is no entrance fee, there will be 1,200 visitors (say per year) and that gives us one point on the demand curve, that for a zero price. This is shown on the diagram below. Now let us assume that an

Number of Visitors (in hundreds)
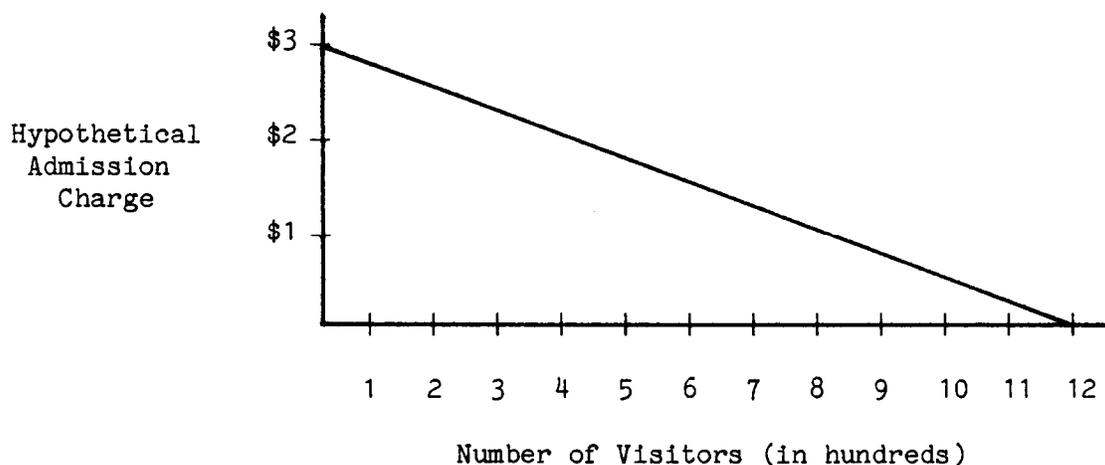
entrance fee of $1.00 per visit is levied. This is taken to have the same effect on visitation rates as a $1.00 difference in access cost related to distance. Accordingly the visitation rate in zone one will drop to that of zone 2 which has a $1.00 higher access cost. Therefore, instead of a visitation rate of 500 persons per 1,000 persons from Zone 1, the rate will drop to 200. Since there are 1,000 persons in Zone 1, this means that there will be a total of 200 visitors from there. Zone 2's visitation rate will drop to that of Zone 3 which has a $1.00 higher access cost than Zone 2, i.e., it will drop to 100 visits per thousand population. Since Zone 2 has two thousand inhabitants, this means a total of 200 visits from Zone 2. By the same reasoning, there will be no visitors from Zone 3. Thus, at a

$1.00 admission fee, there will be 400 visitors--200 from Zone 1 and 200 from Zone 2. This provides us with another point on the demand curve as shown in the figure. Finally, at a $2.00 entrance fee there will be no visitors from any of the zones. This produces still a third point on the diagram--the point at which the quantity demanded will fall to zero.

Obviously, this example is meant to be as simple as possible, and because it established only a few points on the demand curve, would provide only a very rough approximation of an actual curve. But the principle is the same even in much more complicated applications.

VALUING AGRICULTURAL IMPACTS

Agricultural production, even in the most advanced countries, is heavily influenced by factors that are beyond the producer's control. Within the more industrialized countries, yields have increased more slowly over the past decade than before. This may be partly because of man-induced environmental factors, possibly including lower air quality, at least in particular regions. Some efforts have been made in the past to calculate yield reductions in such regions and then these reductions have been multiplied by crop prices to estimate the value of lost production. This apparently straightforward procedure applied in the past is, however, too simplistic and may very well lead to deceptive results.

The reason for this is that some particularly high value agricultural crops, such as vegetables and fruits, tend to be concentrated in particular geographical regions due to specific climate requirements. Given the concentration of such production, and the known adverse effects of air pollution on vegetables and fruits, one might expect price fluctuations for such commodities in response to changes in air quality. The same might occur with more generally grown field crops if the pollution effects are widespread. Any reduction of yields due to air pollution may affect consumers and producers of those commodities differently. That is, if the quantity demanded is not very responsive to price for, say, celery, consumers would suffer a net loss, while producers in general will benefit from the increase in the price of celery resulting from the reduction in supply.

This seemingly perverse result invites introduction into the discussion of another basic idea from demand theory. The relationship between changes in quantity demanded and changes in price is called by economists a price elasticity," or "elasticity of demand." Demand elasticity in quantitative terms is the percentage change in the quantity demanded divided by the percentage change in price. Thus, if price goes up by one percent and the quantity goes down by two percent, the price elasticity is two, and we say that demand is relatively elastic. If the percentage change in price and the percentage change in quantity are the same, we say that demand elasticity is unitary; and if the percentage change in quantity is less than the percentage change in price, we say that demand is relatively inelastic. If demand is relatively inelastic, a reduction in quantity will increase total revenue of producers--the situation cited

above.   For example, let us say that the price of a commodity is $10
and that at that price the quantity demanded is 20 units. Therefore, in
accordance with the explanation given in chapter 3, the total revenue to
sellers would be $200.   Now suppose that the quantity offered for sale
drops by ten percent, that is, to 18 units, but the price rises by
twenty percent, that is, to $12.   Then the total revenue would rise to
18 x $12, or $216.

We can illustrate this situation more generally by constructing a
hypothetical demand curve for celery. In this illustration, area P2, D,
Q2, 0 is larger than area Pl, C, Q1, 0. This means that with
quantity reduction from Q 1 to Q2' total revenue increases.

     While producer's profits may grow because of the higher price of
celery, consumers will lose the consumer's surplus shown by the area
(a), (b), (c), and (d) on the diagram. This is the maximum they would be

Q of Celery
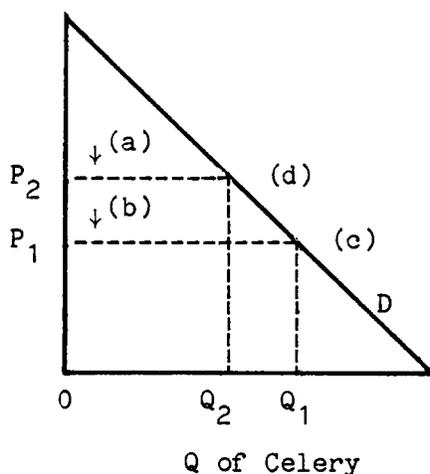
willing to pay to avoid the air pollution. This also illustrates the
idea of "derived demand" introduced but not explained in chapter 2.
The willingness to pay for air quality is not, in this case, because
consumers value the air quality directly, but because it is an input to
something they do value--celery.

     If demand for celery is relatively elastic, the quantity reduction
would result in both a loss of consumer's surplus and a loss of
producer's profits.   In this case, the benefit from reducing air
pollution consists of both the gained consumer's surplus and the
increased profit to producers.

     Where price effects of the kind described may be important, it is
necessary to develop a method which can properly handle them in the
process of analyzing economic losses in agriculture from air pollution.
The agricultural component of our research project developed such a
method and

applied it to Southern California. This case study is reported in chapter 9. A different method to handle the same problem for the study of national economic damages to major field crops, reported in chapter 10, was developed and is explained there.

RESIDENTIAL PROPERTY VALUES--A SUMMARY MEASURE?

In an effort to get a summary measure of the value people place on cleaner air, economists have developed a method called the "property value method" for application in <u>urban</u> areas. The general idea is to assemble information on all the various characteristics which might determine house price (location, lot size, number of rooms, etc.), on characteristics of the owner (chiefly income), and on pollution levels at the site studied. Then, by using the statistical technique (regression analysis) referred to earlier, and explained briefly in the next chapter, it is possible to make an estimate of that part of the difference in house prices which is <u>separately</u> associated with differences in air quality at the different sites. Through a procedure which is a bit intricate, and which we need not review here, these estimates can be used to estimate a summed up (aggregate) "demand" for air quality in the city or metropolitan area being studied. The word, demand, is in quotation marks in the previous sentence because economic theorists have deter-mined that only under a particular set of circumstances can that number be regarded as a valid and accurate estimate of the actual willingness to pay for an improvement in air quality. Nevertheless, the method has some very appealing qualities.

It is relatively inexpensive to do because it can rely on existing data rather than requiring the collection of new data, which tends to be quite expensive. That is not to say that existing data are necessarily high quality, but it can be claimed that the data available for the case studies using this method, reported in chapter 7, were quite good.

Also, if such an estimate can be regarded as accurate, it provides a quick summary measure of the value of air quality to people without the necessity of estimating the value of different characteristics individually. These would include effects on visibility, on soiling and materials damage, and to the extent they are understood, on health.

It would therefore be very useful to run an experiment where demand estimates derived from property value data are compared with the actual willingness to pay for improvement in air quality. This would permit a test of how importantly the theoretical conditions required to make them precisely equal affect the actual outcomes in practice. It is, of course, impossible to do this, because there is no way to get an estimate of willingness to pay which can be regarded as entirely accurate. This is illustrated by our discussion of possible biases in bidding games earlier in this chapter.

What is possible, however, is to compare, admittedly imperfect, estimates made by both techniques for the same people and the same area to test whether they come out pretty close together or yield wildly different

results. This is the main point of the South Coast and San Francisco
Air Basin studies reported in chapter 7. I turn now to the case
studies.

PART II: CASE STUDIES

        In the quantitative work done to implement the concepts and
procedures discussed in earlier chapters, a number of case studies were
conducted. The methods and results of these are presented in this part.
The first section in this part deals with urban air pollution and
drinking water considerations, and the second with rural air and water
pollution.

IIa.   URBAN AIR POLLUTION

        The   exposure   of   concentrated   populations   to   air   pollution
inevitably raises questions about possible health impacts.   Two of the
five cases in this part deal with that issue.   Two other cases deal with
the damaging effects of urban air pollution more broadly and are
designed primarily to test the comparability of two quite different
methodologies for assessing benefits from improved urban air quality,
bidding games, and property value studies.   The final case in this
section examines the relationship between wage differentials among urban
areas and their levels of air pollution as a possible means for
evaluating air quality deterioration.

CHAPTER 5

AGGREGATE EPIDEMIOLOGY--THE SIXTY CITIES

THE SIXTY CITIES STUDY

     The first study undertaken by the research team sponsored by EPA
was concerned with the possible linkage between air quality and health.
Its objective was to improve estimates of how air pollution may be
related to increased risk of death (mortality) from various diseases and
to calculate what the economic benefits from reducing this risk might
be. As explained in earlier chapters, doing this requires three main
classes of information: (1) establishing the link between ambient
conditions and effects on humans (the dose-response relationship); (2)
determining the population at risk; and (3) valuing the economic benefit
from improvement in air quality.

     The method used to develop the first type of information in this
study is one called "aggregate epidemiology." Ideally, in applying
epidemiological techniques to the air quality problem, one would wish to
have information about the history of exposure of individual persons to
air pollution. Furthermore, to isolate the effect of air pollution from
other factors influencing health, one would wish information about the
individual's personal characteristics, for example, their age, their
access to medical care, health-influencing genetic factors, dietary
habits, whether or not they smoke, and perhaps other pertinent data. At
the time the sixty cities study was done, data including this kind of
information for individual persons were difficult, if not impossible, to
get. Accordingly, resort was often made to other more aggregated, and
therefore less suitable, data.

     For example, in the case of the study reported here, information
pertaining to entire cities was used. For instance, total mortality
divided by the population for an entire city was used in the estimation
of a dose-response function. This assumes that the average situation can
represent individual circumstances and responses.   This is a
strong assumption which may bias the results of the analysis to an
unknown extent.

Other studies have used aggregate epidemiology to try to understand
the relationship between air pollution and health. The study
described here differed from the others available at the time it was
done in two principal ways. First, it includes factors which are
thought to be health-related, but which others had excluded due to
poor or unavailable data. These are primarily diet, smoking, and the
availability of medical care.   Second, in contrast to the usual
epidemiological studies, the present study assumed that people do not
merely accept passively exposure

to air pollution, but may take actions to avoid its effects. In that sense, it is more economic in its orientation in that it recognizes that there are tradeoffs between air pollution effects and other values having economic content, for example, incurring the expense of seeing a doctor or moving away from a polluted city. It is primarily in respect to such economic-behavioral responses that economists can make a contribution to the study of epidemiology. Conventional epidemiology tends to neglect the fact that people have an incentive to, and do, adapt to environmental conditions. Instead, it treats them as passive acceptors of whatever occurs.

Before proceeding to further discussion of these matters, it may be helpful to readers not familiar with regression analysis (mentioned several times before and a basic tool in this study and many of the other case studies) to say a little about the technique. In doing this, and relating the discussion specifically to the present case, it will be helpful to refer to the figure below. Along the top, in bold letters, is depicted a

MORTALITY PATE   F(MEDICAL CARE, AGE, GENETIC FACTORS, BEHAVIOR & HABITS, DIET, EXPOSURES)

Heart Disease	Doctors/ Capita	Median Age	Rice	Smoking	V I t,-I
Cancer				Room Density	Saturated Fits
Vascular Disease	Hospital Beds/ Capita			Rac,-	Cholesterol
Pneumonia Influenza					Protein
Cirrhosis					Additives
Emphysema & Bronchitis					Alcohol
Kidney Disease					coffee
Congenital Anomalies					
Diseases of Early Infancy					

simple equation which says that mortality is related to (or, as economists *say,* is a function of) a variety of health-related factors. In such an equation, mortality and the health- related factors are called variables. They are called this because the data on them may take on a range of different values, depending on the particular situation. For example, where the city is the unit of observation, as in our study, both mortality and air pollution differ considerably from city to city. It is these differences that permit regression analysis to work. It can be viewed as complicated kind of averaging procedure that uses concepts based on statistical probability theory.

The variable on the left-hand side of the equals sign is called the dependent variable. This is the variable whose behavior one is trying to explain. The variables on the right-hand side are called the independent

variables, i.e., the ones that are thought to determine what value the dependent variable takes on.

The goal of the mathematical manipulations involved in regression analysis is, given the data on hand, to identify and quantify what separate and independent quantitative effect each of the independent variables has on the dependent variable. One condition for this process to work accurately is that the independent variables must not be interrelated (i.e., themselves correlated). This is almost never the case with real data, and for this, as well as some other reasons, there is always more or less uncertainty about the results achieved.

One such instance of interdependency among variables of particular interest in the present study is the effect of medical care on health. The existing epidemiological literature has failed to show any significant effect of medical care on human mortality rates. This result, which most people would not expect, may have a simple explanation. For example, in our analysis of sixty cities, no effect of the availability of doctors on mortality was shown when a straightforward regression is done where the actually observed number of doctors in different cities is entered as one of the independent variables. A possible explanation for this is that, although availability of doctors most likely does reduce mortality rates (as shown below), doctors prefer not to live in polluted cities. Therefore, relative to the total population there are fewer doctors in such cities. Thus, whatever favorable effects doctors have on mortality rates tend to be canceled by their fewer numbers in those cities. Simple regression analyses cannot untangle the relation of doctors to mortality versus the relation of pollution to mortality. This kind of problem is known to aficionados of such things as "simultaneous equation bias."

To get to this problem, a "two-stage" regression technique was used in which one first estimates how many doctors there would be in a city aside from the influence of pollution, but with other factors the same as otherwise. Then in the second stage, that _estimated_ number of doctors is entered into the analysis rather than the _actual_ observed number of doctors. This technique _separates_ the influence of doctors from the influence of pollution. This recognition of one aspect of human adaptation to pollution had a dramatic effect on the results.

For the full-scale analysis, it was possible to develop for a set of sixty cities the variables shown in the above equation. The dietary and smoking variables had to be estimated quite crudely, since there exist no actual observations on them. For example, cigarette consumption for a particular city was calculated from cigarette sales tax data for the state in which the city was located. Surely one cannot make any great claims for the quality of these data. It was felt, however, that these variables were potentially so important in influencing health and mortality that to exclude them would be inviting even more serious error.

This leads to a further observation on regression analysis. In the language of the trade, a regression equation must be "specified" properly if one is to have any confidence at all in the result. That means that the

"correct" set of variables must be included in the analysis. If all the significant variables are not included in the equation, the equation is misspecified, and a variable that is there may pick up some of the effect actually attributable to one or more of the missing ones. For instance, if smoking is importantly related to health, and if, further, there is a correlation between smoking and air pollution, then if smoking is excluded, there is, so to speak, a surplus effect to be picked up and the air pollution variable will take some of it.

Let us then take a deep breath and turn to a discussion of the results of investigation of air quality dose-response relationships. The table below is a summary of the signs the various variables took in regression analysis. In the table, each column represents a regression equation for a

Variable (Sign of Hypothetical Effect)	Total Mortality Rate	Vascular Disease	Heart Disease	Pneumonia and Influenza	Emphysema and Bronchitis	Cirrhosis	Kidney Disease	Congenital Birth Defects	Early Infant Diseases	Cancer
Doctors/Capita* (-)	-	-	-		-		-			-
Median Age (+)	+	+	+	+		+	+			+
% Nonwhite (+)	+		+			+	+		+	+
Cigarettes (+)	+	+	+							+
Room Density (+)	+			+		+	+			
Cold (+)	+			+						+
Animal Fat (+)			+					•		
Protein (+)	+				+					+
Carbohydrates (?)					-					
NO₂ (+)										
SO₂ (+)										
Particulates (+)				+					+	
R²	.82	.60	.77	.54	.39	.64	.54	.22	.55	.86

*Two-stage estimator employed.

cause, or set of causes, of mortality. A positive (plus) sign means that an increase in the level of the variable tends to increase mortality, and a negative sign (minus) means that an increase in the level of the variable tends to reduce mortality.

The results shown here are only the "significant" ones. That means that they have passed a purely formal statistical test, but in view of the difficulties of equation specification, simultaneous equation bias, and other problems in application, it does not necessarily mean that they are "true." But if one is confident that the equation is specified about right, and the results for a particular variable are fairly large (and "statistically significant"), it means that the hypothesis that the relationship is real and about of the magnitude estimated cannot be ruled out. Associated with each variable in the regression is a number called a

regression coefficient. This number is used to quantitatively estimate the change in the dependent variable when the level of the independent variable changes, for example, when air pollution goes down. Since they are not used explicitly in this discussion, these numbers are not reported here.

Let us look more closely at the results. Both the median age and percent nonwhite variables are widely significant across the estimated variables, and show up with uniformly positive effects on mortality rates.

Cigarette consumption shows significant positive relationships with total mortality, vascular disease, heart disease, and cancer, while room density (average number of persons per room) and cold (number of days in which temperature drops below a specified level) both show significant positive relationships with total mortality, and pneumonia and influenza. Room density also shows significant positive relationships for cirrhosis and kidney disease.

The dietary variables show significance in total mortality, heart disease, and cancer--relationships between heart disease and saturated fats and between cancer and meat consumption (note the positive association for protein) have long been recognized. The dietary variables also show up as significant in emphysema and bronchitis. Not much credence should be given to the individual dietary variables, because the data are poor and the variables are highly interrelated. Our main concern with diet in this analysis is that we have accounted for diet in a general way in specifying an equation where the primary interest is in the air pollution variables.

Turning to the air quality variables, only two significant correlations appear--between particulates and the pneumonia and influenza variable, and between sulfur dioxide and the early infant disease variable. It should be observed that these associations we have found between mortality and air pollution are primarily for diseases of the very young and very old--particularly susceptible groups within the population. Further, these effects are those which one would usually associate with short-term as opposed to long-term air pollution exposures. We have some confidence in these particular results.

It may well be that aggregate epidemiology may be incapable of revealing the long-term consequences of air pollution exposures, if they exist. A reason could be that data on the actual air pollution exposure history of people are not available. In view of both changes in environmental conditions and the mobility of the population, current observations of ambient air quality may simply not be an adequate indicator of actual exposure to capture any effects of air pollution on degenerative diseases. For example, cancer may occur as long as two decades after exposure to carcinogenic substances.

Having investigated the dose-response relationships, we now turn to an economic evaluation of air quality control as it pertains to reduced mortality. This analysis is based on the valuation of risks approach discussed in the previous chapter. As the reader will recall, figures were quoted there which various scholars had obtained by analysis of risky

occupations. Two of the estimates are presented in the following table, along with a sketch of the methods described below.

Benefits = (Population at Risk) x (Value of Safety) x
(Reduction in Health Risk)

Value of Safety Based on a Consumer's Willingness to Pay

Low estimates: $340,000

Source: Thaler & Rosen (1975)

High estimates: $1,000,000

Source: Robert Smith (1977)

(Other recent estimates have even higher range.)

First, to obtain national estimates, we must know, as explained in the text in chapter 3, the population at risk. Since our sixty city sample is entirely urban, and since air pollution-related health effects is principally an urban problem, we used a population at health-related risk of 150 million urban dwellers. As a range for the value of reduced risk, we used Thaler and Rosen's (1975) estimate of $340,000 per life saved as a lower bound, and Smith's (1977) estimate of $1,000,000 as an upper bound. Finally, to get an estimate of reduced risk from air pollution control, we assumed an average 60 percent reduction in ambient urban concentrations both for sulfur oxides and particulates. Then, using the average concentration of these pollutants in our sixty city sample as a basis for calculation, we derived an average reduction in risk of pneumonia mortality for a 60% reduction in pollution from our estimated dose-response functions for these diseases. It should be noted that this is a very large reduction from present levels, and it would be difficult and very expensive to achieve.

Note, in terms of our discussion of chapter 2, that a more complete analysis would have assumed various levels of control at different emissions points and then used a dispersion model, described there, to calculate changes in the population at risk and levels of risk. We would have then used these, along with the dose-response estimates and risk valuations, to calculate associated benefits. The capability of doing this on a national scale does not yet exist. It would be a monumental job to achieve a high level of accuracy in such an undertaking for the entire nation. But this type of capability does exist in various regions.

Multiplying the population at risk by the assumed value of reduced risk, and then by the average reduction in risk, gives a crude approximation of the benefits for a 60% reduction in national urban ambient concentrations of particulates and sulfur oxides, respectively. National

urban totals and the value of the average individual risk reduction are
displayed in the following table.

Disease	Pollutants	Average Individual Safety Benefit (1978 $/Year)	National Urban Benefits (1978 $billion/Year)
Pneumonia Early Infant Disease	Particulates so *2*	29 - 92 5 - 14	4.4 - 13.7 .7 - *2.2*
TOTAL		34 - 106	5.1 - 15.9

      If these results are accurate, and we cannot vouch for how
accurate they may be, they are, in our judgment, conservative.
This is because we believe that air pollution may well have long-term
chronic health effects, and some evidence to that effect is established
in the next chapter, but that, given the available data, aggregate
epidemiology cannot dependably establish them.   Moreover, while
this study explicitly recognized the specification problem, and made
some progress in dealing with it, it did not address the problem in a
fully systematic manner.   This creates further uncertainty about the
accuracy of results. In the next chapter, I turn to a very recent study
that promised to be capable of yielding much more reliable results.

CHAPTER 6

DISAGGREGATE EPIDEMIOLOGY AND MORBIDITY
FROM OZONE EXPOSURE

The most general conclusion to be drawn from the experiment with
aggregate epidemiology discussed in the previous chapter, and from
review of the work of others, is that the results of such studies, if
accurate at all, are so only within very wide bounds. It appears that
only observations on individual persons might improve the situation.
We refer to epidemiology using econometric techniques such as regression
analysis, and performed on data about individual persons, as
microepidemiology.   The objective of the microepidemiology study
reported here was to examine a possible link between exposure to ozone
and health damage. The known physiological effects of ozone suggest that
such a link could exist.

For this purpose, a large amount of effort was expended to build a
suitable data base (data base is a general term that usually is used to
refer to an assembly of quantitative information suitable for analysis).
This was accomplished by merging the information in two existing sets of
data that have recently become available. The first is the 1979 Health
Interview Survey (HIS) data assembled by the National Center for Health
Statistics. The second is 1979 air pollution data from EPA's monitoring
system.   The resulting data base contains a very large number of
observations, a situation which, as we will see shortly, has a number of
advantages.

The HIS was started in 1957 and has been conducted annually since
then. A sample of about 110,000 people located across the country is
interviewed every year. A number of types of information pertinent to
epidemiological study are obtained. Among them:

(1)   demographic characteristics (including age, income, sex,
       occupation, etc.)

(2)   number of days during the two-week period prior to the survey
       on which the respondent had to restrict his or her activity,
       stay in bed and miss work or school

(3)   visits to doctors or dentists during this two-week period

(4)   acute and chronic health conditions (including some
       diagnostic information) accounting for restricted activity or
       doctor visits

(5)   hospital episodes during tile twelve-month period prior to the interview

(6)   smoking habits, history of residential mobility (the preceding two items were elicited only in the 1979 survey), home health care utilization, vaccination history, eye care, and retirement income.

As far as air pollution data are concerned, information was collected from EPA's System on ambient concentration for eight major pollutants for 1979. Using a program that matches individual census tracts to the nearest air pollution monitor, it was Possible to assign each individual in the HIS the air pollution readings nearest to his or her home. While this **s**till does not provide an accurate measure of an individual's dose, it is clearly superior to the assumption that an entire city is subject to the same exposure, a device that had to be resorted to in the macroepidemiological study reported on in the previous chapter. Also, the data set permitted matching individual health status to air quality conditions prevailing for two or three weeks prior to the interview as well as to annual averages and other periods. This is important in trying to identify acute effects.

The final set of data contained about 14,500 adults and about 15,700 children. These were persons who could be matched with air quality monitors and for whom smoking information could be obtained. In the previous chapter, it was pointed out that one of the factors that limits macroepidemiological analysis is the mobility of the population which means that exposure at their current address often reflects long-term exposure only very poorly. A supplement to the 1979 HIS interviews provides information on persons who have resided at the same location for a long period of time. The large size of the whole sample permits these persons, whose exposure history can be defined more accurately, to be studied separately.

An unfortunate aspect of the data set is that it does not permit study of the possible linkage between air pollution and mortality, the relationship analyzed in the macroepidemiological studies. Therefore, direct comparisons of the two approaches are not possible. But the data set does contain information about the presence or absence of chronic respiratory, cardiovascular, and other illnesses. Thus, it was possible to test the proposition that air pollutants not only may induce acute health effects, but may be related to the development or prolongment of chronic conditions which may lead to earlier mortality.

Another advantage of the very large data set is that effects on children, asthmatics, or other potentially sensitive people can be tested. Other efforts to do this have been hampered by small sample size. Many such subsamples were analyzed to test the sensitivity of results to the kind of group selected. For example, some public health specialists believe that environmental pollutants can have an especially adverse effect on children. Experiments to test this hypothesis were done, and they did not confirm it in the case of ozone. Accordingly, the remainder of the

discussion in this chapter will focus on the work done trying to identify impacts on the entire set of adults.

In accordance with information available from the HIS surveys, the researchers tried to identify relationships between ozone levels and four main dependent variables (recall the discussion of dependent and independent variables in the previous chapter). Three had to do with acute illness: these are "restricted activity days," "work loss days," "bed disability days." Finally, the researchers examined the information for a link between ozone and "chronic respiratory disease." The independent variables in general resembled those used in the "sixty cities" study discussed in the last chapter, for example, age, sex, income, and smoking habits, among others, except that in this instance, they pertain to actual individual persons in the sample rather than being averages across entire cities. Having information about individual persons also permitted introducing some other variables which could influence morbidity. One of these, labeled "FAT," was meant to represent the person's general physical condition. It was possible only to construct a crude proxy, and this consisted of weight in pounds divided by height in inches. The hypothesis was that being excessively underweight or overweight might be associated with higher morbidity. In general, results of the analysis supported this view.

One independent variable that deserves special note in the analysis of acute morbidity is "chronic illness." Here the hypothesis is that persons who have a chronic disease may be more subject to episodes of acute morbidity than those who do not. Again, the analysis conducted is consistent with this supposition. Of course, in each instance, ozone levels at the appropriate monitoring stations for each individual were included among the independent variables, as were readings for the other air pollutants.

The method used to try to identify the separate effect of each of these independent variables on the dependent morbidity variables was once again the regression analysis explained in the last chapter. A number of experiments were conducted with regression equations, including different variables (specifications) and different subsamples of the whole sample.

As one would expect from the discussion of the last chapter, the results were sensitive to the specification used. For example, the calculated effect of ozone on health was often influenced by what other pollution variables were included in the equation, for example, particulate matter.

But for the acute morbidity variables--restricted activity days, work loss days, and bed disability days--the relation between them and ozone readings was almost always positive, and in many cases, significant, in the purely formal statistical sense noted in the last chapter. People in the econometrics trade refer to a variable that behaves in this consistent manner as across experiments being "robust." Robustness in the uncertain world of statistical analysis gives one some confidence that what is being observed in the data is real. Although they find some very tentative

evidence to support it, the relationship between ozone levels and chronic respiratory disease is less robust and therefore leaves one in greater doubt as to its genuine existence.

Thus, even epidemiology conducted with information on individual persons and with much better exposure data than is available for macroepidemiology does not yield the clean and persuasive results one would wish and hope for.

With these cautions in mind, let us turn to some sample results concerning the changes in health status that a change in ozone levels might yield. Once a relationship between independent and dependent variables has been estimated, it is then possible to hypothetically change the value of an independent variable and, using this quantitative relationship, calculate the associated change in the dependent variable. For example, one can reduce the observed ozone level and calculate the effect on, say, restricted activity days.

I will present the results from two of the many equations estimated. These may be taken to be representative of those in which the association between ozone and health indicators was positive and significant in the statistical sense.

The first illustration is an equation which tries to establish an association between ozone and restricted activity days (RAD). It is specified as follows:

RAD = F(ozone, sulfates, race, sex, marriage status, income, urban, FAT,

age, smoking, education, chronic health condition, crowding,

temperature, precipitation, humidity)

In this equation, ozone and several other independent variables, for example, income and chronic disease, meet the statistical significance test, but most of the others do not. As an unexplained anomaly, the sulfate variable is negative and significant. This has the hardly credible implication that sulfur pollution is good for you.

If one takes the ozone result at face value, it indicates that each .01 part per million increase in the highest hourly reading for a day could result in 0.25 more RADs per person over a two-week period. (Recall that respondents to the HIS survey were asked to report on their health status for the two weeks immediately prior to the survey.) Or conversely, a similar decrease in ozone would result in a similar decrease in RADS. If this result is extrapolated to a whole year, it means that .01 PPM reduction in ozone would result in .64 fewer RADS, on the average, per person per year. Extrapolating further to a population of about 110 million adults (over 17) in the metropolitan areas of the United States

implies about 70 million fewer RADs for the country, associated with the ozone decrease. The study reported here made no effort to assign an economic value to this environmental improvement, but it is immediately apparent that the per day value would not have to be large to yield an impressive annual benefit. If , for example, the consumers surplus from avoiding a RAD were a mere $10 per day, the aggregate national benefit would be about 700 million dollars per year.

The other illustrative results pertain to the possible effect of ozone on chronic respiratory disease (CRD). The equation specification for this analysis was:

$$CRD = F(ozone, \text{ suspended particulates, sulfur oxide, race,}$$

$$\text{sex, marriage status, income, FAT, age, smoking,}$$

$$\text{education, temperature, precipitation, humidity})$$

In this case in addition to ozone, sulfur oxide (this time positive, but small), race, sex, income, age, education, and humidity were significant in the statistical sense.

If one goes through calculations in spirit like those outlined for RAD above, the results show that .01 PPM reduction in the average annual hourly ozone concentration across the country would cause the incidence of CRD to gradually evolve to a point where there would be about 1,130,000 fewer cases per year. If one assumes that the consumers surplus associated with avoiding one case of CRD is only a thousand dollars, the .01 PPM reduction would ultimately yield benefits of greater than one billion dollars a year. The full benefits are not available immediately because chronic disease lags exposure change by some years.

There are several things to be said about these results: first, while .01 PPM is, from an everyday perspective, a very small number, it is large compared to the actually existing average levels of ozone. It implies about a 20 percent decrease from the average daily maximum reading around the country and a 50 percent decrease from the average hourly reading. It should be noted that such a decrease would be difficult and costly to achieve. It is not necessarily obvious that even if the benefit numbers quoted above were true the economic benefits would outweigh the costs.

Second, as noted, the results are rather robust with respect to the statistical linkage between ozone and acute morbidity. It does not seem unreasonable to argue that it provides support for the view that there is a significant real link. The results with respect to chronic respiratory disease are not robust and therefore have to be doubted.

Third, in general the results of the macro- and microepidemiology studies reported here, and related work of others, do not foreclose the possibility that health benefits from reducing air pollution are large.

But the exact, or even approximate, magnitude of those benefits is far from being established.

CHAPTER 7

AIR QUALITY BENEFITS IN THE SOUTH COAST AIR BASIN
AND IN SAN FRANCISCO

THE BASIC STUDIES

For the household sector, and considering other factors in addition to health, two distinct approaches to valuation of environmental quality have emerged from recent research. The first, as explained in chapter 4, involves the analysis of how some pertinent actual market prices, such as real property prices, are influenced by environmental quality attributes of the properties. The second, also discussed in chapter 4, tries to induce individuals to reveal directly their actual preferences in monetary terms for environmental attributes. Clearly, if these methods are valid, there should be a well-defined relationship between what people do pay through differences in property values and what they say they will pay, provided there are no incentives for them to distort their bids and that influences other than air quality on property values are correctly accounted for.

The first study area where these techniques were tested and compared in our study--the South Coast Air Basin (SCAB)--consists of Orange and Los Angeles Counties and portions of San Bernadino and Riverside Counties of California. This area has a long history of air quality problems. For instance, Spanish explorers in the sixteenth century noted smoke from Indian campfires in the Basin, trapped by inadequate horizontal and vertical air mixing. The post-World War II period, which saw extremely rapid population growth in Southern California accompanied by massive industrial development, was marked by the appearance of smog as the major threat to the regional environment. As a result, air pollution abatement programs began in the late 1960s as a response to the discovery of the automobile's role in smog formation. Air quality deterioration in the SCAB has multiple causes: unfavorable topography and meteorology, and dense population and economic activity with corresponding large emissions.

To conduct the study, a special sampling procedure was developed. It was designed to identify paired communities in the Basin that are similar in as many ways possible except in air quality. If the other characteristics of these communities are not very different across areas (housing styles, sizes, distance to the beach, etc.), the difference in property values between an area characterized by clean air versus an area where air quality is lower should be due mostly to the existence or absence of pollution. This structured, paired communities sampling procedure, rather than a random sample of individuals over the whole region, was chosen <u>primarily</u> to control for proximity to the beach. Nearness to the ocean and

cleaner air are so highly correlated that the most applicable statistical procedure, regression analysis, performed on a random sample would not be able to disentangle these two major influences on house prices in Southern California.

The Los Angeles area was chosen for the initial experiment not only because of the well-defined air pollution problem there, but also because of the existence there of excellent property value data. Twelve census tracts were chosen for sampling for both the property value and 'the companion bidding game study. For the latter, interviews were conducted in these tracts during march 1978. Respondents were asked to state their willingness to pay for an improvement in air quality at their current location. Air quality was defined as poor, fair, or good, based both on maps of the region (the pollution gradient across the area is both well-defined and well-understood by local residents) and on photographs of a distant Vista representative of the differing air quality levels. Households in poor air quality areas were asked to value an improvement to fair air quality, while those in fair areas were asked to value an improvement to good air quality. A total of 290 completed surveys was obtained. **The** map below shows the areas having poor, fair, and good quality air in the South Coast Air Basin.
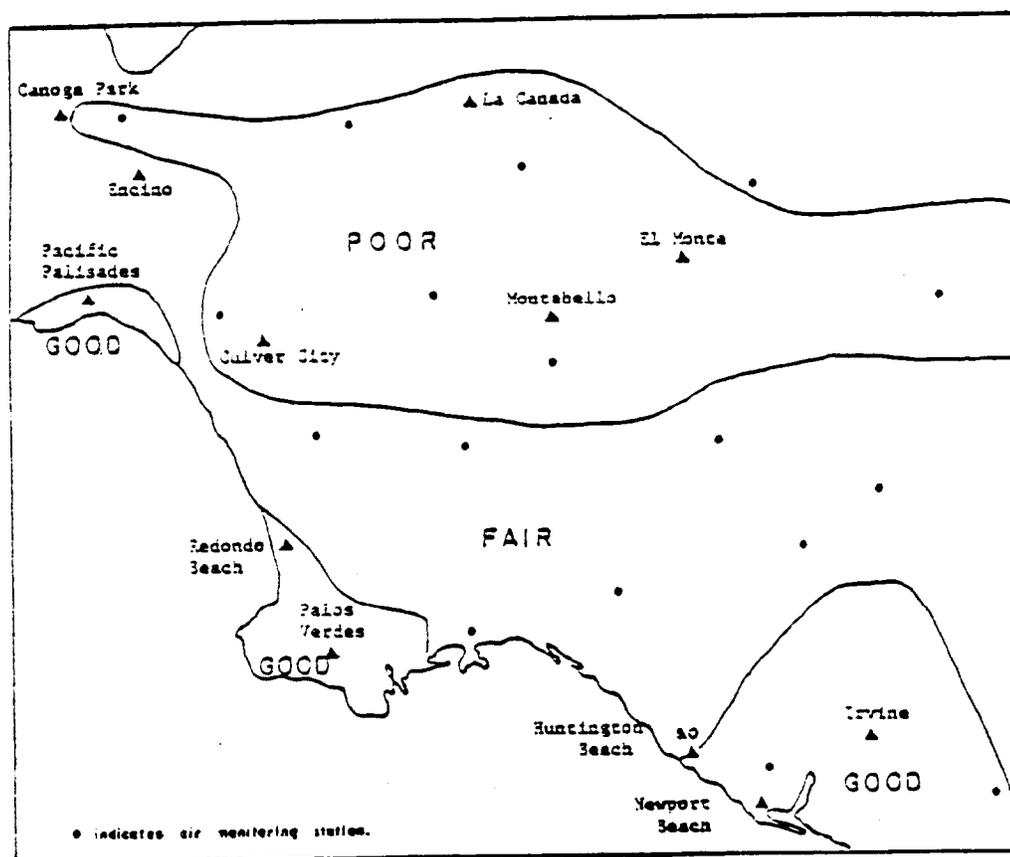
Built into the survey questionnaire were procedures for identifying the various possible biases in bidding games, as discussed in chapter 4. No

biases were found. The results indicate that on the average, households said they were willing to pay $30 per month more for the cleaner air areas. For comparison to the survey responses, data were obtained on 634 single family home sales which occurred between January 1977 and March 1978 in the paired communities used for the survey analysis. Households will choose to locate somewhere along a pollution-property value gradient paying more, other attributes being equal, for homes in clean air areas, depending on their family income and tastes. However, economic reasoning suggests that cost difference between homes in two different air quality areas will exceed the willingness to pay as elicited by a bidding game for similar improvement in air quality. Thus, we would expect house cost difference associated with air quality improvement to exceed estimates of household willingness to pay from the survey responses. This is because property values at a particular location will reflect the air quality preferences of the most air quality- sensitive individuals, whereas average bids for that same air quality will more nearly reflect the average preferences of people living there. Most houses are not for sale at a given time, but given the small number available, their price will be determined by those who want them most, for example, those people with the strongest preference for cleaner air.

A straightforward statistical comparison of the paired neighborhoods indicates that property value differences between poor and fair air quality localities are about $140 per household when computed on a monthly basis. Using more advanced economic models, which better take into account factors other than pollution, such as any remaining influence of distance to ocean and differences in tastes which may influence property values, willingness to pay inferred from the property value differences is about $40 per month. As a reasonably comparable estimate, the survey results, as indicated, show an average bid of slightly less than $30 per month.

The results indicate that air quality deterioration in the Los Angeles area has had substantial effects on housing prices and that these are comparable to what people say they are willing to pay for improved air quality. Moreover, the property value estimates are higher than the average bids, which, as noted above, was expected on theoretical grounds.

Based on these results, rough estimates can be made about willingness to pay for improved air quality throughout the South Coast Air Basin. Difficulties are encountered in making data sets for groups of diverse households exactly comparable. Significant differences exist between the people in the survey and the property value groups in average income, age, and other socioeconomic factors.   Accordingly, any extrapolation to the Basin as a whole must be taken as rather crude and merely indicative rather than exact.

The following table gives estimates of monthly bids for cleaner air by households, results of the property value study, and by extrapolation of the benefits for an approximate 30 percent improvement in air quality within the South Coast Air Basin. The latter estimate, while quite rough, does suggest that economic benefits from an improvement in air quality in the South Coast Air Basin are very large.

(30 percent improvement
                      in air quality)

                                        Annual benefits (in
                                        billions of dollars)
                                        1977 Dollars
                                        for the South Coast
                                        Air Basin

    Property Value Study

        Based on straight- $135 $3.96
          forward comparison
          of communities

        Calculated $ 42 $ .95
          willingness to pay
          taking account of
          other factors

    Survey Study

        Mean Bid $ 29 $ .65

        The results of this experiment also suggest that survey
instruments, when compared with property value techniques, may provide a
reasonable way to get environmental quality benefit estimates.   The
survey approach has the advantage that new data can be collected at low
cost on specific environmental problems.   The investigator is not tied
to the availability of existing data sets which are usually not designed
to meet his particular needs.

        As a caution, however, it should be kept in mind that the South
Coast Air Basin studies were conducted in an area where individuals have
both an exceptionally clear-cut pollution situation that they have
themselves experienced and where there exists a well-developed property
value market for clean air. The effect of clean air on property values,
and in turn, on the degree to which people are aware of increased
housing prices in high air quality areas, appears to be exceptionally
well-defined in the South Coast Air Basin.   Therefore, it should be
recognized that the results of this experiment may well not carry over
completely to other situations where air quality is not so well-
specified, either through actual market prices or the perceptions of
people.

        In view of the possible uniqueness of the Los Angeles Basin, a
follow up study was done replicating as much as practical the Los
Angeles study.   The place chosen was the San Francisco Bay area.
This is a large shallow basin ringed by hills stretching from Southern
Marin to Santa Clara Counties.   The basin tapers into a series of
sheltered valleys including Santa Clara, Livermore, and Napa.
While the area typically has better

ventilation than the Los Angeles Basin, still this topography gives the area great potential for trapping and accumulating air pollutants.

The map below shows the study area. The numbers on the lines indicate increasingly higher levels of smog pollution.
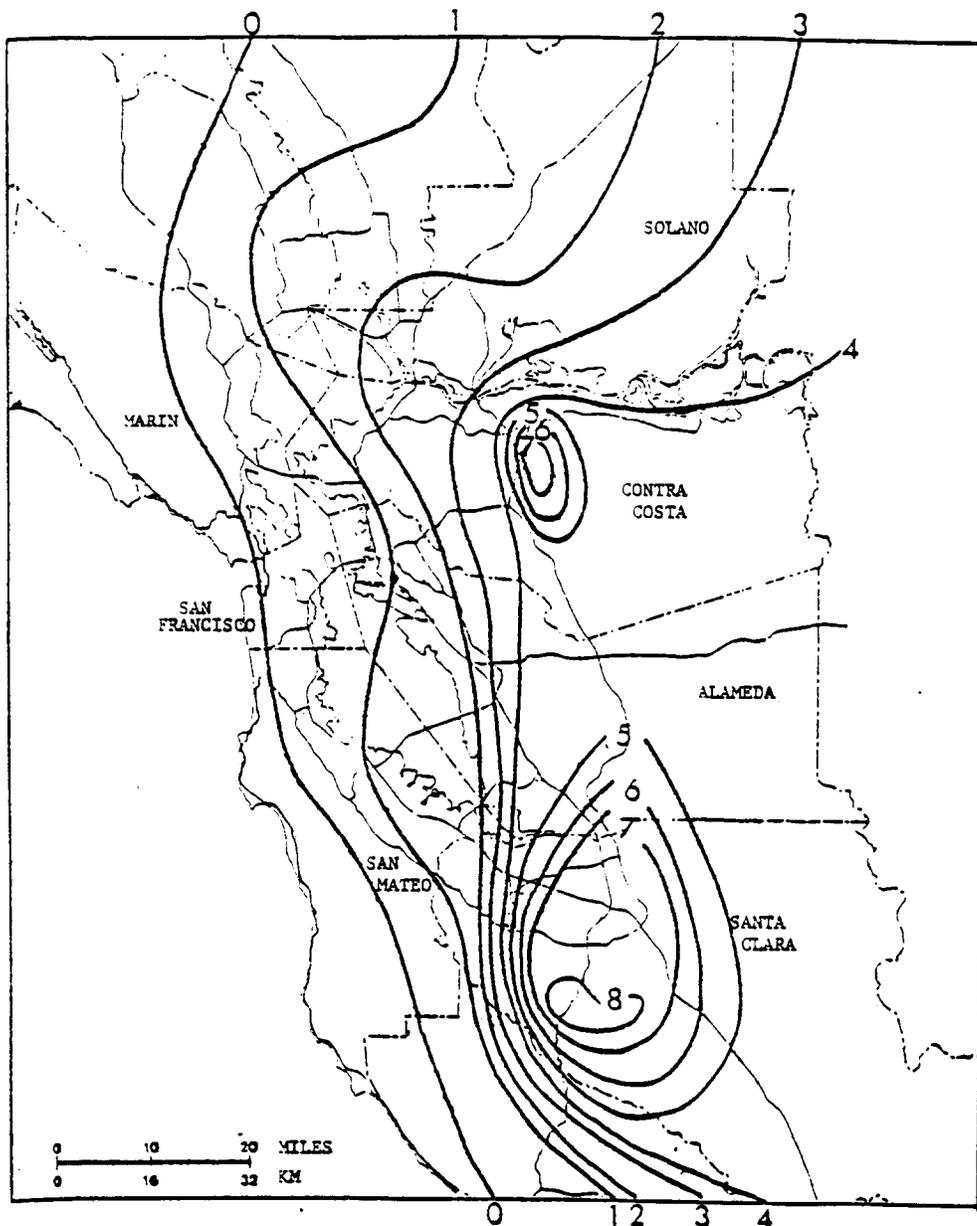
As in the case of Los Angeles, both property values as they related to were applied. These were compared with each other, given the hypotheses explained earlier, and to the Los Angeles results. Let us turn first to the property value study.

While the intention was to make the two studies as comparable as possible, there were some inevitable differences in both the situations and in the data available that made some adaptations necessary. For example,

in Southern California, as suggested, the mild year-round climate encourages a variety of ocean-related recreational activities. Beach front activity is highly valued, and beach front property has generally been densely developed. In the San Francisco area, the Bay is the most accessible body of water to major population centers; however, the Bay does not offer the same scenic or recreational experiences found along the coast of the Los Angeles area. In the Bay area, ocean front property is located over the ridge of the Santa Cruz Mountains and is less accessible to the major employment centers. As a result, much of the beach front property maintains a rural atmosphere.

Accordingly, it was not necessary to adopt the paired communities approach of the Los Angeles study to control for access to the beach. This made a more nearly random sampling approach possible, which has the advantage of providing a more dependable basis for extrapolating the sample results to the entire area.

Another principal difference between the areas is air quality. Smog is considered to be the major problem in both regions. The city of San Francisco itself has a less severe air pollution problem than Los Angeles. However, some cities included in the region (San Jose and Los Gatos, for example) suffer from severe pollution problems.

Thus, while the San Francisco region provides suitable contrast in air quality from place to place, still, air quality degradation is not in general so severe, and one would expect also possibly not so well-defined in people's minds. Accordingly, it was judged to be an excellent place to see whether the Los Angeles results would hold up in this different situation.

Data on property values were gathered or constructed for 2,500 households in the region. These same households also were subsequently used for interviewing. In addition, data were collected on about 5,000 residential property sales in areas where these families live. Unfortunately, the sales data available for San Francisco were not as accurate as the Los Angeles data. The data were used in regression analyses to try to isolate the effects of degraded air from other factors affecting air quality, such as income of residents, house characteristics, access to work places, etc.

Results of the San Francisco study as compared with the South Coast Air Basin study were in accordance with the hypotheses made about them.

First, one would expect a thirty percent improvement in air quality to yield less benefit per capita in an area where air is already relatively clean. Two types of results from the San Francisco study support this supposition: (1) a thirty percent improvement in air quality yields a much larger benefit estimate, by both the property value and survey method, for the dirtiest subarea in the San Francisco region than the average for the region as a whole; and (2) a thirty percent improvement in air quality, again as estimated by both techniques, yields an average benefit estimate

between five and six times as high in the Los Angeles region as it does in the San Francisco region.

Second, one would anticipate more variability of results from subarea to subarea in a region (San Francisco) where the pollution problem is both less intense and less well-defined than in the Los Angeles area. Again, this supposition is borne out.

As before, on theoretical grounds, one would suppose that the property value study would yield higher estimates of benefits than the survey approach. As in the South Coast Air Basin case, this expectation is met in the San Francisco study, and the relationship between the two alternative estimates is about the same as in the former.

Accordingly, the two studies have a broad consistency in that the differences in their findings are expected differences. In general, the San Francisco study supports the conclusion of the Los Angeles study that survey instruments may provide a reasonable, low cost way to get environmental quality benefit estimates.

AN ILLUSTRATIVE BENEFIT-COST ANALYSIS

While the basic purpose of the studies reported on in this volume was to develop improved methods for evaluating the benefits from air quality improvement or maintenance, an illustrative benefit-cost analysis was also done. This is included simply to illustrate how benefits estimation fits into the economic analysis of environmental policy. Not much credence should be accorded the actual numbers. The subject of the study was the benefits and costs of meeting national ambient standards in the South Coast Air Basin. Selection of this area, aside from its intrinsic importance, permitted use of the information developed for the benefits study reported earlier in this chapter.

The national ambient standards for oxidants (.12 ppm maximum hourly concentration--since the study was completed, the basis for the standard has been changed from oxidants to ozone) and nitrogen dioxide (.05 PPm annual average concentration) are consistently violated throughout the Basin with the notable exception of the immediate coastal areas which were characterized in the previous discussion of the Los Angeles area study as having "good" air quality. Accordingly, if the entire South Coast Air Basin were to be brought into compliance with ambient standards, areas that were in the earlier study characterized as having "fair" or "poor" air quality would then be characterized as having "good" air quality. The development of an aggregate benefit measure for achieving ambient standards (note that this is a different objective from the "thirty percent improvement" assumed in the earlier study) for the entire basin is then done by extrapolation. Benefits are taken to be the aggregate willingness to pay for all households in both "poor" and "fair" air quality areas to have "good" air quality, as defined for both the property value and survey studies.

In making the necessary benefits estimates, the property value results were the ones actually used. These results allow calculation of household willingness to pay as related to income and air pollution. It is this relationship that was used for benefit calculations. It assumes that income and population affect willingness to pay for air quality improvement in the same way throughout the Basin as they did in the limited sample. The estimates are strictly for household willingness to pay and exclude any agricultural and ecosystem effects. Agricultural benefits for the area are discussed in chapter 8.

Since benefits were calculated for moving from the current (1976 emissions inventory) level of air quality to the ambient standards, costs must be calculated on the same basis. However, analysis indicated that costs for on-road mobile source control measures were substantially more better done than those associated with stationary source controls. Therefore, only the costs attributable to on-road mobile source control were examined in the study. The benefits that are counted are also, necessarily, then only those corresponding to the share of total emissions reductions which are accomplished by mobile source control.

Although a careful engineering cost study of using mobile source control to achieve ambient standards would have been desirable, the objective of the study was, as noted, mostly illustrative, and resources *for* it were quite limited. The study was therefore forced to use cost estimates found in literature. Unfortunately, in many cases these are quite uncertain. For the most part, manufacturers statements and government publications were relied upon for cost calculations.

In addition, the state of California's <u>Air Quality Management</u> Plan (January 1979) was the basis for the calculation of required emissions reductions--the necessary "link" between emissions and ambient conditions discussed in chapter 3. Calculations presented in the plan indicate that to achieve ambient standards in 1979 would require reductions of about 975 tons per day in reactive hydrocarbons, about 6,000 tons per day of carbon monoxide, and about 500 tons per day of nitrogen oxides. Of these amounts, it was estimated that mobile source controls are responsible for about 730 tons per day, all of the reduction, and about 400 tons per day of hydrocarbons, carbon monoxide, and oxides of nitrogen, respectively.

Applying these methods and data, it was found that benefits of achieving ambient standards for air quality in the South Coast Air Basin for 1979 (note this is a much larger improvement than the 30% reported in the table above) fall in a range of 1.5 to 3.0 billion dollars per year. Of this total, on-road mobile source control would be responsible for approximately 1.4 to 2.6 billion dollars. The corresponding total basinwide control costs fall in the range of .6 to 1.32 billion dollars. It therefore appears, with due regard to all of the many uncertainties involved, that the benefits of achieving mobile sources controls in the South Coast Air Basin could outweigh the costs.

CHAPTER 8

AIR QUALITY, WAGES, AND NATIONAL BENEFITS
FROM URBAN AIR POLLUTION CONTROL

As indicated in previous chapters, one of the lines of study in searching for improved methods to estimate benefits of air quality is to look for actual human responses, reflected in prices of things, that might give a clue as to how much people value clean air. Application of the property value approach discussed in chapter 6 is one such effort. This approach is based on the idea that people's residential locational choices reflect the ambient air quality as well as a number of other characteristics of particular sites.

Another way in which human behavior, reflected in a price, might display preferences with respect to air pollution is the differences in compensation that people might demand for performing particular jobs at different locations with differing air pollution characteristics. The idea is that, in considering job and location choices, workers will take into account pollution in the area as well as other work place characteristics. One of the studies in the program of work being discussed here was designed to test this idea.

As is, unfortunately, always the case in this game, the data available for doing the analysis are far from ideal. A basic source of information used was the Panel Study of Income Dynamics, sponsored by the Survey Research Center at the University of Michigan. This study yielded usable wage information on about 1400 heads of households across the country. The information obtained in this survey included the household's state and county of resident and type of employment. The location information permitted matching of other information about variables that might influence real (price-correlated) wages, one of which might be pollution. As in the case of the epidemiology study described in chapter 5, a set of "independent" variables was specified that was thought to influence wages, data about them were developed, and the regression technique used to try to estimate the separate influence of each of them on wages.

The general form of the equation used was as follows:

Wage = f(whether the individual is a union member, whether the individual is a veteran, the size of the individual's family, the individual's health status, the individual's education, the length of time the individual has spent an his present job, the climate in the individual's area of residence, job hazards, and levels of pollution-sulfur dioxide, total suspended particulates, and nitrogen dioxide).

Of all of the independent variables, the worst quality of data is for the air pollution variables. This is both because some of the measurement procedures are not very dependable and because, in some areas, there are not many monitoring stations, and there may not be one close to the person's place of work--the pollution data are available only on a county basis.

Further, uncertainty about the accuracy of results comes from the fact that, because of data limitation, it was not possible to include all variables that might influence wages. For example, the availability of recreational opportunities and social services might influence wage rates. If variables are excluded that have an important influence, we know that the results may be biased. In chapter 5, the specification problem was discussed more extensively in connection with its role in epidemiology analysis.

These qualifications having been made, the results of the analysis show that only total suspended particulates are statistically significantly related to wages. The estimate of this relationship and of the other variables that influence wages can be used to make an estimate of the damage avoided (benefit) of reducing suspended particulates in particular urban areas.   This is done by putting the actual observed value of all the other independent variables for that metropolitan area in the equation, except that the secondary standard for particulates is substituted for the actual value, and calculating the implications for wages using the regression relationships computed from national data.   This result is then adjusted for the size of population of the particular metropolitan area.

This kind of calculation was done for the Denver metropolitan area and the Cleveland metropolitan area. The resulting total benefits per year for Denver were about $240,000,000, and for Cleveland about $70,000,000.

An attractive feature of the methodology just described is that it is fairly straightforwardly adaptable to producing a national estimate of the benefits of pollution control. It is a relatively simple matter to make an estimate of the type described above for each metropolitan area in the United States and then to add them up to form a national benefits total. But doing so would have required more data collection and calculation than available resources permitted.

A very rough approximation of this procedure can, however, be done very simply as follows:

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3.   These results are roughly consistent with those found in a related study by another member of the research team--Maureen Cropper. They are reported in "Inter-City Wage Differentials and the Value of Air Quality," Journal of Urban Economics, September 1980.

First one assumes that the situation in Denver is characteristic
of metropolitan areas in the West, and Cleveland of conditions in the
East. Then one computes the per capita benefits for each metropolitan
area and multiplies the result times the total population of the Western
and Eastern metropolitan areas, respectively. When these calculations
are done, an estimate of yearly benefits of meeting secondary standards
of about $5 billion dollars is obtained for the West, and about $4
billion dollars for the East, and about $9 billion for meeting the
secondary standard for suspended particulates everywhere. This is, of
course, an exceedingly crude procedure, and the amounts given are simply
meant to be illustrative of the method.

     We presume that if these figures have any validity at all that
what is being measured is primarily the more visible and tangible
aspects of air quality--visibility and soiling--rather than health
effects. If this is so, the benefits to health from a large improvement
in air quality should be added to these estimates. In chapter 5, we
estimated that such benefits could range between about 5 and 16 billion
dollars per year. If this range is also accepted, our total estimated
urban benefit from a large improvement in air quality might be between
15 and 30 billion dollars per year.

     While the basis for these figures is scandalously weak, and they
cannot be put forward as genuine estimates but only as illustrative of
methods, I do not necessarily find them incredible. For example, in the
relatively more carefully done studies in the South Coast Air Basin
discussed in chapter 6, annual benefits from a large improvement in air
quality were, as estimated for the benefit-cost study, in the range of
1.5 to 3.0 billion dollars. If we compare this to the higher of the two
national estimates, it does not seem unlikely that benefits in Los
Angeles could be five to ten percent of the total. While metropolitan
Los Angeles has about 2% of the U.S. population, it also has the
nation's most severe widespread air pollution problem. It does seem
unlikely, however, that the Los Angeles area could have as much as ten
to twenty percent of the benefit from a large improvement in national
air quality to meet ambient air quality standards and protect health.
It therefore seems unlikely, based on this slender bit of evidence, that
the number given is an overestimate of national urban air quality
benefits.

     It should be noted in closing that some, possibly important,
benefits are not captured, or not fully captured, by the methods and
data presently available. An example is materials damage which could be
quite large.

     Finally, in closing this section on urban damage, the reader
should be reminded that the central objective of the research reported
in this volume is to improve the methods rather than to make actual
estimates. Any numbers presented as illustrious in the text must be
appropriately discounted in light of that fact.

IIb. RURAL AND REGIONAL AIR AND WATER POLLUTION

The urban cases reviewed in part IIa are all instances where one starts with a degraded condition and wishes to know the benefits of improving it. The first four cases reviewed in this part are also of that type. They concern Southern California agriculture, national agriculture, freshwater fishing benefits from water quality improvement, and national benefits from water quality improvement. But there are also very important rural air pollution issues that raise the question of what it is worth to protect an area that is still relatively pristine.   The cases of this type that are reviewed in the later chapters of this section are concerned with the matter of   protecting visibility in National Parks,   protecting groundwater   from contamination, and with protecting water courses and other parts of the ecosystem against acid rain.

CHAPTER 9

AIR QUALITY BENEFITS TO SOUTHERN CALIFORNIA AGRICULTURE

As indicated in chapter 3, agricultural production is affected by many influences beyond the control of individual producers. In agricultural regions within or nearby urban areas, air pollution has, in recent decades, become one of these influences. As further pointed out in chapter 4, when these agricultural regions, say because of unique climate characteristics, dominate the national or regional production of selected crops, output price increases may occur when air pollution reduces crop yields. These price increases, again as explained in chapter 4, will reduce the well-being of consumers. In addition, if increases in market prices are insufficient to offset reduction in output (demand is relatively elastic), producers may also be made worse off. On the other hand, if demand is relatively inelastic, they will be made better off. Consumers, however, are always made worse off.

Seasonally (mainly in winter and in spring), Southern California produces a major share of the nation's vegetables and fruits. Also, large volumes of field crops such as cotton and sugar beets are grown in the region. The adverse biological effects on many of these crops of smog that periodically blankets the region are well-documented. However, attempts to assess economic impacts of these effects have been few. Moreover, as explained in chapter 4, those attempts that have been made simply multiply the estimated reductions in yields by an invariant price. This method is, as we have seen, especially inappropriate for crops having geographically concentrated production patterns since their market prices will vary with the quantity available from the region. Furthermore, the method is unable to account for changes in cropping patterns that may be induced in response to pollution. This difficulty resembles that of standard epidemiology which, as explained in chapter 5, does not account for human economic responses and adaptations to pollution.

In the research presented in this chapter, a more general and powerful methodology was employed to assess the economic impact of air pollution upon fourteen annual vegetable and field crops in four agricultural subregions of Central and Southern California. These subregions are shown in the map below.

The study included an analysis of changes in comparative economic advantages between and among crops and growing locations in response to increased air pollution. In addition, the method used makes it possible to distinguish between the impact upon consumers and that upon producers of these air pollution-induced changes.

■ = agricultural pro-
ducing areas of
study crops (Source
Johnston and Dean,
pg 35).

• = air pollution
monitoring stations
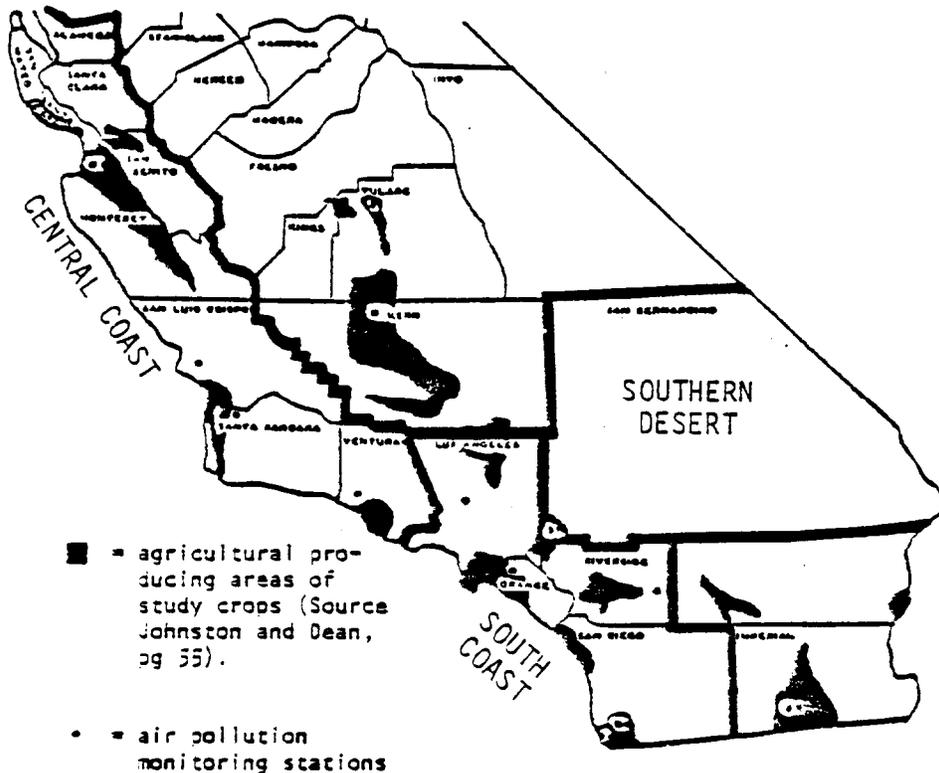
The particular method used in this analysis is called <u>mathematical</u>
<u>programming</u>. This is a type of economic modeling analysis which, given
information about available technologies and about the costs of inputs
and the demands for outputs, can be used to find the maximum value for
an economic objective.   For example, in the case of a private
business, this procedure might be used to find that combination of
inputs and outputs that would make the firm's profits a maximum.

For the crops and farming operations in the analysis reported
here, the method was asked to find that combination of crops and outputs
that would not only give maximum profits to the farmer, but that would
maximize the sum of those profits **Plus** the consumer's surplus obtained
by solutions of the problem--once under the assumption that there is no
air pollution, and then again, under the assumption that the levels of
air pollution prevailing in 1976 existed.

The difference between consumer's surplus plus profit' under the
two circumstances is, then, an estimate of the economic damage, or
inversely, of the benefits of cleaning up from a condition of 1976
pollution to no pollution at all.   The needed information about the
links between air pollution and yield and about demand elasticities for
various crops were both obtained from the large published literature
which exists in Southern California on these matters, and through
original statistical analyses by the researchers.

For the regions analyzed, the following table presents estimated
air pollution-induced percentage yield reductions for 1976 for the
fourteen crops studied, given the actual 1976 cropping patterns and
locations. Four vegetable crops, broccoli, cantaloupes, carrots, and
cauliflower, displayed no yield effects in these estimates. Reductions
in lettuce yields occurred only in the South Coast, and these effects
were slight. However, lima beans, celery, and cotton suffered
substantial yield reductions, while potatoes, tomatoes, and onions
exhibited moderate losses at observed pollution levels.
Regional percentage yield reductions were by far the greatest in the
South Coast, followed by the Southern San Joaquin, the Southern Desert,
and the Central Coast regions. This ordering of regions by yield
reductions corresponds to how they rate in terms of smoggy conditions.

	Region			
Crop	Southern Desert (1976)	South Coast (1976)	Central Coast (1976)	Southern San Joaquin (1976)
__Vegetables__		% Reduction in Yield		
Beans, processing green lima	--	15.71	1.37	9.45
Broccoli	--	0.00	0.00	--
Cantaloupes	0.00	0.00	n.a.	0.00
Carrots	0.00	0.00	0.00	0.00
Califlower	--	0.00	0.00	--
Celery	--	12.57	1.23	--
Lettuce, head	0.00	0.03	0.00	0.00
Onions, fresh	0.00	1.99	0.40	--
Onions, processing	0.00	1.99	0.40	1.35
Potatoes	--	4.20	0.43	1.95
Tomatoes, fresh	0.00	4.20	0.43	1.95
Tomatoes, processing	0.00	4.20	0.43	1.95
__Field__				
Cotton	9.40	18.70	n.a.	6.90
Sugar Beets	0.00	1.63	0.33	1.10

To estimate the extent to which air pollution reduced crop
production in the individual study regions, the 1976 percentage yield
reductions were used to calculate what per acre yields for each crop in
each region would have been if there had been no air pollution.
Given these new per acre yields, the mathematical programming model was
used to calculate new cropping patterns and locations of production, as
well as associated effects on producer profits and consumer's surplus.

The results show that the Southern Desert region would experience
a slight increase in production of most crops susceptible to air
pollution

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damages, with significant increases in the production of processing onions and cotton. Those crops more resistant to air pollution damages, such as carrots and lettuce, exhibit slight declines in. production.

For the other three regions, some crops, such as cauliflower, lettuce, and broccoli, that are rather tolerant of air pollution, record minimal changes in production levels. However, broccoli and cantaloupes in the South Coast region are two exceptions. The very significant decrease in the production of these air pollution-tolerant crops is due to their substantially reduced profitability relative to crops that are more sensitive to air pollution. Production of those air pollution-sensitive crops, such as lima beans, potatoes, tomatoes, cotton, and onions, generally tends to increase in each region.   As would be expected, there are only minimal changes in crop production in the Central Coast region, since 1976 air pollution levels were relatively small.

We now turn to the central objective of the analysis--estimated differences in the value of consumer's surplus plus profit "with" and "without" 1976 levels of air pollution, and the distribution of these difference among producers and consumers. The following table gives this information for all the regions combined.

	Total Consumer's Surplus Plus Producer Profit $	Producer Profits $	Consumer Surplus $
With air pollution effects	1,447,733,227	1,086,788,371	370,944,856
Without air pollution effects	1,503,024,714	1,122,024,497	381,000,217
Estimated losses due to air pollution	45,291,487	35,236,126	10,055,361

The results indicate that elimination of 1976 oxidant air pollution and attendant net increases in aggregate production would have increased 1976 producer profits by about $35 million and consumer surpluses by about $10 million, resulting in an increase of about $45 million in the total. This latter figure represents a little under four percent of the $1.22 billion total farm value of the fourteen crops produced in the four regions in 1976. About $30.0 million of the estimated potential increase in the total is due to an improvement in cotton yields.   While this is a significant amount, accepting the results in chapter 6, it is outweighed by urban damages in the same region by at least a factor of ten. This result

for the most severely polluted major agricultural region in the country
and for the assumption that <u>all</u> pollution is eliminated   (probably an
impossibility and certainly ineconomical) suggests the Possibility that
the economic costs of air pollution in the agricultural sector are also
relatively small in the rest of the United States.   That this
presumption is not correct is shown in the next chapter where ozone
damage to field crops across the nation as a whole is assessed by the
use of a procedure designed especially for that purpose. The reason is
that the total value of major crops like wheat, corn, cotton, and
peanuts is so enormous that even relatively small reductions in yield
can cause large economic losses for the national as a whole.

CHAPTER 10

OZONE DAMAGE TO U.S. AGRICULTURE

        The study described in the previous chapter is a rather detailed
look at pollution damage in a single, but very important, agricultural
region in the United States. It was able to incorporate adjustments to
pollution, for example, crop switching, in considerable detail.
In principle, this type of approach could be applied, region by region,
to the entire country. But the resources required to do it would be
considerable and well beyond those available for the project described
here.

        Therefore, in the interest of estimating national agricultural
benefits, it was necessary to develop a simpler methodology, that could
use existing data sets. Data limitations laid some restrictions on the
study. The only pollutant considered was ozone, and the only crops
considered were wheat, corn, cotton, soybeans, and peanuts. But ozone
is thought to be the major pollutant affecting agriculture, and these
five field crops account for more than 60 percent of the total value of
U.S. agricultural production.

        The methodology developed to assess agricultural damage on a
national scale is called the "Region Model Farm" (RMF) approach.
Essential to this approach is a set of data developed and maintained by
the U.S. Department of Agriculture. The USDA refers to these data as
the "Firm Enterprise Data System" (FEDS). FEDS provides people studying
agriculture with sample operating budgets that describe the entire cost
structure for producing an acre of a particular crop in a specific
region of the continental U.S. The budget is representative of the
average agricultural practice in that region and is verified with a
battery of farm level surveys every two years. A single budget for the
production of soybeans in southeastern North Carolina, for example, may
include cost information on as many as 200 inputs to agricultural
production, the average yield per acre to be expected, and the total
number of acres planted in the region. FEDS divides the U.S. into over
200 producing areas. Thus, when the present study examines the cost of
producing wheat, for example, it considers production cost for over 160
regions where wheat is produced in the United States.

        The reason why this fine detail on costs is needed is that the
major way in which pollution affects agriculture is through yield
reduction. Since this is so, reduction of pollution will permit a
particular amount of agricultural production to take place at reduced
cost. This cost reduction is one, and the largest, component of
benefits (reduced damage) of pollution control. Thus, if one can
calculate this reduction on a national

scale, a major step will have been taken in estimating agricultural benefits. To do this, total costs of agricultural production must be calculated before and after pollution control, and since costs of production vary by region, the fine regional detail provided by FEDS is needed to do this accurately.

To calculate cost, the study assumed that for each of the FEDS producing areas, the representative farm budget for a particular crop type reflects both the cost and yield existing for that budget year, for given prices of inputs, outputs, and ambient ozone concentrations. The FEDS budgets are on a per acre basis and can be added up across all of the planted acres covered by a budget for a particular crop.

Given these data, the aggregate cost of production can be estimated for whatever the actual output is in a given year. The procedure used to do this assumes that production is limited by available land for a particular crop in a given region. All the regions capable of producing the crop under consideration are then arrayed in order of increasing cost for the entire country under the further assumption that each region produces the maximum output that available land will allow. This latter assumption will be true for all regions except the highest cost region included, where the maximum output may not be needed to complete the total output actually produced in a particular year, say, 1982.

One can illustrate how this works with the aid of a simple graph that shows the results of this procedure for only the least cost region, say for corn, and for the next higher one.

Quantity of Corn Produced
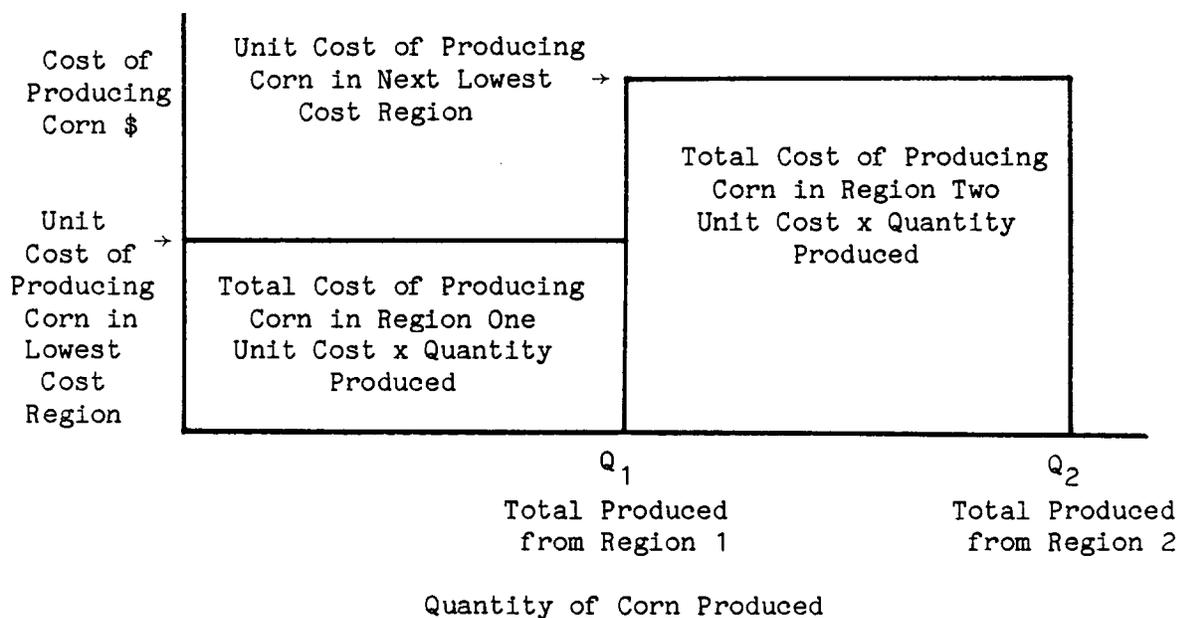
As shown, the total cost of producing corn in the lowest cost region is the unit cost times the amount produced there, and similarly, for the next lowest cost region, and so on, until the quantity produced equals actual recorded national output for that year. Since there are up to 160 regions that might produce in a particular crop, a graph like the above, but with all the regions included, would come pretty close to a smooth curve when seen as a whole. Let us depict such a graph as a smooth curve and refer to the following diagram.

Cost of
Production
of Corn

Total
Cost of
Production
of Corn 1982

Q

Corn Output 1982
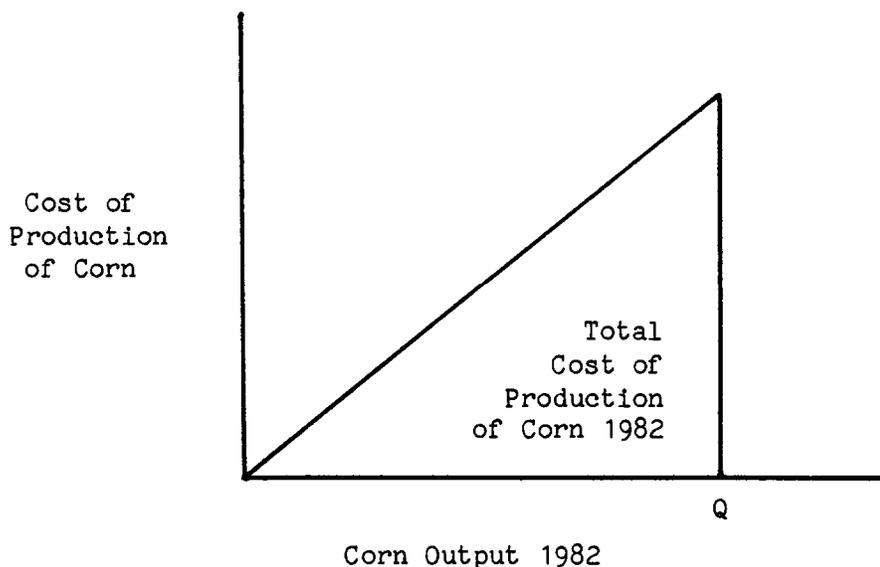
To economists, a curve of the above type is known as a "marginal" cost curve. It displays the increment in total cost for each unit as output is increased. In parallel with principles discussed in chapter 2 with respect to demand concepts, the area under a marginal cost curve equals the total cost of producing whatever number of units of output are produced.

How are these ideas related to estimating the benefits from reduced ozone? As stated, the major source of benefits (reduced damages) comes from being able to produce any specified output at lower cost when pollution effects are controlled. The effect of this is to shift the marginal cost curve downward as depicted below.

The area B, the difference between the areas under the two curves, would then be the benefit of reducing pollution to such an extent that marginal production costs would fall to the lower curve.

We have seen how the upper curve can be calculated with existing data, but how do we get to the lower curve? To do it, three items of further information are needed. First, one must know what existing levels of ozone are in each producing area. Secondly, one must know how a proposed ozone policy would affect these levels, and third, one must know how this change in levels would affect yields (the dose-response relationships we have

Cost of
Production
$

Marginal Cost of
Production Before
Pollution Control

B

Marginal Cost of
Production After
Pollution Control

Q

Quantity of Output
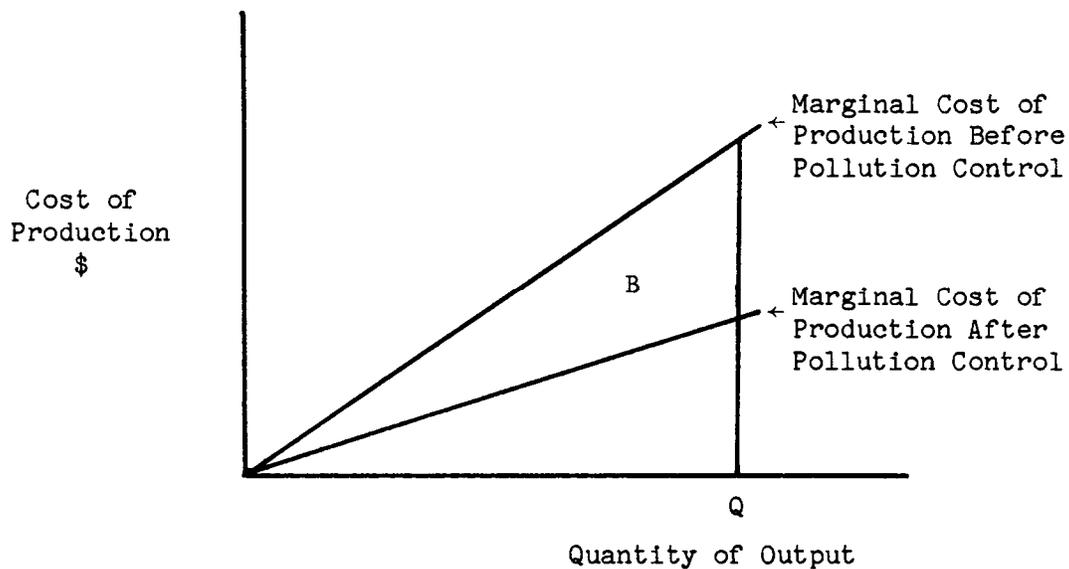
encountered so frequently). The first two items were supplied by EPA specialists based on extrapolations from ozone monitoring stations and on estimated effects of possible pollution control policies.

The third item was estimated by the research team from another data set available from USDA. These data result from experimental work conducted by the National Crop Loss Assessment Network (NCLAN). The approach involves subjecting particular crop varieties to alternate levels of ozone under laboratory conditions of experimental control. The relation between yield and ozone concentrations for each crop was estimated from these data by statistical regression--a technique we have encountered numerous times in previous chapters.

With these items of information at hand, it is a straightforward matter to estimate a marginal cost curve corresponding to a new level of ozone concentration.

But as indicated in chapter 4 and reemphasized in the previous chapter, if costs are significantly affected by pollution, a price change will occur, and if the demand for the product is at all elastic, an associated change in consumer's surplus will take place. Thus, to get a complete estimate of benefits, one must calculate the change in consumer's surplus as well as the cost change. In the following diagram, if the demand curve is as shown, price would fall from P1 to P2. In an industry where there is no significant element of monopoly; price is determined by the intersection of the marginal cost line and the demand line. This is because at any price above this, consumers are willing to pay more than it costs to produce additional units of output, and at any lower price, additional units of output cannot be sold for what it costs to produce them.
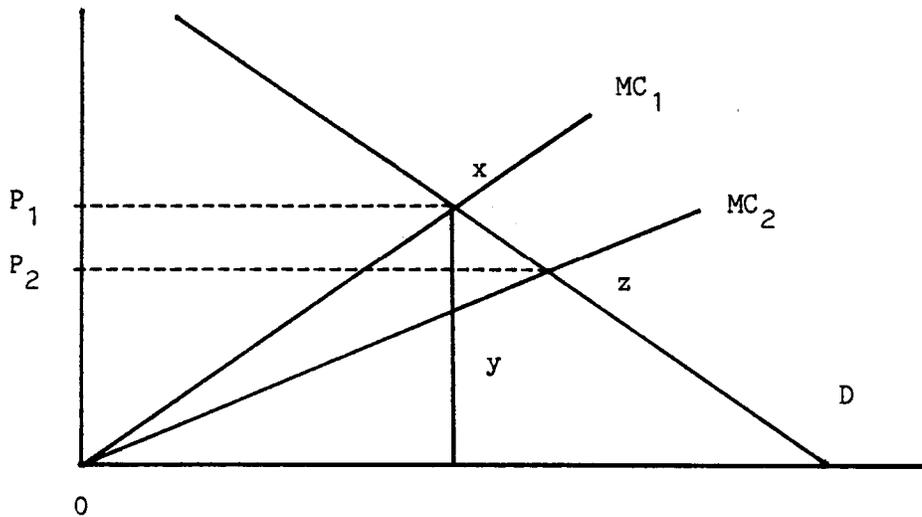
In the diagram, the area 0, x, _y_ is the reduction cost discussed in connection with the earlier diagram. But the area x, _y,_ z is an __additional__ benefit which, in accordance with principles discussed earlier, consists of increases in both consumer's surplus and producer's profit. To estimate this additional benefit quantitatively, one must have an estimate of the elasticity of demand for each crop.   For purposes of the study described here, these estimates were taken from the published literature.

Using these tools, estimates of benefits were made for two different regimes of ozone change. The first was specified by EPA and must be regarded as highly unrealistic. The second was developed by the research team and seems more plausible.

Under the EPA-supplied scenario, it is assumed that for any hypothetical ozone standard which is to be evaluated, all rural areas will be exactly at that standard. Since at present particular areas may be either above or below that standard, under this scenario gains and losses may cancel out. It is even possible that change from the existing situation to a tighter standard, given the uniformity assumption, could results in negative benefits. Since ozone stems mainly from urban areas, a more realistic assumption would be that if the standard is tightened in those areas, levels would also fall in the affected rural areas and not rise anywhere. The latter was assumed in the scenarios developed by the research staff.

It should also be said that there are very few ozone monitors in rural areas so that the estimates for those areas are mainly extrapolations from measurements made in the nearest urban areas. The accuracy of these extrapolations is very uncertain, thus adding to the uncertainties inherent in other parts of the estimating procedure.

Interestingly, even under the EPA scenario, a substantial reduction in ozone concentrations is calculated to yield large benefits. For example, in the southeastern United States, which is the largest soybean producing

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region in the nation, the average rural ambient ozone concentration was estimated to be about .055 parts per million (PPM) in 1978.   The concentration at urban monitors is usually about twice that estimated for rural areas, or in this case, about .11 or .12 PPM.   The current national ambient standard is .12. According to the model calculation, a standard of .05 PPM, if that concentration prevailed everywhere in rural areas in the region, would yield benefits in soybean production of more than six hundred million dollars. An extreme reduction to .01 PPM would yield benefits of more than two billion dollars in that region alone, according to the model, but such a large reduction is probably impossible to achieve.

As noted, benefits were also calculated on the basis of more realistic assumptions about what would happen to ozone levels in rural areas when the urban ozone standard is tightened--namely, that concentrations in rural areas would also go down. It was assumed that alternative ambient standards would apply at monitor sites where ozone is actually measured. The translation of that standard into ambient levels in rural areas was then accomplished by means of a very simple dispersion model (see chapter 3).   Otherwise, the methodology was the same as that described in this chapter and used to estimate the EPA scenarios. The table below gives some of the results. It was assumed that the national ambient standard of .12 PPM was met initially at each monitoring site.   This is the base for the calculation of benefits associated with increasingly strict hypothetical standards. The values in the table are in 1978 dollars and represent total national benefits for each crops listed.

O3 Concentration PPM	Peanuts	Cotton	Corn	Wheat	Soybeans
.09	138,482,784	224,659,050	103,913,808	122,513,392	1,077,526,832
.10	91,143,616	154,706,848	83,359,392	83,394,032	864,235,888
.11	26,731,088	73,451,376	42,747,408	42,794,544	218,492,344
.12	0	0	0	0	0

The table shows large national benefits from comparatively small reductions in ozone concentrations. This is because, even though effects on yields may not be especially large, the total value of annual production of these crops is so enormous that even a small yield response translates into a large number of dollars of benefits. For example, the total national production (price lines quantity) of soybeans has in recent years been in the twelve to fourteen billion dollar range.

As usual, uncertainties pertain to these results. But they do suggest that agricultural benefits of ozone could be quite large.

CHAPTER 11

NATIONAL FRESHWATER RECREATION BENEFITS OF WATER POLLUTION CONTROL

INTRODUCTION

One of the most important pieces of national environmental legislation created during the 1970S was the comprehensive Amendments of the Federal Water Pollution Control Act. These amendments, signed into law in 1972 and further amended in 1977, in reality constituted a major piece of legislation in their own right, dramatically redirecting the water pollution control efforts of the nation and setting out ambitious national goals, expressed both in terms of discharge controls and of resulting water quality.

Criticism of the amendments and debate over their goals and requirements began during the legislative process and has continued, with more or less heat, to the present. One important critical position is that the goals are too ambitious, that is, the benefits of meeting the goals (and related requirements) are asserted to be too small to justify the costs of compliance. This argument over the balance of benefits and costs can never be resolved entirely by research but the project described in this chapter was undertaken in the conviction that it should be possible to improve methods for estimating at least some of the benefit categories associated with water pollution control. The particular one addressed is the benefits from recreational fishing in fresh water bodies of the United States. From the outset the intent was to design a method for estimating benefits for the nation as a whole rather than benefits for particular sites. In this respect, it resembles the study discussed in the previous chapter.

In undertaking this research a primary question concerned the ways in which water quality improvement would affect fresh water fishing in favorable directions. Two major ways were identified.

First, it tends to increase the total availability of fishable fresh water bodies by reducing the incidence of conditions such as low dissolved oxygen and heavy sediment loads that make it difficult for fish to survive.

Second, it produces changes in the types of fish that can survive in particular water bodies. Simply put, clean water means "game" fish such as trout or bass and dirty water means rough fish such as carp or buffalo. In general, fishermen prefer game fish. Therefore, pollution control tends to increase the amount of water yielding high quality fishing relative to that yielding low quality fishing. Given this view of the benefit producing mechanism, one can one work toward a methodology for making national

benefit estimates based on it. As explained in Chapters 3 and 4, and illustrated a number of times since, benefit estimation for environmental improvement requires the understanding of a number of linkages. There follows a brief review of them in the context of this particular study:

   (i)   how implementation of the law will affect pollution discharges by location, quantity, and pollutant type across the entire nation;

   (ii)   how the prepolicy and postpolicy discharge levels affect ambient water quality (or how ambient quality changes as discharges change) in terms not only of such familiar indicators as dissolved oxygen, but in terms of supportable fish population types;

   (iii)   how increases in total amounts of water supporting recreational fishing and shifts in the composition of that water toward more highly valued fish species affects numbers of anglers and the amount of time they spend fishing.

In addition, one needs to be able to value

   (iv)   fishing activity of various kinds (i.e., for practical purposes based on days spent fishing for various species--rough fish vs. game fish.)

   The novelty of this study and its main contribution to methodological development lies in the ingenious way it was able to link models together to structure these linkages and how it was able to take existing and newly developed data sets to estimate them quantitatively. I turn now to a discussion of each step in the procedure seriatim.

DISCHARGE REDUCTIONS AND LINKAGES TO AMBIENT QUALITY AND FISH

An initial need is an understanding of the "fishability" of the nation's water prior to the implementation of the Federal Water Pollution Control Act. A data base was available from the Fish and Wildlife Service that permitted estimates of fishable water by state (the state is the basic geographical unit on which this study operated). But these data do not provide a basis for the breakdown between rough fish and game fish mentioned above and basic to the methods used in this study. For this purpose the researchers did their own survey of state fish and game officials asking them for a breakdown by species category for their own states. Using these data they found that for the contiguous 48 states and the District of Columbia, there are about 30.6 million acres of fishable fresh water consisting of about 20.4 percent cold water game fisheries, 68.4 percent warm water game fisheries, and 11.2 percent rough fisheries.

   To go from this present condition to how fishability would be affected by implementation of discharge controls requires a knowledge of the amount and locations of discharges prior to implementation of the 1972 amendments

and the same information after implementation. Then one must estimate how this change will affect ambient conditions in water courses, and how, in turn, these would affect fishability.

The first three kinds of information were established by the use of the Resources for the Future's Water Quality Network (WQN) model described in chapter 3. This model was designed specifically to answer those questions and it was run for four scenarios representing, albeit roughly in some cases, stages in the implementation of the law. In what follows, I will focus on only one of these stages. This is for simplicity and also because the quantitative benefits results must still be regarded as rather experimental. The stage of implementation is the Best Practical Control Technology Currently Available (BPT for short) requirement that was to be achieved by all point sources of wastewater discharge by July 1, 1977. This goal may reflect about where we are now in our current control efforts.

At best, the WQM model provides a reasonable estimate of the impact of policy changes on one important aspect of ambient conditions: dissolved oxygen--it does not translate directly into fishability. Indeed, making that step is an undeveloped discipline. Accordingly, rather heroic measures were called for. Fortunately, a fisheries biologist was willing to use his knowledge and skill to make a survey of the literature to develop a set of rules that appeared to capture whatever consensus exists on the water quality conditions needed for the survival and reproduction of fish populations of various types. These rules were then applied to the results of the WQN model to provide estimates of the acreage of different kinds of fishing availability by state, and by aggregation, for the nation as a whole. The results for BPT for the whole country are shown below:

Baseline and Projected

	Fishable water total		Fishery shares	
	(1000 acres)	Coldwater gamefish	Warmwater gamefish/ panfish	Rough fish
Pre-FWPCA/CWA conditions	30,615	0.204	0.684	*0.112*
Pollution control to level represented by Best practicable technology (BPT)	30,721	0.227	0.736	0.037

The reader may be struck by how small the increases in total fishable water is; only about one hundred thousand acres from a base of more than thirty million. This is because a very large proportion of U.S. fresh waters was already fishable before implementation of the water pollution law. However, at the same time, the water regarded as unfishable or supporting rough fish only is projected to decline dramatically. This does not mean a proportionate decline in rough fish populations, but rather a large increase in the water rough fish will share with warm and Coldwater game fish.

The next step is to devise ways of converting the water quality results into changes in fishermen's participation in various kinds of fishing. I turn to a discussion of that in the next section.

Before proceeding, however, it is pertinent to note that what has been discussed so far are not types of research and modeling that are in the usual purview of economics. But the situation is reflective of the fact, as we have also seen in other chapters, that existing models of natural systems rarely fit the needs of the economist who would estimate the benefits of environmental improvement. Accordingly he is often forced into disciplinary imperialism.

BEHAVIORAL ECONOMIC ASPECTS OF THE STUDY

I now turn to steps in the analysis that are more clearly economic in character. To finally wind up with an estimate of total activity in various types of fishing, the individual fisherman's chain of decision about recreational fishing is broken down into several logical stages.

The first choice is whether to do any fishing at all. The hypothesis adopted in the research on this question is that the decision of whether to fish or not is sensitive, among other things, to the opportunity to fish, represented by the quantity of fishable water. The object of this first stage of the research is then to quantitatively estimate how the decision to fish is influenced, in the population at large, by the availability of fishable water. Regression analysis is the method used to try to sort out from the data the separate influences of availability of fishing opportunity and those other influences that might affect the decision (e.g. income, sex). Regression analysis is the basic econometric tool we have encountered so many times in these pages and which is briefly explained in chapter 5.

The indicators of existing fishable water are the state level estimates, already mentioned above, divided by the state population to get a per capita measure. This is rather crude but a more refined indicator was not available.

The other needed data for this stage of the research were obtained from a very large survey (more than 300,000 individuals) conducted by the Fish and Wildlife Service in 1975. This was a telephone survey and its primary intent was to determine whether or not individuals participated in

hunting, fishing, and other recreational activities associated with wildlife. The survey also contained information on other pertinent variables such as age, sex, income, etc. so that it was Possible to include them in the regression analysis and control for their Possible effects on participation. The dependent variable was the decision to fish or not to fish. Since the measure of fishable water availability was included among the independent variables, once the coefficients of the equation are estimated, the size of the availability variable can be changed and the corresponding change in participation calculated. We have seen regression analysis results used in a similar way in other chapters of this volume. For example, in projecting the effect of air quality improvement in chapter 8.

So far, all the analysis permits us to do is to project fishing in general as a function of water quality. But since, as I have indicated, different types of fishing (warm water game fishing, cold water game fishing, and rough fishing) probably differ in value we must also be able to project how likely a representative individual is to pick each of these types if he does decide to fish.

For this purpose data developed by the Fish and Wildlife Service for a subsample of the large telephone survey mentioned earlier could be used. A mail questionnaire was sent to more than 50,000 persons who had declared themselves to be hunters and fishermen in the large sample. For this subgroup detailed information was gathered on their participation patterns, socioeconomic characteristics, and preferences. Data for the fishermen only was used in analyzing the second stage in the decision chain, namely once a person has decided to fish how likely is he to participate in each of the three types of fishing given the availability of water suitable for each type. While the analysis of the decision also uses regression techniques, a very complicated mathematical model involving simultaneous equations had to be used, and it is not Possible to explain it, even in general, in a book intended for a nontechnical audience. Suffice it to say that a means was developed for predicting the likelihood of different types Of fishing given the availability of different types of fishing water and given that one had decided to fish at all.

The final stage in the decision chain is the decision that once a fisherman has decided to engage in a certain type of fishing, how much time (many days) he will spend in that activity? The same set of mail survey data was used in the analysis of this question, but once again I must ask the reader to make a leap of faith and not inquire how.

But the drift of the analysis is now clear. The steps are as follows: the amount of increase in total fishable water and fishable-type water associated with water pollution control is given for the nation as a whole from the models of the previous sections. Given this, the results of stage 1 are used to calculate how much fishing participation will increase in general. Then, the results of stages 2 and 3 are used to calculate how this increase in participation will be distributed across the fishing types and how many days Of increased fishing of each type will occur nationally

as a result of the pollution control policy. This process, and some re-
sults, is laid out in the table below:

	Water Quality	
	Base	BPT
Probability of being a fisherman	0.2793	0.2794
Total fishermen (10 6)	59-16	59.18
Probability of doing some:		
Coldwater gamefish fishing	0.3708	0.3931
Warmwater gamefish fishing	0.6840	0.6776
Rough fishing	0.3499	0.3536
Days per angler per year of:		
Coldwater gamefish fishing	13-76	13-73
Warmwater gamefish fishing	18.22	18.49
Rough fishing	10.14	10-55
Total days per year of:		
Coldwater gamefish fishing (106)	301.8	319.3
Warmwater gamefish fishing (10 6)	737.4	741.4
Rough fishing (10)	209.8	220.8

The final problem confronted by this research on the benefits from
improved fresh water fishing opportunities is how to assign dollar value
benefits (willingness to pay) to the increase in each category of
fishing activity.   The approach adopted was to estimate a demand curve
for fishing days for each category and to use those to calculate
consumers surplus. The travel cost method, described in general terms
in chapter 2, was the technique selected. I now turn to a brief
discussion of how it was applied in this study.

Recall that the basic assumptions of the travel cost method is
that higher costs of access as reflected in distance from a recreational
site will have the same effect on visitation as an equivalent emissions
fee assuming zero distance from the site.   In chapter 4, I
presented a very simple example of how this relationship is used to
develop a demand curve by assuming successively higher admissions fees
and using information on access costs to estimate their effects on
visitation. This establishes points on a demand curve, i.e., the
relationship of price to the number of visitor days. The area under the
demand curve, by principles discussed in

chapter 2, is the total willingness to pay of participants for the total number of visitor days to the site, say a trout fishery.   If one then divides the number of visitor days into this number, one obtains the average willingness to pay in fishing for trout. The researchers who conducted the study collected data from a large number of fishing sites around the country which permitted them, by statistical means, to make exactly such a calculation yielding average willingness to pay per Visitor day for each type of fishery.

        We are now at a point where a national benefits estimate can be made. The point of all the earlier machinations was to derive an estimate of how many days of increased recreational fishing of each type would correspond to the water quality changes resulting from a reduction of waste water discharges corresponding to the implementation of a pollution control policy.   Having these numbers in hand, it is a simple matter to multiply them by average willingness to pay *for* a day by fish type and get a total benefit number for freshwater fishing in the United States. When this is done the following results are obtained for BPT:

Valuation Base	Total Benefits Over Base (Millions of 1980 Dollars)
Low	307
High	683

        A few words of explanation are needed about the difference between the low and the high estimate. For the low estimate travel cost is figured based on only out of pocket expenses--gasoline, restaurant food, motels, etc.   This is the conventional method.   The higher estimate takes account of the fact that the fisherman may also attach a cost to the time it takes to get to the site. For the higher figure an estimate of this Cost is made by attaching average wage rates to the travel time needed to get to the site.

        Needless to say large uncertainties attend these numbers and, as already said, they must be regarded as largely experimental. Nevertheless, in view of the heavy costs of the national water quality improvement program they may strike the reader as being quite low. There are several things to be said in this connection. First, the reader should recall that in terms of the availability of fish species the vast majority of the nation's fresh water was already fishable prior to the 1972 amendments. Secondly these estimates are partial in the sense that they consider only the fresh waters of the United States, and even then they do not include as values that may be accrued to fisherman the possible effects of pollution control on the aesthetic aspects of the fishing experience. At present, the search is underway to extend the methodology developed in this study to effects of pollution control on marine (salt water) recreational fisheries.

CHAPTER 12

A SURVEY RESEARCH METHOD FOR ESTIMATING NATIONAL
WATER QUALITY BENEFITS

INTRODUCTION

The research reported in the last chapter was designed to yield national recreational fishing benefits of water quality improvement. But its basic approach was still to use subregions as units of analysis and to aggregate by adding up the results. In this sense it was still "site specific," although less so than, **say,** the visibility study reported in the next chapter. Thus it can be described as a large scale simulation falling somewhere between a particular site (or micro) study and a national survey that asks respondents directly about their willingness to pay for national programs of pollution control. This last procedure we have called the "macro" approach. Among other potential advantages of such an approach, two are especially important. First, a randomized national sample of persons can be interviewed which permits well-established statistical procedures to be used to extrapolate the results to the entire population. Second, one can inquire about "intrinsic" or existence benefits as well as user benefits.

The second reason invites a bit of explanation. Because the U.S. population politically supports very expensive programs of water pollution control, much more costly than the benefits estimated for recreational users in the last chapter for example, the researchers were led to believe that there must be some form or forms of benefits accruing to persons who do not actually use particular water bodies. We termed such benefits variously as intrinsic or existence benefits. These benefits may accrue because persons value the options for possible use that are opened to them when water bodies are cleaned up. This type of value has been discussed widely in the economics literature and has come to be called option value. Other intrinsic values may accrue from a sense of national pride or rectitude associated with having clean waters. One of the main conclusions of the research reported in this chapter and in the following one, which as mentioned deals with air quality, is that intrinsic benefits definitely exist with respect to environmental improvements or maintenance. Moreover, and with the usual caution about accuracy of results, not only do they exist, but they are large, perhaps larger than user benefits in some instances.

Some aspects of the water quality situation made it more appealing for an experimental application of the macro approach than is air quality. Chiefly, goals of our national policy are set out in a manner that would

let most of the population understand what they mean in terms of ordinary experience. The objectives are stated to be to make all the nation's water fishable and swimmable in successive stages. Furthermore, most of the cost of these programs is to be paid from taxes levied at the national levels so that respondents can be realistically asked how much in added tax burden they are willing to pay for improved water quality across the whole nation. Neither one of these situations holds with respect to air quality, so it would be much harder to pose understandable and realistic alternatives in a national clean air survey.

A macro study, then, is potentially useful for doing a benefit-cost analysis for whole national water programs. It should be noted, however, that it is not a substitute for site-specific studies in other applications. For example, determining whether or not the benefits outweigh the costs of a water quality improvement program in the Potomac Estuary would require a site-specific study.

RESEARCH PROCEDURES

One problem with national surveys is that they are quite expensive. What made it possible to conduct an experiment with the macro approach, given available resources, was that the researchers were able to piggyback some water quality questions onto a survey being funded by another source. After the interview for the other survey was completed, the interviewers administered a sequence of benefits questions that had been carefully pretested by researchers on the benefits project. From the respondents' perspective, the two interviews appeared as one long interview. In all, 1,576 personal interviews of a national probability sample of persons eighteen years of age and older were completed. The sample was designed and the interviews were conducted by Roper and Cantil.

A penalty of this add on approach proved to be that an unfortunately large number of persons failed to complete all of the questions. In part this was because they came at the end of an already fairly lengthy survey and in part because it was not possible to undertake special training of the interviewers to administer the benefits section. Because of the likelihood of item response bias (caused by respondents failing to answer individual items), the researchers regarded their estimates as only suggestive and warn against regarding them as definitive. The main intent of the experiment was not to develop definitive estimates at this stage but to test whether a macro approach is applicable to water quality benefits investigation.

The low response rate presumably could be cured by an improved questionnaire and by training of the interviewers. A study is currently being planned in which both of these elements will exist.

WATER POLLUTION LADDER AND VALUE LEVELS

The levels of water quality for which the research team sought willingness to pay estimates are "boatable," "fishable," and "swimmable." These levels were described in words and depicted graphically by means of a "water quality ladder." Use of these categories, two of which are embodied in the law mandating the national water pollution control program, permitted avoidance of the communications problems associated with description of water quality in terms of the numerous abstract technical measures of pollution (oxygen depletion, for example). Although the boatable-fishable-swimmable categories are widely understood by the public, they did require further specification to ensure that different people perceived them in a similar fashion.

Boatable water was defined in the text of the question as an intermediate level between water which "has oil, raw sewage and other things in it, has no plant or animal life and smells bad" on the one hand, and water which is of fishable quality on the other. As discussed in the previous chapter, fishable water covers a fairly large range of water quality. Game fish like bass and trout cannot tolerate water that certain types of fish such as carp and catfish flourish in. In pretests, experiments were made with two levels of fishable water--one for "rough" fish like carp and catfish, and the other for game fish like bass--but a single definition of "fishable" was adopted as water "clean enough so that game fish like bass can live in it" under the assumption that the words "game fish" and "bass" had wide recognition and connoted water of the quality level Congress had in mind. Swimmable water appeared to present less difficulty for popular understanding since the enforcement of water quality for swimming by health authorities has led to widespread awareness that swimming in polluted water can cause illness.

Because willingness to pay questions have to describe in some detail the conditions of the "market" for the good, they are inevitably longer than the usual survey research questions. Respondents quickly become bored and restless if material is read to them without giving them frequent opportunities to express judgments or to look at visual aids. The questionnaire for this experiment was designed to be as interactive as possible by interspersing the text with questions which required the respondents to use the newly described water quality categories. They were also handed the water quality ladder card which was referred to constantly during the sequence of benefits questions.

The following figure shows the card. The top, step 10, was called the "best possible water quality," and the bottom, step 0, was the "worst possible water quality." The card is "anchored" by designating five levels of water quality at different steps on the ladder. Level E, at .8, was specified as a point on the ladder where the water was even unfit for boating. Level D, 2.5, was where it became okay for boating; C at 5 was fishable, B at 7 was swimmable, and 9.5 was identified as A, where the water is safe to drink.

(WATER QUALITY LADDER CARD)

BEST POSSIBLE
WATER QUALITY

10

A SAFE TO DRINK

9

8

7 B SAFE FOR SWIMMING

6

5 C GAME FISH LIKE BASS CAN LIVE IN IT

4

3 D OKAY FOR BOATING

2

1 E

0

WORST POSSIBLE
WATER QUALITY
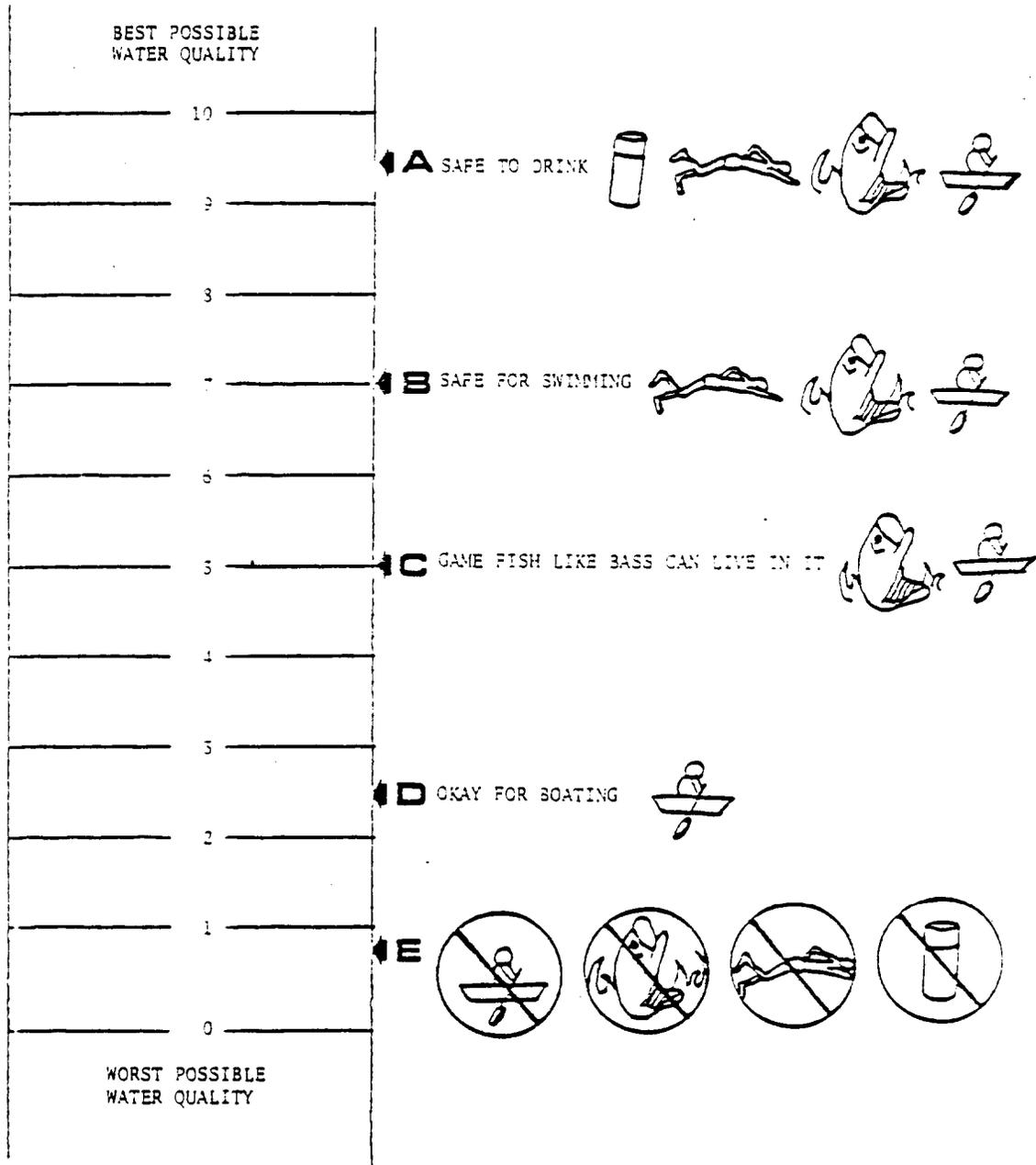
WILLINGNESS TO PAY QUESTIONS AND ANSWERS

Questions about willingness to pay should seem realistic to respondents. Accordingly, they were couched in terms of annual household payments in higher prices and taxes because this is the way people do pay for water pollution control programs. A portion of each household's annual federal tax payment goes toward the expense of regulating water pollution and providing construction grants for sewage treatment plants. Local sewage taxes pay for the maintenance of these plants. Those private users who incur pollution control expenses, such as manufacturing plants, ultimately pass much or all of the cost along to consumers in higher prices. Thus, this payment method has a true ring for the respondents.

As explained in chapter 4, "starting point bias" can be an important problem in bidding games and surveys. That is, a high starting bid from an interviewer may elicit a higher bid from a respondent than a low starting bid. A major methodological innovation of the research reported in this chapter is the development of a device for eliminating such a bias, the "payment card."

In this technique, the respondent is given a card which contains a menu of alternative amounts of payment which begin at $0 and increase by a fixed interval until an arbitrarily determined large amount is reached. When the time comes to elicit the willingness to pay amount, the respondent is asked to pick a number off the card (or any number in between) which "is the most you would be willing to pay in taxes and higher price each year" (italics in the questionnaire) for a given level of water quality. Thus, the interviewer suggests no bid at all.

It turns out, however, that this presents some problems of its own. In initial pretests, it was found that the respondents had considerable difficulty in determining their willingness to pay when a card was used which only presented various dollar amounts. A number of them expressed embarrassment, confusion, or resentment at the task, and some who gave amounts indicated they were very uncertain about them. The problem lay with the lack of benchmarks for their estimates. People are not normally aware of the total amounts they pay for public goods even when that amount comes out of their taxes, nor do they know how much they cost. Without a way of psychologically anchoring their estimate in some manner, they were not able to arrive at meaningful estimates. They needed benchmarks of some kind which would convey sufficient information without biasing their responses. The most appropriate benchmarks for willing to pay for water pollution control would appear to be the amounts they are already paying in higher prices and taxes for other nonenvironmental public goods. Amounts were identified on the card for several such goods and further pretests were conducted. These showed the benchmarks made the task meaningful for most people.

But the use of payment cards with benchmarks raises the possibility of introducing its own kind of bias. Are the respondents who gave amounts for water pollution control using the benchmarks for general orientation or are they basing their amounts directly on the benchmarks themselves in some

manner? In the former case, people would be giving unique values for water quality; in the latter case, they would be giving values for water quality relative to what they think they are paying for a particular set of other public goods.   If the latter case holds and their water quality values are sensitive to changes in the benchmark amounts or to changes in the set of public goods identified on the payment card, their validity as estimates of consumer surplus for water quality are suspect. Tests for this kind of bias were conducted in the pretest by using different versions of the payment card. No bias was found, and so the "anchored" payment card was deemed to be a suitable device for the full-scale experiment.

Tests were also conducted to attempt to discover if any of the other sorts of bias discussed in chapter 4 were inherent in the questionnaire. Again, none were found.

A final point on the payment card. What people actually pay *f or* publicly provided goods varies with their income. To correct for this, four different payment cards were developed corresponding to four income classes.   At the appropriate point in the interview, the interviewer gave the respondent the payment card for his or her income category which had been established by a prior question.

As already discussed, the respondents valued three levels of water quality which were described in words and depicted on the water quality ladder. They were first asked how much they were willing to pay to maintain national water quality in the boatable level. Subsequent questions asked them their willingness to pay for overall water quality to fishable quality and swimmable quality. The average willingness to pay amounts given by the respondent for the two higher levels consists of the amounts they offered for the lower levels plus any additional amount they offered for the higher level.

The average annual amounts per household (1981 dollars) for those respondents who answered the willingness to pay questions turned out to be:

$$
\begin{array}{lr}
\text{Boatable} & \$152 \\
\text{Fishable} & 194 \\
\text{Swimmable} & 225 \\
\end{array}
$$

The most substantial benefit is for boatable water. The respondents are willing to give about 20% more for fishable water than boatable water, but only about 15% in addition to make the water swimmable. As we will see later, these are large amounts.

The data also permitted making a rough distinction between   the recreation and the intrinsic values discussed earlier.   Since the willingness to pay questions measure the overall value respondents have for water quality, the amount given by each respondent represents the combination of recreational and intrinsic values held by that person. But it was possible to tell from the questions whether or not a person actually engaged in water-based recreation. It was reasoned that the values

expressed by the respondents who do not engage in in-stream recreation should be almost purely intrinsic in nature.   In calculating the average willingness to pay amount for the nonrecreators alone, therefore, we get an approximation of the intrinsic value of water quality. By subtracting this amount from the total the recreators are willing to pay, one can estimate, in a rough way, the portion of the recreators' benefits which are attributable to intrinsic values.

When this is done, it is found that intrinsic value constitutes about 45% of the total value for recreators, 100% for the nonrecreators (of course), and about 55% for the sample as a whole.   If this is a correct reflection of reality, it is a major finding and may have large implications for the future study of benefits from environmental improvement. This matter will be pursued further in the next chapter, which deals with visibility in the national parks.

It was noted earlier that, while the sample of persons interviewed was initially chosen to be random, quite a few respondents failed to give useable answers. Any aggregate national benefit estimate based on these data could not therefore be put forward as accurate. Therefore, I make such an estimate simply to illustrate that the results of this experiment imply very large values.

There are about 80 million households in the United States. Assume that the sample results imply an annual willingness to pay of $200 per household to have high quality recreation waters throughout the country. This would imply a total willingness to pay of $16 billion. According to results explained earlier, this would divide about equally between user and nonuser values. At first this might seem quite out of line with the value of well under a billion dollars calculated for recreational fishing in the last chapter.   But this is not necessarily the case. Recall that that estimate is for a relatively small increase in the nation's fishable waters and that the estimate from the national survey is the value people attach to making and maintaining the whole of the nation's fresh waters of high recreational quality.

But the objective of this experiment was not to produce an accurate estimate of national benefits, rather it was to test the feasibility of using a macro approach to the estimation of water quality benefits. In that, it succeeded.

CHAPTER 13

THE VALUE OF VISIBILITY IN THE NATIONAL PARKS

     The first case reported in this volume that involves primarily a
preservation issue instead of an amelioration one is visibility in the
national parks. Historically, Americans have placed a high value on
good visibility, that is, the ability to see distant objects clearly.
This yearning for the appreciation of atmospheric visual clarity is
evidenced in the country's early literature and art, including the
journals of Lewis and Clark as well as the masterpieces of the great
American landscape artists of the 19th century. Today that love of
visibility is demonstrated not only by the millions who flock each year
to our Western parks, but also in the high prices brought by those
artists' works of a century ago and by the interest in Ansel Adams'
simple, yet dramatically clear, black and white photographs of Yosemite
and other wonders of the U.S. National Park Service.

     Over the past 100 years, Congress has acted to preserve many of
our nation's natural wonders. It did so by creating and by continually
expanding the National Parks, National Wilderness Areas, National
Monuments, National Recreation Areas, and Wild and Scenic Rivers.

     Since the 1950s, there seems to have been an increasing concern
that this beauty is threatened by industrial development and population
growth. Pollution from coal-fired power plants became a special
concern with the advent in 1963 of the first unit of the Four Corners
Power Plant near Farmington, New Mexico. It produced a plume that could
be seen clearly for many miles, reducing the clarity of the Visual
experience in areas of northwestern New Mexico, southeastern Utah,
southwestern Colorado, and northeastern Arizona.

     By the later 1960s and the early 70s, smog began to appear in
Yosemite Valley on warm summer days. Battles erupted over proposed
coal-fired power plants on the Kaiparowits Plateau and near Capitol Reef
National Park, both in southern Utah, because of their possible effects
on visibility.   The increased publicity and concern resulted in
magazine and newspaper articles decrying the loss of visual clarity,
particularly in the western United States and precipitated political
pressures in Congress for legislative steps to protect visibility.
Those pressures culminated in the August 1977 adoption by Congress of
the nation's first specific visibility protection requirements for
national parks and national wilderness areas.   One of the large
issues raised by these developments is whether the value of visibility
protection outweighs the cost, including both air pollution control
equipment and the regulatory system. The study reported in this

chapter was designed to improve our ability to measure the benefits of
visibility and to provide some actual preliminary estimates of the value
of that visibility in several major national parks and for the region in
which they are located. The region and parks located in it are shown in
the map below. We refer to this as the Grand Canyon Region.
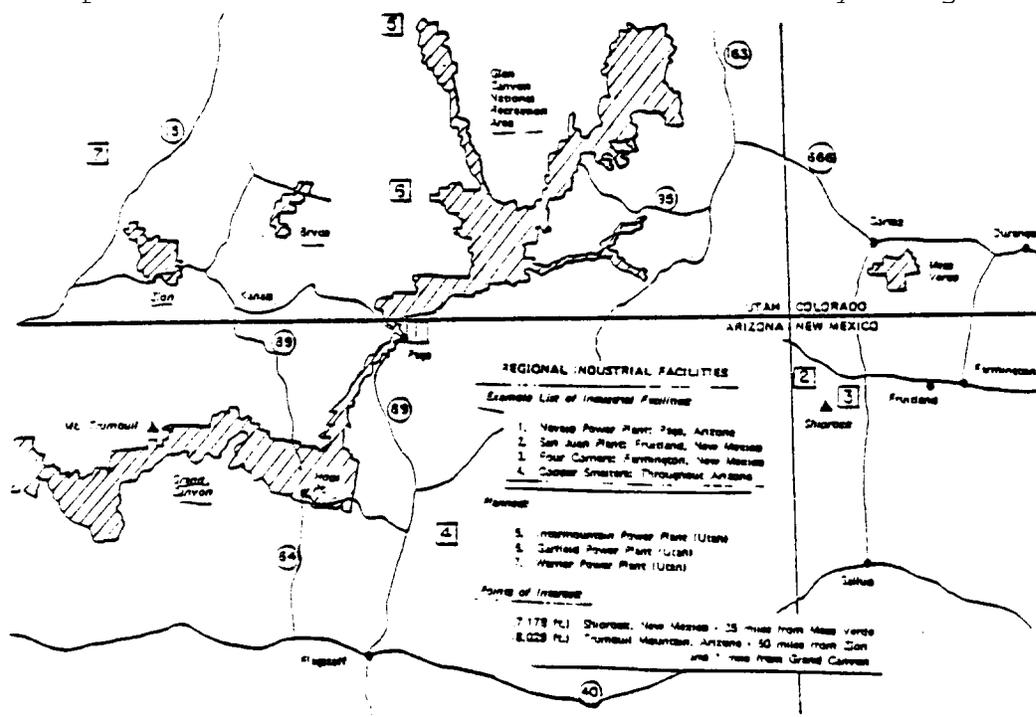
        Visibility is the ability to see both color and detail over long
distances. Human perception of visual air quality is associated with
the apparent color contrast of distant visual targets. As contrast is
reduced, a scene "washes out" both in terms of color and in the ability
to see distant detail.

        What, then, is the nature of the preservation value of visibility?
That value has at least two Possible components.

        First, a scenic resource such as the Grand Canyon attracts large
numbers of recreators. The quality of the experience of these
recreators depends in great part on air quality, in that scenic vistas
are an integral part of the Grand Canyon "experience." Accordingly,
air quality at the Grand Canyon is valuable to recreators. We might
call this economic value, or willingness to pay by users for air quality
at the Grand Canyon, user value. Thus, recreators in the National
Parklands of the Southwest should be willing to pay some amount to
preserve air quality for each day of their own use if their recreation
experience is improved or maintained by good air quality.

        The second component of preservation value we have termed
existence value. This concept was introduced in the abstract, in chapter
4, and

explained in a more specific context in the last chapter.   Individuals and households which may never visit the Grand Canyon may still value Visibility there simply because they wish to preserve a national treasure.   Visitors also may wish to know that the Grand Canyon retains relatively pristine air quality even on days when they are not visiting the park.   Concern over preserving the Grand Canyon may be just as intense in New York or Chicago as it is in nearby states and communities.   Thus, preservation value has two additive components, user value and existence value.

During the summer of 1980, over six hundred people in Denver, Los Angeles, Albuquerque, and Chicago were shown five sets of photographs depicting both clear conditions and regional haze, each set consisting of five photographs of a national park vista with different visual air quality of a general nature; that is, generally increased haziness.   The vistas are from Grand Canyon, Mesa Verde, and Zion.   Summer was chosen for the survey because it is the season of peak visitation.

These photographs were placed on display boards as full frame 8 x 10 inch textured prints, arranged from left to right in ascending order of visual air quality, with each vista a separate row.   An example for the Grand Canyon is shown below.

WORST				BEST

DESERT VIEW 9 AM

WORST				BEST

TRUMBULL MT. 9 AM

WORST				BEST
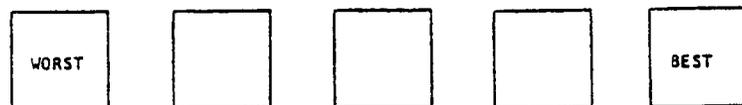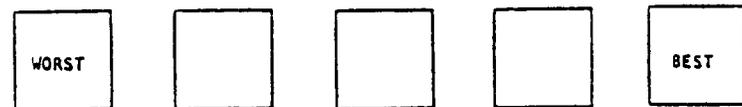
TRUMBULL MT. 3 PM

The participants were asked how much they would be willing to pay for visibility as shown in the five sets of photographs, from worst to best.   They were also asked about their willingness to pay to prevent a plume from being seen in a pristine area.   Two photographs were used in this connection, one with and the other without a plume.   The photographs were taken from Grand Canyon National Park at the Hopi fire tower observation point and toward Mt. Trumbull. They were both taken at 9 a.m. , so the

lighting on the Canyon wall and other features is the same.   Both photographs have the same light, high cirrus cloud layer in the sky. The plume is a narrow gray band crossing the entire vista in the sky, except where it is in front of the top of Mt. Trumbull. The source was not industrial or municipal pollution, but a controlled burn in the area around the Grand Canyon. However, the effect was comparable to what a large industrial source might produce.

The bidding game based on these photographs reveals the household's willingness to pay for preserving or improving the degree of visibility in specific locations of the National Park area described earlier. The bids offered by interviewees in the preservation value section of the survey encompasses both pure existence value and user's valuation of preserving visibility.   Since the results did not permit a completely clean distinction between the two types of bids, further discussion will concentrate on the preservation value section of the survey.

The benefits derived from the interview results can be extrapolated to populations larger than that in the sample (the sample was chosen in as random a manner as practical) by applying statistical techniques to the results of the survey. The amount of bids offered by interviewees to preserve or improve visibility is related to such factors as income, education, and other personal characteristics. These relationships can be quantified using the regression type of analysis that has been explained earlier. After this is done, it is possible to estimate the value of benefits to residents of the whole Southwest region as well as the entire nation. This is done by substituting the average values for these characteristics for each state into the relationship established by the regression analysis technique described previously and calculating what the average value of the bid of a person in that state would be. This value can then be multiplied by the population of the state as a whole to get a total bid.

When the analysis is performed for the southwestern United States (for residents of California, Colorado, Arizona, Utah, Nevada, and New Mexico), the following values are obtained. The figures are willingness to pay for preserving present average conditions (middle picture) to the next worse condition as depicted by the pictures and to prevent plume blight. As the table indicates, the aggregate benefits for the Southwestern region from preserving visibility in the Grand Canyon National Park, the Grand Canyon region, and for avoiding a visible plume over the Grand Canyon is:

Benefits for	Total ($ million)
Grand Canyon	470.0
The Grand Canyon Region	889.0
The Plume	373.0

about $470, $889, and $373 million, respectively.   To estimate the aggregate national benefits from preserving visibility, a similar analysis is done for the entire U.S., but additional survey data from Chicago are included, and the following values are obtained.

Benefits for	Total ($ million)
Grand Canyon	3,370.0
The Grand Canyon Region	5,760.0
The Plume	2,040.0

These figures even though their accuracy is highly uncertain, imply that very large existence values characterize the areas in question. However, some very recent and highly preliminary experiments with surveys imply that these figures may be much too high. This matter is taken up again in the concluding chapter.

Several other observations on the outcomes of the analysis of the actual interview results are worth mentioning.   First, in the conventional view of the demand for environmental quality, there is a smooth tradeoff between higher successive levels of environmental quality and economic benefits, with successive units commanding less incremental willingness to pay. This is embodied in the depiction of demand curves in chapter 2, viz.
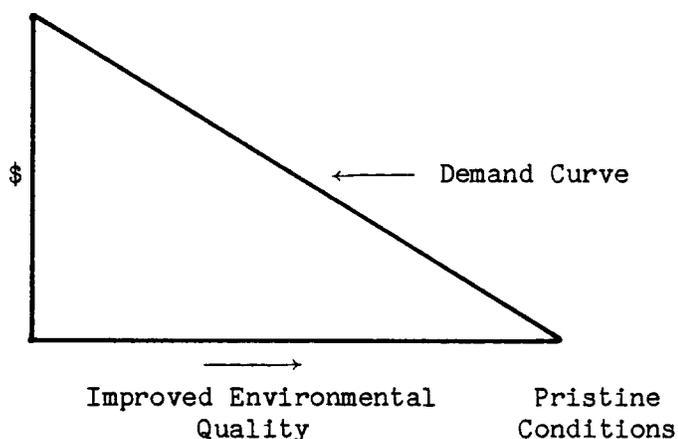
The survey respondents, however, placed a much higher value on a small initial diminution in visual clarity than on comparable subsequent decreases. This would produce a very unusual demand curve, resembling what mathematicians call a step function, something like the following figure.

Second, again somewhat contrary to expectations, neither past nor prospective visits to the Grand Canyon Region were shown to be important

Improved Environmental
Quality
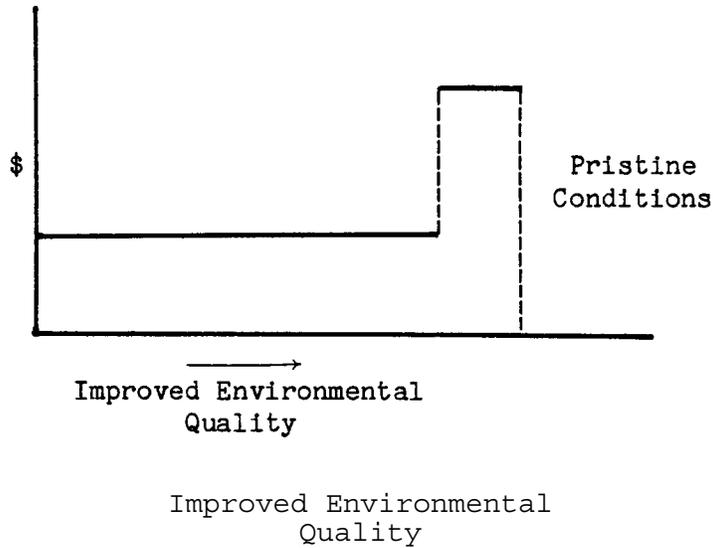
determinants of preservation value. On the average, those who had never seen the Canyon valued it as highly as those who had.

Third, once more unexpected, distance from the region had no significant relationship to the size of household bids. When corrected for income and other differences, people in Chicago bid fully as high as those closer by. However, preliminary further investigation suggests that this result may not be very robust, being sensitive, for example, to the sequence in which people are asked about their valuation of various public goods. Further investigation is clearly indicated, and the matter is discussed further in the concluding chapter.

Because the Grand Canyon is the dominant feature in a region with many visitor attractions, one must be especially cautious in extending these preliminary findings to other recreational attractions.   It seems likely that there are only a very few natural phenomena in the United States about which Americans have such strong feelings. Obvious candidates for this short list, would be Old Faithful (in Yellowstone National Park), Niagara Falls, and perhaps a few others.

The main conclusion of this study is that the magnitude of the annual benefits when aggregated across households is impressive. While these are necessarily rather crude extrapolations, the survey results suggest that Americans place great value on the preservation of air quality in the Grand Canyon region, and that this valuation is not necessarily localized in the Southwest. Further, the survey results suggest that pure existence value may overwhelm a substantial user value for the national parks in the region.

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CHAPTER 14

BENEFITS FROM CONTROLLING ACID RAIN

As indicated in chapter 3, acid rain and other mechanisms for the dispersion and deposition of acid formed from sulfur and nitrogen emitted from various sources are complex and ill-understood phenomena. In addition, methods for estimating the economic losses resulting from damages or economic benefits of prevention of acid rain are not well developed, nor was it possible within the scope of the project described here to make much progress in developing them.

Consequently, since the estimates of benefits made for controlling acid rain are very crude and of no particular interest in terms of methods development, our discussion here will be very brief. It is included primarily because of current intense interest in the phenomenon, and the analysis that was done provides some guidance concerning directions for future research. The acid deposition problem among all the areas covered in this volume is perhaps the one most crying out for additional methods development and improved estimates.

Let us turn first to possible effects on the activities of agriculture and forestry.

Increases in soil acidity can have a negative effect on the yields of certain field crops. But it appears that this could be offset by modest increases in liming operations which already occur for acid-sensitive crops and that the benefits of controlling acid rain for this purpose would therefore be small. It is known that there can also be direct damage to the plant from acid deposition on leaves, flowers, and fruits, but there is virtually no basis for estimating the amount of such an effect.

As far as forest growth is concerned, as in the case of agriculture, there can be both indirect, through the soil, and direct effects. Indeed, again as in the case of certain field crops, there may even be short run favorable effects as the acid dissolves plant nutrients and makes them more available to the trees. But the longer term effect of this would be reduced soil fertility and slower tree growth. If some strong assumptions are made, an estimate can be made of damages resulting from retarded growth. If one assumes, and there is some evidence pointing in this direction from Swedish studies, that acid rain would reduce timber growth in Minnesota and east of the Mississippi (the area of the country thought to be most affected by acid) by five percent annually, the reductions in yield would decrease the worth of timber production about six hundred million dollars per year. Assuming other services of forests, such as

watershed protection, fishing, and hunting, were to also be reduced by five percent, and based on crude estimates by others of the possible overall value of these services, the total damage including timber and other services might come to about one and three quarters billion dollars. This is a substantial sum, but not very large relative to the costs of controlling acid deposition.

There might also be effects on human health, say by the acid dissolving and mobilizing heavy metals so that larger concentrations would get into drinking water or the human food chain. The present state of knowledge does not permit even very crude estimates to be made of this possibility. Higher acidity in municipal and industrial water systems might also result in increased erosion in piping, appliances, cooling systems, etc. But the adjustment of acidity in such systems, by the use of lime, is a routine operations and can be accomplished at small cost.

The big danger in water courses appears to be to those features of the aquatic ecosystem itself which mankind values. Acid conditions in a water course tend to destroy the small plants and animals (plankton), that are the initial links in the fish food chain, and this has a negative effect on fish population. But the primary way in which fish populations are destroyed is different. As noted earlier, acid in water bodies tends to mobilize heavy metals and increase their concentration in the water. The reproductive capacity of many species of animals, including fish, is adversely affected by the presence of excessive amounts of heavy metals. Thus, for a time, as fish numbers decline, the ones that remain increase in size as competition for food declines, but then rather abruptly there are
none left. This, of course, destroys commercial and recreational fisheries. The value of fish taken by commercial fresh water fishing in the United States is not very large, so the loss there, at least as measured by present market prices, would not be very great.

The value of fresh water recreational fisheries is, on the other hand, relatively enormous. Let us make the extreme assumption that all the recreational fisheries in Minnesota and other areas east of the Mississippi would totally disappear. If we then take estimates of willingness to pay for fishing from other studies, it appears that the loss could, at an Outside limit, be on the order of ten billion dollars per year in 1979 prices. Additional losses would be caused by the decline of terrestrial and aquatic animals (other than fish) who are partly or wholly dependent on the aquatic food chain--certain species of water fowl, for example.

The other area where our study suggests really major damages might occur is deleterious effects on materials. As indicated in chapter 3, acid corrodes metals, eats away at limestone, is harmful to paints and other coatings and finishes, and damages cloth. Given the huge number of such items which exist and are exposed to the atmosphere, it is not very surprising that benefits from protecting them might be large. Again, in Sweden, where the problems of acid rain first received widespread attention (because of prevailing winds, Sweden gets inputs of sulfur and nitrogen compounds from the Ruhr, the Rotterdam petrochemical complex, and Great Britain), a study has been made of per capita damages of corrosion and

soiling.   If one makes the assumption, once again very gross, that this same estimate can be applied to all persons dwelling in Minnesota and east of the Mississippi, one gets an annual benefit of avoiding acid rain of about fourteen billion dollars.

Putting together the various dollar estimates (agriculture, 1-3/4 billion; aquatic ecosystems, 10; and materials damage, 14), one gets benefits of preventing acid rain in 1978 dollars of about twenty-six billion dollars--a hefty number indeed. But as stated, many extreme assumptions were made in generating these numbers, and they are no doubt too high by quite a lot. An educated guess by the research team was that the actual figure is probably not more than five billion dollars for a condition that is characterized by severe effects in the entire eastern United States.

Of course, even this number cannot be taken very seriously, because even if it were correct, in all other respects it neglects the large adjustments in demand and supply which would accompany the types of changes contemplated. An approach much more like that described for agriculture study in the South Coast Basin in chapter 8 would be appropriate in a more sophisticated study.

Perhaps the greatest utility from the acid rain benefits study to this point is to give some perspective on where the greatest potential benefits of protection from acid rain are likely to lie. These are, in rough order, materials damage, aquatic ecosystems effects, and agriculture and forestry. These categories of damages certainly merit further study.

But progress in economic research on these questions is highly dependent on improved dose-response relationships. As indicated in chapter 4, the relation between intrusions of acid into a water course and the path to ultimate effects appears to be extraordinarily complex, including possible sudden changes after a period of time when everything appears all right on the surface, and the difficulty, if not impossibility, of reversing them after they have occurred.   Ecologists place great value on diversity of species as   an indicator of a healthy, stable ecological system. Acidification of streams is known to reduce diversity.   But it is not well understood how this ultimately affects characteristics of the stream that man values.   This problem seems ripe for joint work between economists and ecologists.

All three of the case studies in this part of the volume, taken together, support a broad generalization. The damage potential of air pollution, in economic terms, to commercial activities that use biological systems (agriculture, forestry, and fisheries) does not appear to be strikingly large.   On the other hand, damages to biologically-based recreational activities and to materials are potentially very large but, at present, are also very ill understood.

CHAPTER 15

BENEFITS FROM AVOIDING GROUNDWATER CONTAMINATION

     While the extent of groundwater contamination is not accurately
known, the problem is thought to be widespread and is the focus of much
public apprehension.   Contaminants in groundwater range across an
enormous list Of chemical substances, and usually no thorough checks for
contamination are made until there is reason to suspect a problem.

     Even at extremely low concentrations, many toxic chemicals pose
serious, irreversible, health risks. In many of the cases checked, well
water has been found to contain concentrations above, and often several
orders of magnitude higher than, those commonly encountered in raw or
treated drinking water drawn from contaminated surface sources.

     Thus, while water from most wells is no doubt safe, the widespread
nature of the contamination and its potential seriousness merit the
public attention the problem **is** getting.   The intent of the case study
in this chapter is to develop methods for estimating benefits from
preventing contamination of groundwater-based drinking water supplies.
This, so far as I know, is the first study to attempt to quantify such
benefits.   As in the studies discussed in other chapters, the
quantitative results reported here must be regarded as largely
experimental, but the numbers turn out to be impressively large.

     For any chemical source, the extent of groundwater contamination
is determined by the characteristics of the underground storage medium--
called an aquifer. Groundwater in shallow, alluvial aquifers typically
moves less than a foot per day. That flow is governed by recharge and
discharge rates from the aquifer, and by the aquifer's permeability.
Contaminants are transported by diffusion together with the slow
underground flow of groundwater. In that oxygen-poor environment,
chemical or physical processes of contaminant degradation proceed very
slowly.   Thus the contaminant plume may move great distances, with
hardly a change in toxicity levels, and may therefore reach drinking
water wells.

     Among the principal sources of groundwater contamination are waste
disposal landfills and impoundments, accidental spills of chemical
substances,   and   abandoned   oil   and   gas   wells.   Most   groundwater
contamination can be traced to chemicals leaching into the aquifer from
poorly constructed and managed industrial or municipal landfills,
surface impoundments, or outright illegal dumps.   Contamination from
such sources has often been in process for years, and sometimes for
decades. To date, most groundwater contamination incidents have been
discovered only after a

drinking water source has been affected. By the time suspected aquifer contamination is verified in samples drawn from drinking water wells, the problem may be irreversible. Stricter regulation of the disposal of potential contaminants in other environmental media, particularly air and surface waters, and the consequent rising cost of such disposal, is likely to increase the flow of wastes to land disposal and aggravate the threat to groundwater.

Benefit analysis of controlling groundwater contamination requires, as usual, quantification of several linkages between sources and receptors. One must know the location and strength of actual or potential sources of contamination. One must be able to model the spread of the contaminant plume in the aquifer. One must know the numbers of persons exposed to contaminated groundwater and the extent and timing of their exposures. One must know the "dose-response relationship," the nature and extent of health effects on the population at risk. And finally, one needs a way of converting health effects into monetary, or dollar values.

This is a very tall order, and we are far from being able to quantify these linkages with precision. In each case, there is a need for substantially improved methods and data. With these cautions in mind, let us proceed to the case study. It involves the situation associated with Price's landfill near Atlantic City, New Jersey.

Actually, while it is referred to as a landfill, this is rather euphemistic--dump would be a better word, but I shall stick with the conventional usage. Price's landfill occupies approximately twenty-two acres extending across the boundary of Egg Harbor Township and the town of Pleasantville, New Jersey. Until 1967, it functioned as a sand and gravel quarry. During 1968, when the pit was excavated to within approximately two feet of the water table, people from the surrounding area began to dump trash into it with the permission of the owner, Charles Price.   In 1969, Price began commercial operations which continued until the landfill was closed in 1976.

In 1970, Price applied to the New Jersey Department of Environmental Protection for a license to conduct a sanitary landfill operation. The application listed the materials that Price intended to accept at the landfill, and specifically excluded "Chemicals (Liquid or Solid)." He was issued a certificate authorizing operation of a solid waste disposal facility.

In July 1972, authorities inspected the landfill, citing Price for accepting chemical wastes and formally advising him of the violation. Nonetheless, Price continued accepting significant quantities of chemical wastes until November 1972. After that date, no chemical wastes were disposed of at the landfill, although it continued in operation. In 1976, Price terminated the landfill operation and covered the site with fill material. The site has not been used since then.

But during the period May 1971 to November 1972, Price accepted approximately 9 million gallons of the toxic and flammable chemical and

liquid wastes, either in drums or directly into the ground. These included (to name just a few) acids (glycolic, nitric, and sulfuric), caustics and spent caustic wastes, cesspool waste, chemical resins and other waste chemicals, chloroform, and cleaning solvents.

Price's Landfill is situated over the Cohansey aquifer, the principal source of Atlantic City's water supply, and the separation between landfill and aquifer is a relatively permeable layer.   Waste from the landfill is free to leach into the aquifer; the direction of flow in the aquifer is eastward, which is toward Atlantic City's wells. Chemicals in the leachate can therefore be carried into the private and public water supply wells, and people can be exposed to those chemicals in drinking water. Test wells drilled near the landfill by EPA show that groundwater in the aquifer is contaminated and that the plume of contamination is indeed moving toward Atlantic City's wells.

But estimation of actual or potential human exposures requires either considerable information on, or heroic assumptions about, the mechanism by which toxins are transported from the source of contamination to the water supply wells. This is the second linkage mentioned earlier. It will be clear shortly why discussion of this linkage logically precedes the first quantification of the source of the contamination.

Efforts to understand and model the source to receptor links, called groundwater solute transport, are relatively recent. While there has been considerable earlier work on salinity transport, study of the more difficult cases of chemically reactive toxic groundwater contaminants is less advanced.   Improvements in our ability to model these phenomena must be a prime objective for future research.

For purposes of analyzing the Price's Landfill situation, the researchers chose and estimated numerically a technique called the Wilson-Miller solute transport model. This relatively simple model was chosen because of limitations of time and funding for the research. The model chosen does appear to fit the Price's Landfill situation relatively well and was judged adequate for conducting this experiment. Future research should check to see if more complex models yield substantially different results.

But to apply any solute transport model, it is necessary to have so-called source-term information: the amounts of materials entering groundwater and their distribution over time. This is the first linkage mentioned earlier.   Much of the activity at Price's landfill was illegal. It therefore seems unlikely, to say the least, that careful records of what went into the pit were kept. Indeed there is no information at all about the amounts of the large number of chemical substances dumped there. Where such records exist, or if leaching rates are known or can be calculated, deliveries of pollutants to the aquifer can be estimated directly. In the Price landfill type of situation, typical of many existing groundwater contamination situations, there is only one way to estimate the quantity of the source. Since we have information on what is already present in test wells drilled by EPA, the solute transport model can be run "backwards," so

to speak, and used to infer what the amount of the source had to be to produce the existing groundwater concentrations. This is why, logically, discussion of the transport model precedes discussion of the source term.

The reader should be cautioned that this estimate, while necessary, is based on many assumptions and involves great uncertainty. Just to give one example, the procedure assumes that releases occur at a constant rate. This may not be true for some pollutants, and "slugs" may be released which cause transients of pollution in much higher concentrations than would be predicted by the model.

But given the computed source term, the model can be run "forward," so to speak, to compute concentrations, at any well drawing on the aquifer-the production wells of Atlantic City, for example--and for any time after some contaminant enters the aquifer. Those concentrations and the times at which they are projected to occur were computed for the wells from which the Atlantic City Municipal Water Authority pumps its water. Assuming that no mitigating action is taken, this provides the link that specifies the exposure of the population to contamination from Price's landfill.

To take the next step, one must have dose-response information-- that is, the actual health risk stemming from the contamination. To make this link, information published by EPA was used. There is a section of the Clean Water Act that requires EPA to estimate excess cancer risks for 129 chemicals called "Priority Pollutants." Many of these "Priority Pollutants" are ones leaching from Price's landfill into the Cohansey aquifer. Using this information, the probability of excess mortality from cancer was estimated for the population of Atlantic City. While this procedure is the best available based on existing information, the reader should be aware that, for this purpose, the risk factors provided by EPA are both incomplete and very uncertain. For example, there are many pollutants that have been identified in groundwater that are not on the EPA list, and extrapolations from animal toxicity tests to human risks are quite uncertain. In addition, it is assumed that each chemical risk is independent of each other chemical risk so that risks can simply be added up across chemical categories. It is well known that "synergism" can occur which make the combined toxicity of two chemicals greater than the sum of the effects of each one taken independently.

Again, with all these cautions in mind, I turn to the next, and final step, monetary evaluation of damages. The value of risk the researchers chose to use is a range that reflects the underlying uncertainty and reasonably well spans the range of values discussed in chapter 4. The range chosen was from one hundred thousand dollars to one million dollars per death. These values were then multiplied by the mortality numbers calculated in the risk analysis to get a total benefit from averting the damage which would otherwise emanate from Price's landfill. The range turns out to be from 180 million dollars to 1.8 billion dollars.

Those are large figures, and one must be clear about what they mean. Say that, at some site like the Price's landfill site, there is a comparable release of contaminants into a similar aquifer, and that the release goes unnoticed for two decades. Then there will be human exposures through drinking water, and incremental mortality risks f aced by the exposed population over their remaining lifetimes. Valuing this

incremental mortality risk produced the above numbers. At a site at which groundwater contamination has already occurred, those figures represent the damages that might be avoided by measures taken to prevent future exposures, either by restricting access to, or by cleansing, the aquifer. Needless to say, those figures are impressively large. But the limited information there is indicates that the costs of cleansing aquifers are always large and the cost of obtaining an alternate water supply may be large. This analysis, shaky as the numbers necessarily are, suggests that in the case of groundwater contamination affecting drinking water supplies, prevention is the best cure.

CHAPTER 16

CONCLUDING NOTES

It seems fair to claim that the research reported in this volume marks a substantial step forward in our ability to address the issue of benefits from environmental quality improvement or maintenance. Methods have been developed or improved, new data have been collected, some case studies have been provided, and some highly preliminary estimates of national benefits from environmental improvement or maintenance have been presented. Furthermore, some broad insights have resulted from the work. While so far I have done my best to fairly state, in nontechnical terms, the findings of my colleagues in this enterprise as they interpreted them, the following generalizations and interpretations about findings are strictly my own.

Firstly, while our national air quality standards are based upon alleged health effects, in fact, it appears from the work reported here that we know very little for sure about the health consequences of air pollution. The team's work on both aggregate and microepidemiology is consistent with air pollution as a source of acute effects on an important scale. However, human evidence of chronic effects is tenuous at best. This is certainly not to say there are none, but conclusive demonstration of such effects, or lack thereof, still awaits improved data and methods.

Secondly, while our air quality standards are, as said, mostly founded on presumed health impacts, it appears, based on the limited evidence our studies were able to develop, that other economic damages from pollution may be fully as great or even much greater. Damage to materials appears to be a very large cost of poor air quality but, so far, it has defied accurate quantification. In the preservation of values area, it appears that protecting visibility, especially in the West, yields large benefits. In the East, preventing deterioration of water course recreational values through acid deposition appears to involve large benefits. But, again, we are, alas, some distance from a complete and accurate quantification of these values.

Thirdly, the interviewing done in connection with the "Visibility in the National Parks" study suggests that there may also be a large category of benefits which we have termed "intrinsic." That is, people may be willing to pay for clean areas, in some cases on a really substantial scale, even if they do not benefit directly from their use. This may result from a feeling of national pride in having a clean environment, especially in areas of outstanding natural beauty or unusual cultural importance. Establishing these values in an accurate and complete manner is still a frontier area in benefits research.

Fourthly, in the area of water quality a large scale simulation study suggests that the <u>additional</u> benefits to recreational fresh water fishing from marginal improvements in water quality resulting from implementation of national policy are not impressively large. This is because so much of the nation's fresh water is already fishable. However, an experimental national survey suggests that the willingness of the public to pay to improve and maintain the quality of the nation's water is large--on the order of many billions of dollars per year. This research also suggests that a large portion, perhaps half, of these benefits are of the non-user, intrinsic variety. This further suggests that, in addition to the value of this type people may attach to some particularly treasured sites, they may also find a large intrinsic value in achieving certain nationally declared goals such like "swimmable" waters virtually everywhere in the country. A full-scale national water quality survey now underway and designed by members of the research team should shed much additional light on the matter of both user and intrinsic benefits

Fifthly, methods have been developed to study the agricultural benefits of controlling air pollution. These, in contrast to earlier studies, take account of various economic adaptations and adjustments, for example crop or variety switching and the elasticity of demand for agricultural products. Early findings suggest that while damages in a highly polluted specialty crop area such as Southern California may be significant, the main source of benefits from reduced pollution could come from major field crops like soybeans and wheat. This is because the total value of production of these crops is so huge that even a relatively small increase in yields is associated with large benefits.

Sixthly, the groundwater "episodes" study implies that the benefits from protecting large concentrations of population, such as the Atlantic City area, from the toxic pollution of groundwater used for drinking are potentially very large. In most cases they should easily outweigh the costs of preventative measures.

Finally, I would like to close with some observations of a general methodological character. The methods pursued in the studies discussed here can be divided into two broad classes--those based, however indirectly, on observed human behavior and those based on asking questions about hypothesized situations. The former are based on actual actions like travel to recreation sites and house prices paid. The attraction of the behavior-based methods is that they reflect responses to real, not hypothetical, situations and therefore are based on real, not hypothetical decisions. But these behavior-based methods have equally real limitations. For one thing, they are not applicable to all situations of interest in environmental benefits evaluation, for example, protecting a beautiful large vista from Visual impairment. Further, they are limited to user benefits, and some of the research surveyed here has suggested that intrinsic benefits may be very important in certain cases.

For these reasons resort is made to methods based on asking questions contingent on certain hypothetical situations. These are the contingent valuation methods of bidding games and other surveys. Inevitably, doubts

arise about the accuracy of such methods given the hypothetical nature of the situations they examine.

On the one hand the research reported here tends to support the view that careful questionnaire design can control previously identified sources of bias (starting point, strategic, etc.), and the South Coast and San Francisco experiments tend to support the view that bidding games can provide reasonable indicators of benefits from hypothetical improvements in air quality, at least in certain instances. One reason may be that persons residing in the regions studied, especially the Los Angeles area, have a very clear understanding of the situation they find themselves in and have mentally processed much information about it and have taken decisions based upon it.

Very recent and highly preliminary experiments with bidding games have suggested that where this close familiarity with the situation being studied is not the case, a source of bias may exist that could have substantial implications for some bidding game results. The visibility in the parks study is perhaps the prime candidate among those discussed in this volume. Recall that one interesting result of the study was that the reported willingness to pay of respondents did not appear to diminish with distance, e.g., those surveyed in Chicago had fully as high a willingness to pay to protect visibility at the Grand Canyon in the initial survey as those who were questioned in Denver. In one set of later experiments, based on such a small sample that the results should not be regarded as anything but suggestive of hypotheses for future research, further bidding games were conducted in those two cities. In both cities, instead of being asked questions only about willingness to pay for visibility in the national parks, respondents were first asked about their willingness to pay for other, closer to home, environmental public goods. When this was done in Chicago, willingness to pay for visibility in the national parks dropped sharply below the result found in the previous survey. In Denver this was not the case, perhaps because the questions about visibility were less hypothetical to those in Denver and therefore their answer better thought out than was true of respondents in Chicago. In another set of experiments, again because of limited resources conducted with a highly inadequate sample, persons were asked first about their willingness to pay for a national improvement in water quality. Another sample was then asked about the same improvement in water quality plus an improvement in air quality. The resulting willingness to pay for both was about the same as the willingness to pay for water quality improvement alone in the case of the first group.

These kinds of highly experimental results have lead members of the research team to speculate that people may have "mental accounts," one of which may be for environmental improvement. If this is the case, when they are asked about a hypothetical, but rather dramatic, environmental improvement they may allocate everything in their environmental account to it, neglecting alternative environmental improvements which, if confronted with them, they would also regard as valuable. An important further development in contingent valuation techniques will be to devise methods to

structure them so as to avoid the one issue at a time procedure that has characterized most applications so far.

In conclusion, while I believe that the research reported here represents a significant improvement in our understanding of environmental quality economic values, much remains to be learned. Total accuracy about a matter of this difficulty is an impossible dream, but I believe that the work done so far demonstrates that steady progress is feasible.

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