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AN APPROACH TO VALUING VISUAL POLLUTION
FROM WESTERN ELECTRICITY PRODUCTION

by

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ABSTRACT

This paper outlines an approach to valuing visual pollution from electric power plants. The differences between public-good pollution externalities, such as these aesthetic damages, and other market failures are discussed. Approaches generally used to value externalities are briefly described.

The approach used relies heavily on an earlier application of bidding games to estimate people's willingness to pay for abatement of emissions from the Four Corners power plant in northwestern New Mexico. The results of these surveys were used here to estimate the value of visual pollution from electric power plants for residents of and visitors to the Four Corners Air Quality Control Region, as a function of power plant emissions in that region.

The approach presented here for the Four Corners region is structured so that replication for other air quality control regions is relatively easy. Preliminary results of this procedure for all of the air quality control regions in the Western Systems Coordinating Council area are presented. Visual pollution damages from electric power plants to residents of and recreational visitors to these western regions are estimated to total more than \$100 million annually by 1985. These damages are expected to occur unless additional pollution controls are implemented, even if these subject populations do not increase.

Readers are cautioned that the estimates given are probably accurate only to an order of magnitude. Reasons for the probable inaccuracies in the calculations are discussed; many of these problems concern variations across areas and over time of background particulate levels, prices of substitutes and complements for visual aesthetic opportunities, and socio-economic characteristics, numbers and preferences of the residents and visitors. Methods of correcting some of these difficulties through future research are suggested.

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AN APPROACH TO VALUING VISUAL POLLUTION FROM WESTERN ELECTRICITY PRODUCTION

INTRODUCTION

This report presents part of the results of a Battelle-Northwest (BNW) joint effort with the Los Alamos Scientific Laboratory (LASL) to develop a methodology for assessing the costs, risks and benefits associated with electricity production in the western United States. More specifically, the region examined was the Western Systems Coordinating Council (WSCC) area shown in Figure 1. During the first year of the project the emphasis was on providing a preliminary overview calculation to help identify areas for more intensive work to be done later.

The initial calculations presented here deal with the valuation of the aesthetic effects of power plants. These estimates consider only the visual pollution effects of power plants, primarily the visibility impacts of airborne particulate emissions. This focus was selected largely because of the lack of (1) existing survey data on and (2) funding for original work to estimate people's willingness to pay for removing or to be compensated for tolerating, other types of aesthetic pollution impacts of power plants. There was also an overall project focus on airborne rather than water or land related impacts during the first year of the project.

This introductory section of the paper briefly notes the differences between public-good pollution externalities (which include aesthetic damages of power plants), and other types of externalities. The problems with valuing externalities as opposed to private market products are outlined. The approaches which have been used in valuing externalities are briefly described.

The second section discusses the valuation method used. The Randall, Ives and Eastman study ⁽¹⁾ which conducted surveys to determine how much people were willing to pay for abatement of emissions from the Four Corners power plant is reviewed. The approach taken here to generalizing their results is described. People's preferences for clean air are

expressed here in terms of the value of visual pollution to them vs. power plant emissions, rather than their willingness to pay for abatement of visual pollution vs. abatement of emissions. This change from the Randall, Ives and Eastman approach allows inference of the extent of visual pollution which might be associated with power plant emissions larger than those observed in this earlier study. How these results could be used to help determine socially optimal emissions standards or effluent charges for power plants is then indicated.

The third section presents the estimates of the value of visual pollution from electric power plants in the West. An illustrative example for the Four Corners Air Quality Control Region is given and preliminary results of a generalized procedure for valuing visual pollution associated with power plants throughout the WSCC area are presented.

The final section indicates the many assumptions and approximations involved in these estimates. This section also presents recommendations for research to improve the results presented in this paper.

Figure 1. Regional Electric Reliability Councils of the United States with the Western System Coordinating Council Area Shaded

DEFINING EXTERNALITIES

In the absence of "market failures," such as "externalities", the market price at which a good is exchanged represents the value to society of the last unit of this product which is bought and sold. However, externalities, such as visual pollution from electric power plants, by their nature cannot be valued in this way; there are no private markets in which they are traded. When externalities exist, the private market demand and/or supply curves do not correspond to the marginal social benefit and/or marginal social cost curves, respectively. In such cases unregulated, perfectly competitive private markets do not produce items in the "socially optimal" quantities.

Socially optimal quantities of a good are produced when the marginal social benefits to society from the consumption of the last unit of the good are equal to the marginal social costs to society from the production of this last unit. When all benefits to society associated with the consumption of a good accrue to the individuals buying the good, then the highest price they are willing to pay for each unit they consume is equal to the marginal social benefits to society from consumption of that unit; therefore, the private market demand curve is the same as the marginal social benefit curve. When all the costs to society associated with the production of a good accrue to the individuals selling the good, then the lowest price for which they are willing to sell each unit of the good is equal to the marginal social cost of that unit; therefore, the private market supply curve is the same as the marginal social cost curve. Thus, if there are no market failures, socially optimal quantities of all goods are produced and consumed when the sales price of the last unit of each good is equal to its private market production cost. Economists have shown that normal operation of perfectly competitive private markets, where all producers and consumers act in their own best interests, will cause these conditions to occur when these markets are in equilibrium.

There are several types of market failures and many economists have attempted to categorize them. The taxonomy of market failures presented in Table 1 and described below is somewhat different from earlier schemes proposed in the literature.⁽²⁻²⁵⁾ Although it draws heavily on these earlier efforts, there is not space here to summarize all of the intellectual debts. A separate paper on this subject is planned.

"Imperfectly competitive markets" are one major type of market failure. When markets are not perfectly competitive, producers are able to restrict production and raise prices compared to the perfectly competitive equilibrium output and price. In the absence of government sanctioned cartels or monopolies, imperfectly competitive markets are caused by economies of scale in the production process or indivisibilities of some factor inputs. Economies of scale exist when "minimum optimal scale" is large compared to industry sales. "Minimum optimal scale" is the smallest output of a single plant or firm at which the lowest possible average costs of production occur given current prices and technology.⁽²⁶⁾ The electric power industry is a commonly cited example of significant economies of scale which have caused government regulation of these "natural monopolies."

"Externalities" are the other major type of market failure. When externalities exist, all the benefits of consumption and/or all the costs of production are not reflected in the private market demand and supply curves, respectively, and the normal operation of unregulated perfectly competitive private markets will cause over- or underproduction and consumption of some goods. All types of externalities may be either positive or negative. If a positive externality exists, too little of the associated good will be produced and consumed; if a negative externality exists, too much of the associated good will be produced and consumed compared to the socially optimal quantity.

Table 1. Types of "Market Failures"

- I. "Imperfectly Competitive Markets":
 - Economies of scale or indivisibilities in production
- II. "Externalities"
 - A. "Common Property": Publicly available factor inputs to production
 - 1. Naturally existing
 - 2. Deliberately produced
 - 3. By-products of other production or consumption
 - a. "Congestion": externalities affecting others producing the same thing
 - b. "Pollution": externalities affecting others doing other things
 - B. "Public Goods": Publicly consumed goods
 - 1. Naturally existing
 - 2. Deliberately produced
 - 3. By-products of other consumption or production
 - a. "Congestion": externalities affecting others consuming the same thing
 - b. "Pollution": externalities affecting others doing other things

"Common property," as the term has been generally used in the literature, refers to publicly available factor inputs to production. More specifically common property has meant those naturally occurring inputs which have a positive influence on production. The literature on common property problems emphasizes the excessive effort, compared to the socially optimal level, which is devoted to obtaining these inputs before someone else does. There have been several attempts to measure the extent of this effort in excess of the socially optimal level.⁽²⁷⁾ Examples of this type of common property include most commercial fisheries, common oil pools, and ground water resources.

Common property could also include publicly available factor inputs which are deliberately produced for their own sake or are by-products of other production or consumption activities. Examples of deliberately produced common property are hatchery raised fish and "social overhead capital" such as the legal system as it affects businesses. By-products of other production which are common property include the pollinization of orchards by bees kept by someone else for their honey, and the heat island effects in cities caused by many office buildings being heated or cooled.

While all these externalities may be either positive or negative, the terms generally used to describe these by-products are "congestion" and "pollution." ^(13,20) "Congestion" refers to those externalities which affect other producers or consumers of the same item. "Pollution" refers to those externalities which affect producers or consumers of other things.

Both "congestion" and "pollution" may affect consumers as well as producers. However, when externalities affect consumers they are "public goods" rather than "common property." An item is called a "public good" not because it is publicly produced, but because it is "publicly" consumed.

That is, it can be consumed by everyone at no additional cost once it is produced for anyone. No one can be excluded or can avoid consumption of a public good, whether they like it or not. Thus, a public good may be a public bad for some people.

There are few "pure" public goods under this definition, i.e., the externality affecting the consumer is not often exactly equal to the good being consumed. National defense is the most commonly cited example of a pure public good. Most public goods are publicly consumed within a limited geographical area--a television program, for example. They are therefore not pure public goods.

Most examples of public goods discussed in the literature are either deliberately produced or naturally existing externalities. Examples of naturally existing public goods include sunsets and the Grand Canyon. Examples of deliberately produced public goods include national defense and radio and television broadcasts. However, just like common property, public goods may be by-products of other production or consumption, as well as naturally existing or deliberately produced.

Congestion externalities which are public goods include crowded beaches and traffic congestion where all persons are commuters. Like all externalities congestion may be either good or bad; some people enjoy crowded beaches more than quiet ones. Where traffic "congestion" involves both business and recreational travelers, the externality between the two groups is really a pollution externality. Traffic "congestion" affecting business travelers is common property while that affecting recreational travelers is a public good.

The aesthetic effects associated with the production of electric power are pollution externalities which are also public goods. They are by-products of electric power production, but they are not common property and not congestion externalities because the persons affected are not engaged in the production of electric power and they are not producers of other products; they are residents of and recreational visitors to the area physically affected by electricity production activities.

VALUING EXTERNALITIES

The amount of a private market good that people want to buy depends on many things including the price of the good, the prices of substitutes and complements of the good, and people's incomes. Economists depict these dependencies graphically using a "demand curve" which is a price vs. quantity relationship for the good with all other variables held constant (Figure 2). Changes in these other variables shift this demand curve for the product. The total demand curve for the product that the industry producing this good faces is the sum of all quantities that each person would buy at each price. This means summing all individual's demand curves, as depicted in Figure 2, horizontally.

Figure 2. Demand Curve for a Private Market Product

People's willingness to pay for externalities, such as visual pollution, can be similarly depicted (Figure 3). However, we cannot observe this willingness to pay directly through private market prices for such items, because private markets for these goods do not exist. Also, the individual bid curves must be summed vertically for pure public goods to get the aggregate bid curve or the schedule relating society's willingness to pay for a unit of visual pollution abatement vs. the extent of visual pollution abatement, for example. The summation must be done vertically for pure public goods, because each person's consumption of the item does not reduce the amount available for others as it does for purely private goods.

Figure 3. Willingness to Pay or Bid Curve for an Externality

Many goods are neither purely public nor purely private. For these goods the social demand curve or aggregate bid curve is neither simply the horizontal nor the vertical summation of the individual demand or bid curves. In these cases one should horizontally sum the private market demand components

and vertically sum the public good bid components. Then, if the private and public aspects of the good are separable, one can sum the private demand and public good bid curves vertically to get the appropriate social demand or aggregate bid curve for the good.

The approaches which have been used to obtain the individual and aggregate bid curves for public goods fall into two broad categories: (1) private market proxies and (2) direct inquiries. (See Table 2.) The approach selected in an individual case depends on the nature of the information which is available and the expected use of the results.

Table 2. Alternative Measures of Externalities

I. Private Market Proxies - Observed Behavior

- A. Responses or limited willingness to pay (amount individuals now pay to retain current or obtain next best state)
- B. Substitutes or alternative cost (minimum amount individuals must pay to retain current or obtain next best state)
- C. Use of complements or concurrent payments to estimate maximum willingness to pay or equivalent variation

II. Direct Inquiries - Behavioral Intentions

- A. Willingness to pay or equivalent variation (maximum amount individuals would pay to retain current state or to obtain alternative state)
- B. Compensating variation (minimum compensation for individual to be indifferent between current and alternative states)

Private Market Proxies

The use of land value changes to measure location specific externalities is an example of using a private market response. If the view from a particular parcel of land is inhibited by particulate emissions from a power plant, the resulting change in the value of the land is one measure of the value of the pollution externality. However, many other variables may be influencing land values at the same time and there is often not enough data to allow econometric estimation of how much of the change in land values should be attributed to any single variable. Further, changes in land values measure only the capitalized value of the site specific effects from increased particulate emissions. The corrosive effects on materials and human health as well as the visual aesthetic effects all have site specific aspects; however, these effects are not entirely site specific. Thus, the use of land value changes alone leaves out some things, while use of land value changes in conjunction with other measures carries a great risk of double counting.

Sometimes private market substitutes are used as measures of externalities. For example, material corrosion effects of air pollution can be measured by repair and replacement costs. Also, human health effects can be measured by medical expenses incurred and wages and productivity lost. However, this approach also omits some factors. For example, the health effects have a "pain and suffering" component which is not measured in this way, although litigation results may provide some idea of their magnitude. However, quick and concrete results are usually more easily obtainable with this approach than with the alternative methods of valuing externalities.

All of the private market substitution and response measures of the value of externalities tend to provide underestimates by considering only market prices and ignoring changes in producer's and consumer's surplus. Consumer's surplus is the amount of money consumers would have been willing to pay in addition to what they do pay for all units of a good they buy.

Producer's surplus is the amount of money producers receive in addition to the minimum amount for which they would have sold each unit of a good they sell.

The prime example of using private market complements to measure externalities is in recreation. The recreation benefits or losses from projects have traditionally been measured by looking at how much people pay for the opportunity to enjoy a similar recreation experience in a similar area. This procedure always uses the cost of travel to the site but should also include depreciation on equipment which is specialized to the type of recreation in question, and the value of the time spent recreating and enroute. The key assumption of constancy of tastes allows the econometric estimation of an aggregate demand curve which yields the consumer surplus as the measure of benefits.

Direct Inquiries

The second major approach to valuing externalities is to measure their perceived value to people using bidding games and other forms of direct inquiries. Information is provided to people about the nature of the externality and questions are then asked about (1) how much they would be willing to pay for the opportunity to enjoy (or to avoid) the experience compared to the alternative state and/or (2) how much they would have to be compensated to be indifferent between the experience and the alternative state. Economists have termed these equivalent and compensating variations, respectively.

Direct inquiries into the value of an externality require individuals' judgments or statements of their behavioral intentions. This is in contrast with private market proxies, which use observed behavior to make this link. While observed behavior would be preferred, frequently not enough data is available to use these private market proxy approaches. The results of direct inquiries concerning people's behavioral intentions were used in this paper as evidence of how much people are willing to pay for reductions in visual pollution. More specifically, this study looked at the equivalent variation as measured by bidding game results.

VALUATION METHOD USED

The visual pollution valuation approach used here relies heavily on the recent paper by Randall, Ives, and Eastman.⁽¹⁾ Therefore, their study is first reviewed to provide the reader with the background necessary to understand how their approach has been modified and extended.

THE RANDALL, IVES, AND EASTMAN STUDY

Randall, Ives, and Eastman used survey techniques, called bidding games, to estimate how much people were willing to pay for reductions in visual pollution. They studied the region (shown in Figure 4) around the Four Corners coal-fired power plant located near Farmington, New Mexico. This power plant had five units in operation in 1970 with a total capacity of 2,080 MWe and uses bituminous coal from the Navajo mine, also in San Juan County, New Mexico. The coal is low in sulfur but high in ash content. It also has a heating value lower than most coal and would, therefore, be less attractive to the electric power industry if it could not be used in a mine mouth plant.

In 1970 this Four Corners power plant emitted 96,000 tons of particulates, 73,000 tons of sulfur oxides, and 66,000 tons of nitrogen oxides into the atmosphere. These emissions reduced the long-distance visibility and the depth and color perception in this region. Other aesthetic impacts were related to strip mine operations, power transmission lines and the power plants themselves, modifying the often otherwise untouched landscape.

Figure 4. Counties in Randall, Ives, & Eastman Study Area - Four Corners Interstate Air Quality Control Region

Residents of and recreational visitors to the Four Corners Air Quality Control Region were shown three sets of photographs depicting three levels of these aesthetic environmental pollution externalities. One set of photos showed the visibility associated with the plant operating without pollution control devices, strip mine spoils banks prior to leveling, and obtrusively placed transmission lines. A second set of photos showed the visibility after scrubbers had reduced particulate emissions,

which are the most damaging to visibility; spoils banks were leveled but not revegetated; and transmission lines were placed less obtrusively. The third set of photos represented zero visual pollution from power plant operations; it showed the plant when there were no visible emissions (because the plant was not operating) and no visible damages to the landscape from strip mining or transmission lines (a photo of arid land in its natural state). Of the three forms of pollution damages, the reduced visibility was by far the most significant to respondents. (Note that the existence of the plant causes some fixed externalities similar to the fixed private costs of its construction, while the operation of the plant causes variable externalities, such as reduced visibility, similar to the operation and maintenance costs of the plant.)

Questionnaires were designed to elicit the maximum amount that each respondent would be willing to pay to have a situation with less visual pollution than existed at the maximum emissions observed from the Four Corners plant to that time. Different vehicles for payment were tested, including increased sales taxes, increased electricity bills, monthly payments and recreational user fee increases. These interviews were conducted during the summer of 1972.

MODIFICATIONS OF THE RANDALL, IVES, AND EASTMAN APPROACH

The results of the sales tax bidding games for residents of the area and the results of the user fee bidding games for recreational visitors were used in this paper. These results were judged to be easier to extend to other areas than the electricity bill game results because identification of the consumers of electricity from each power plant was not necessary.

Randall, Ives and Eastman divided their study region into four zones based on estimated concentrations of particulate pollutants. Residents subject to higher concentrations of pollutants were expected to bid more than those less damaged. However, they did not find these zonal differences to be statistically significant consistently across all four zones. Therefore, the approach used here has been simplified by pooling all bids from

residents in the air quality control region regardless of their proximity to the power plant(s). Also, none of the recreational sites studied by Randall, Ives and Eastman were in the high pollution concentration zones near the plant and they reported that further stratification of recreational respondents did not yield consistently statistically significant differences among distance zones either. Therefore, only their distinction between residents and visitors has been maintained in this extension of their work.

In the Randall, Ives and Eastman study, the amounts that all groups of people were willing to pay for a given level of pollution abatement were summed vertically (see Figure 3) for each of the three emissions levels studied. They then fitted an aggregate bid curve to the resulting three points using the following curve form:

$$B(A) = C \ln \left[\frac{K}{K-A} \right]$$

- where C = an empirically estimated constant
- K = an empirically estimated parameter relating visibility to emissions
- A = tons of particulate emissions abated annually
- B = the aggregate dollar bid for that level of abatement as opposed to the zero abatement alternative

In this extension of their work two average bid curves were estimated: one for residents and one for recreational visitors. This allows estimation of the aggregate bid in each air quality control region in WSCC without having to re-estimate the aggregate bid curve for each of the regions having more or less residents and visitors, and for each region over time as these subject populations change. Thus, replication of this approach is much easier than that presented by Randall, Ives and Eastman. The resulting relationships between average bids (per household and per visitor party day) and abatement are given in Figures 5 and 6. Details of the estimation of the equations are given in Appendix A.

Randall, Ives, and Eastman used the maximum emissions from the power plant that they studied, i.e., the Four Corners power plant with no abatement controls in 1970, as their reference point. That is, for their study $A = (96,000 \text{ tons of particulates/year} - E)$ where E = actual tons of particulate emissions from the power plant per year. Thus, when $E = 96,000$ tons of particulates/year, $A = 0$ and $B = 0$. That is, people would pay nothing unless visibility improved. This way of presenting the survey results implies that people would have negative bids for emissions levels greater than 96,000 tons per year; that is, they would have to be compensated to allow larger emissions than the maximum amount they had experienced. Some may be tempted to say that no implications for larger emissions sources than the one Randall, Ives and Eastman studied are sensible based on their findings because of the apparent shift from equivalent variation below this level to compensating variation above it. This conclusion would be too hasty, however.

By changing the reference point from zero abatement to zero emissions it is possible to further generalize the results of the Randall, Ives and Eastman surveys. To do this I will refer to emissions rather than abatement of emissions and to peoples' willingness to pay to avoid damages caused by emissions compared to the zero power plant emissions case. By contrast Randall, Ives and Eastman used willingness to pay to reduce damages below those associated with the maximum emissions that had been observed in the Four Corners Air Quality Control Region at the time of their study. The old and new reference points are shown on Figures 5 and 6. Setting a new coordinate system at this new zero point one can visualize turning the relationship 180 degrees around both axes: once around the vertical axis to change from abatement to emissions units and once around the horizontal axis to change from bids for reduction of damages to bids for avoidance of damages. These bids for avoidance of damages are estimates of the value of visual pollution damages people feel they would

Figure 5. Estimated Average Resident's Bid Curve for Reduction of Visual Pollution

Figure 6. Estimated Average Recreational Visitor's Bid Curve for Reduction of Visual Pollution

suffer at the different emissions levels. Thus, they are still estimates of the equivalent variation over the entire range of emissions levels, rather than switching to a compensating variation measure at some arbitrary emissions level. The algebraic equivalents of these geometric changes are described in Appendix A. These new relationships between emissions and the value of visual pollution are as follows (see Figures 7 and 8, respectively):

The value of visual pollution to residents in 1972 dollars per household per year is given by

$$\$71.32 - \$75.15 \ln \left[\frac{156,643}{60,643 + E} \right] \quad (1)$$

The value of visual pollution to recreational visitors in 1972 dollars per visitor party day is given by

$$\$2.10 - \$2.52 \ln \left[\frac{169,746}{73,746 + E} \right] \quad (2)$$

To use these results to determine an optimum level of power plant emissions in a given air quality control region one would first differentiate the value of visual pollution curves for both groups (Equations (1) and (2)) with respect to emissions. This gives two marginal value of visual pollution curves as shown in Figures 9 and 10. These curves would be multiplied by their respective subject populations and the results would be added vertically (see Figure 3) to get the marginal value of visual pollution per ton of particulates associated with any level of power plant emissions. This price would then be added to the marginal value of other pollution effects of these emissions, such as health effects, corrosion of materials, etc. These marginal value of pollution estimates would be compared to the marginal costs of reducing these emissions. Emissions should be reduced until the marginal value of the pollution avoided equals the marginal costs of further emissions reduction.

Figure 7. Estimated Value of Visual Pollution to the Average Resident from Power Plant Emissions

Figure 8. Estimated Value of Visual Pollution to the Average Visitor from Power Plant Emissions

Figure 9.

Marginal Value of Visual Pollution for Residents

Figure 10.

Marginal Value of Visual Pollution for
 Recreational Visitors

ESTIMATED VALUE OF VISUAL POLLUTION

Randall, Ives, and Eastman estimated that \$15.54 million (in 1972 dollars) in benefits due to visual pollution damages avoided was associated with the particulate emissions control standards of 1972 and that \$24.67 million (in 1972 dollars) in such benefits would have been associated with zero particulate emissions from the Four Corners power plant in that year. Thus, the 1972 emissions control standards still allowed over \$9 million (in 1972 dollars) in visual pollution to the Four Corners Air Quality Control Region.

In this section preliminary estimates of the value of visual pollution in the Four Corners Air Quality Control Region in 1975 and 1985 are first presented. These results provide an illustration of the procedures and a comparison with the Randall, Ives, and Eastman results noted above. The results of replicating these calculations for all air quality control regions in the WSCC area are then given, along with a preliminary estimate of the value of visual pollution caused by power plants, for the whole WSCC region in the same two years. These estimates were made using (1) the value of visual pollution curves for residents and recreationalists described above and derived in Appendix A, (2) the 1975 power plant emissions data given in Appendix C,⁽²⁸⁾ (3) the 1970 resident household data given in Appendix D,⁽²⁹⁾ and (4) the 1975 recreational visitation data given in Appendix E.⁽³⁰⁾

For the preliminary overview calculations given in this paper, 1975 visitor information for areas under the control of the National Park Service was obtained. This data shows over 8 million visitor days,⁽³⁰⁾ or almost 2.3 million visitor party days (assuming 3.5 visitors per party) to areas under the National Park Service control in the Four Corners Air Quality Control Region in 1975. (See Appendix E for data on individual parks in this and other air quality control regions in the West.) However, recreational visitors to the region in 1972 totaled over 8.5 million recreational visitor party days according to Randall, Ives, and Eastman. The difference in these figures is due to the fact that their estimates of recreational visitors included National Forest and State Park visitors as well as visitors to areas under the control of the National Park Service.

Using the average National Park Service growth in visitation rate of about 4.1% from 1972 to 1975⁽³¹⁾ to update the Randall, Ives, and Eastman 1972 estimates, yields about 9.6 million visitor party days for this region in 1975. This implies that the 1975 National Park Service visitation data given in Appendix E probably represents about one-quarter of the total recreational visitor party days in the Four Corners Air Quality Control Region. Therefore, total recreational visitors to each air quality control region are assumed to be four times the National Park Service visitation estimates.

The results presented here reflect adjustments made to correct for inflation between the time of the surveys (1972) and 1975. This was done using the consumer price index (CPI) for all commodities in the case of the residents, and the CPI for "reading and recreation" for the recreational visitors.⁽³²⁾ The assumption behind the choice of these indices was that the bids were some fraction of the cost of the activity involved for each subject population. This is a general cost of living index for residents and as close to an index of recreational costs as is available for recreational visitors. See Appendix A for the necessary adjustments in equations (1) and (2).

VALUE OF VISUAL POLLUTION IN THE FOUR CORNERS AIR QUALITY CONTROL REGION

Table 3 shows the capacity and location of the existing and planned coal-fired power plants in the Four Corners Air Quality Control Region as given in the 1976 WSCC plan.⁽³³⁾ Power plant emissions for each existing plant for 1975 were taken from tapes provided to LASL by the National Emissions Data Service of the U.S. Environmental Protection Agency.⁽²⁸⁾ These data for all air quality control regions in the WSCC area are given in Appendix C.

For the Four Corners Air Quality Control Region these data show over 35 thousand tons of emissions in 1975 as opposed to 26 thousand tons of particulates reported in the Randall, Ives, and Eastman study for 1972. While the capacity of the Four Corners power plant is given in the 1976 WSCC plan as 2,172 MWe in 1975 as opposed to a 1972 capacity of 2,080 MWe reported by

Table 3. Existing and Planned Power Plants in the Four Corners Air Quality Control Region (33)

<u>Plant Name</u>	<u>Location (County & State)</u>	<u>Expected Com- pletion Date</u>	<u>Capacity (MWe)</u>
Four Corners	San Juan, NM	Existing	2172
Navajo *	Coconino, AZ	April 1976 *	2250
Huntington *	Emery, UT	June 1977 *	845
Cholla *	Navajo, AZ	June 1979 *	966
Emery	Emery, UT	April 1980	830
San Juan *	San Juan, NM	May 1980 *	1588
Warner Valley	Washington, UT	June 1980	500
Coronado	Apache, AZ	May 1982	1050
Kapairowitz**	Kane, UT	December 1983**	3000
TOTAL			13,201

* Although the Navajo plant is now completed, and some units of the Huntington, Cholla and San Juan plants are also now operating, the decision was made to call plants "existing" only if they were so designated in the latest WSCC Plan (Reference 33). Thanks are due B. C. Ives, University of New Mexico at Albuquerque for this more current information.

** Although Kapairowitz has now been cancelled, it is included here because it is in the latest WSCC Plan (Reference 33).

Randall, Ives, and Eastman, this is not sufficient to explain the larger emissions. Emissions are 30% higher than one would expect based on the minor increase in capacity alone. It appears that either coal with a higher ash content than before is being used, or a lower percentage of the particulate emissions is now being removed, or the amount of time the plant is operating has increased. The latter seems the most likely explanation. Assuming that the same type of coal is being burned in the same way with the same percentage of particulate emissions being removed by control devices implies that uncontrolled emission levels would have reached over 130 thousand tons by 1975.

Emissions data is also given in Appendix C for 1985 by air quality control region. This data essentially assumes no further emissions controls beyond the 1975 levels. (See Appendix C for further details.)⁽²⁸⁾ We also assume that uncontrolled emissions levels for the Four Corners Air Quality Control Region will be the same 60 tons per MWe as in 1975. Thus, it is assumed that uncontrolled emissions in this region would be over 790 thousand tons by 1985.

The sensitivity of the 1985 results to this assumption is tested by alternatively assuming a further 50% reduction of power plant emissions in this region due to additional controls. The resulting estimates of the visual pollution damages incurred and avoided in the Four Corners Air Quality Control Region are presented in Table 4. This shows that the annual value of visual pollution associated with power plants in the Four Corners area is expected to increase to over \$30 million annually (in 1975 dollars) by 1985 unless further pollution controls are implemented. A further 50% reduction in emissions per MWe would limit these aesthetic damages to residents of, and visitors to, this area to under \$19 million annually (in 1975 dollars).

Table 4. Summary of Visual Pollution Estimates for the Four Corners Air Quality Control Region

<u>Year</u>	<u>Power Plant Emissions (tons/year)</u>	<u>Estimated Annual Visual Pollution Damages Incurred (Millions of 1975 Dollars)</u>	<u>Estimated Annual Visual Pollution Damages Prevented by Power Plant Emission Controls (Millions of 1975 Dollars)</u>
1972 (Randall, Ives, & Eastman)	26,000	10.8 (9.0 in 1972 dollars)	18.8 (15.5 in 1972 dollars)
1975	35,297	14.8	23.3
1985	94,362	30.9	60.0
1985	47,181	18.7	72.3

While considerable visual pollution exists even after most of the particulate emissions from the plant have been removed, the existing emission control devices prevent even more visual pollution. Table 4 shows that these aesthetic damages avoided are expected to reach \$60 million annually (in 1975 dollars) or more by 1985.

VALUE OF VISUAL POLLUTION IN THE ENTIRE WSCC REGION

The Four Corners Interstate Air Quality Control Region studied above is one of the comprehensive network of Air Quality Control Regions established by the U.S. Environmental Protection Agency.⁽³⁴⁾ (See Figure 11 and Appendix B.) These regions were designed "based on jurisdictional boundaries, urban-industrial concentrations, and other factors, including atmospheric areas, necessary to provide adequate implementation of air quality standards" as provided in Section 107 (a) (2) of the 1967 Amendment to the Clean Air Act of 1963 (42 USC 1872 et seq.).⁽³⁴⁾

Those air quality control regions which contain at least some of the WSCC region are shaded in Figure 11. These air quality control regions are the basic replicating units for the valuation of visual pollution in the entire WSCC region. For each of these regions, power plants which have a capacity of 300 MWe or more have been identified⁽³³⁾ and located geographically within the air quality control region⁽²⁸⁾ (see Table 5). The power plant emissions in each region were then determined by LASL as described in Appendix C.⁽²⁸⁾

Using these emissions levels, the household data in Appendix D and the recreational visitor data in Appendix E, the illustrative case of the Four Corners region was replicated for each air quality control region in the west. The number of resident households in each air quality control region was multiplied by the damages per household calculated for the given emissions level from equation (1). The recreational visitor party days to the area were multiplied by the damages per visitor party as given in Equation (2). Adjustments for inflation from 1972 to 1975 were made as described in Appendix A. These two groups' dollar bids were then added to get a total value of the visual pollution damages caused by power plants in each region. These damages for each region were added to get the estimated aggregate damages for the entire WSCC area. The results of these calculations are given in Table 5.

These estimates show that the areas of the largest visual pollution damages to residents from electric power plant emissions are the Los Angeles, Portland, Denver, Four Corners, San Francisco, Wyoming, and Lake Mead areas. For recreational visitors the areas of largest aesthetic damages are the Four Corners,

Figure 11. EPA Air Quality Control Regions of the United States
 With Those Regions Containing Some Portion of the WSCC Area Shaded

Table 5. Estimated Annual Value of Visual Pollution For
Air Quality Control Regions in the WSCC Area

Air Quality Control Region			Estimated Annual Value of Visual Pollution to Residents (thousand 1975 \$/yr)		Estimated Annual Value of Visual Pollution to Visitors (thousand 1975 \$/yr)		Estimated Annual Total Value of Visual Pollution (thousand 1975 \$/yr)	
No.	Name	Power Plants	existing in 1975	proposed for 1985	existing in 1975	proposed for 1985	existing in 1975	proposed for 1985
35	Portland	Beaver Centralia	10,191	10,249	8	8	10,199	10,257
201	East Oregon	Boardman Fossil	208	208	0	0	208	208
49	Boise	Pioneer	0	523	0	0	0	523
156	Eastern Montana	Colstrip	0	610	0	52	0	662
52	Cheyenne	Laramie River	0	406	0	5	0	411
245	Wyoming Intrastate	Jim Bridger Naughton Wyodak	1,263	2,115	4,928	8,372	6,191	10,527
194	Casper	Dave Johnson	676	676	0	0	677	677
163	NW Colorado	Craig Hayden	17	114	127	357	144	971
5	Denver	Cherokee Vailmont	5,395	5,395	0	0	5,395	5,395
161	SE Colorado	Comanche	417	820	0	0	417	820
46	El Paso-Las Cruces	Newman	15	27	2	5	17	32
89	Four Corners	Cholla Kaiparowitz Coronado Emery Navajo Huntington San Juan Warner Valley Four Corners	4,133	8,455	10,647	22,443	14,780	30,898
25	Phoenix, Tucson	Agua Fria Irvington Kyrene Ocotillo Saguaro	473	493	3	3	476	496
62	Arizona, Southern NM	Apache	2	130	0	7	2	137

TABLE 5: CONTINUED

No.	Name	Power Plants	Estimated Annual Value of Visual Pollution to Residents (thousand 1975 \$/yr)		Estimated Annual Value of Visual Pollution to Visitors (thousand 1975 \$/yr)		Estimated Annual Total Value of Visual Pollution (thousand 1975 \$/yr)	
			existing in 1975	proposed for 1985	existing in 1975	proposed for 1985	existing in 1975	proposed for 1985
47	Arizona, Nevada	H. Allen Mohave Reid Gardner	934	3,020	1,409	4,644	2,343	7,644
10	San Francisco	Contra Costa Pittsburg Hunters Point Potrero	2,755	3,163	47	54	2,802	3,217
146	North-Central Calif. Coast	Moss Landing	181	181	4	4	185	185
152	South-Central Calif. Coast	Morro Bay	29	29	0	0	29	29
6	Los Angeles	Alamitos El Segundo Etiwanda Grayson Steam Harbor Haynes Huntington Beach Long Beach Mandalay Ormond Beach Redondo Beach Scattergood Valley	32,890	33,118	21	21	32,911	33,139
150	San Diego	Encina South Bay	455	605	6	8	461	613
153	SE California Desert	Cool Water Lucerne Valley	95	888	1	20	96	908
WSCC TOTALS			60,130	71,266	17,203	36,503	77,333	107,769

Wyoming, and Lake Meed areas. The most significant increases in these visual pollution damages are also expected to be in the Four Corners, Lake Meed, and Wyoming areas. Total visual pollution damages in the WSCC area are estimated to be about \$77 million annually in 1975 (in 1975 dollars) and to grow to nearly \$108 million annually (in 1975 dollars) by 1985.

SOURCES OF ERROR AND RESEARCH RECOMMENDATIONS

The estimates of the value of visual pollution associated with electric power production presented above require many assumptions that probably introduce considerable error in the results. However, even order of magnitude estimates are important at this stage in the debate over the value of environmental impacts of electricity production. Order of magnitude estimates of the various impacts and the costs of ameliorating them should be important in establishing priorities for subsequent improvements in these calculations.

The assumption which probably introduces the greatest error concerns the treatment of background particulate concentrations including emissions from sources other than electric power plants. Because of the nonlinear relationship found between particulate emissions and the value of visual pollution, errors in the estimates presented above are probably introduced by use of this relationship for areas where natural background levels or emissions from non-power plant sources are different from the Four Corners Air Quality Control Region at the time of the original surveys. Knowledge of these background levels and emissions compared to those in the Randall, Ives, and Eastman study would allow adjustment for this bias, if people feel damaged by these other airborne particulates in the same way as they indicated being damaged by those from the Four Corners power plant. For example, if we knew the background particulate levels in the Los Angeles area (translated into a tons/year basis), we could compare this to the background levels in the zero power plant emission case studied by Randall, Ives, and Eastman and adjust the zero power plant emissions point for the Los Angeles area accordingly. Without such an adjustment, the use of equations (1) and (2) to estimate the value of visual pollution shown in Table 5 for areas like Los Angeles, where visibility is already poor due to emissions from other sources, overestimates the actual value of visual pollution caused by power plants in this area. This same problem applies to calculations done for the Four Corners area at later dates than the

original surveys as well as other areas in all time periods. Forecasts of emission levels from other sources would thus be needed to make these adjustments over time.

In addition to adjusting the zero power plant emissions levels for background levels of airborne particulates, there are a few other improvements that could be made without conducting additional surveys. Foremost among these is better data on the number of residents and visitors in the areas affected by visual pollution. Also, forecasts of these subject populations are important in improving the estimates of the value of visual pollution expected in the future.

Data used in this report on recreational visitors to parks in the WSCC area covered only visitors to National Park Service controlled areas. This amounts to a fraction of the total visitation, which includes national forest and state park visitors as well. The estimate of the size of this fraction which was used here was extremely crude. More complete historical recreational visitor data would increase the reliability of the resulting visual pollution damage estimates.

Estimates of future changes in these visitation patterns should be made to forecast the total value of visual pollution to visitors in future years rather than assuming no change, as was done in this paper. The various park management agencies may have some existing forecasts, but to make an accurate visitation forecast one must treat the interaction between visitation rates and the extent of visual pollution over time. Finally, one must decide how to treat the visual pollution damages to those for whom the value of these damages is so large that planned visits are cancelled.

The data on resident populations could be improved also. In this paper 1970 data on the number of households in each air quality control region in the WSCC area was used. It was assumed that these household figures had not changed by 1975; this obviously introduces some error into the results. Also these resident household numbers should be forecast to get estimates of visual pollution damages to residents in future time periods, rather than simply assuming no change over time.

Some errors in the estimates of the value of visual pollution could not be corrected without additional survey data. Other researchers are continuing to pursue these bidding game approaches to valuing aesthetic affects of power plants, so it is possible that their efforts may solve some of these problems. (35,36)

One problem that may be ameliorated by this other work is the uncertain error introduced by extrapolating beyond the observed range of emissions levels experienced. The Randall, Ives, and Eastman approach prevented such extrapolation, while the approach presented here was deliberately designed to permit the greatest possible inferences from their survey results.

Problems related to the extrapolation beyond the range of experience include changes in many variables among areas and over time which may affect the shape and level of the visual pollution valuation functions. In this paper these variables have been assumed to be constant over time and among regions, but they almost surely are not and will not be constant. In addition to the background particulate levels noted earlier, these include preferences and socioeconomic characteristics of the resident and visitor populations, visual aesthetic opportunities, and prices of substitutes and complements for these aesthetic goods.

Ways are not now available to adjust the bids for changes in these variables, because the nature of their impacts on the visual pollution valuation functions has not been studied sufficiently. However, Randall, Ives, and Eastman estimated the income elasticities of the bids and generally found that people's willingness to pay for reductions in visual pollution increased with income, as one would expect. They attributed the lack of such a finding for some groups to a small sample for one group and a lack of income variation within some of the groups sampled. More information about elasticities of the bids with respect to the socioeconomic characteristics of the residents and visitors, plus information on the variation of these characteristics among areas and over time would be needed to adjust for these effects.

Visual aesthetic opportunities vary considerably from area to area and, perhaps to a lesser degree, over time. There is just more to see that people find pleasing in some places than in others. These differences in things to see constitute much of the differences in recreational opportunities in the

different regions. The characteristics of the viewscape are also important. For example, distance vision is likely to be more important to people standing on the rim of the Grand Canyon than to those watching Old Faithful in Yellowstone. Adjustments for these differences among regions cannot be made without more information about them. New bidding game surveys for at least a few more areas seem necessary to get this information.

A complete treatment of the value of visual pollution from electric power plants should consider all sources of visual pollution related to these plants. This study included only those considered in the Randall, Ives, and Eastman bidding games, namely particulate emissions as they act to reduce visibility, strip mine spoils banks and transmission lines. Other factors which should be considered include the visible plume and fogging possibilities from thermal discharges. The extent of these effects varies widely according to the meteorological conditions near the power plants. While some work has been done on valuing thermal pollution effects,⁽³⁷⁾ new surveys on the aesthetic effects of fogging are in order.

Additional surveys could also reveal information about differences in preferences among areas. However, tastes or preferences can change over time as well and there is no way of accurately predicting these effects even for goods where perfectly competitive, private markets exist. For example, people may adjust their expectations to existing conditions. This has been observed in work on the "permanent income hypothesis"^(38,39) and may also be relevant to the variation of visual pollution among areas and over time.

In estimating the demand or bid curve for any good, the prices of the substitutes and complements for the good are assumed to be constant. If these prices change, these functions could shift and/or change shape. Substitutes and complements for visual aesthetic opportunities may be difficult to specify, but the direction of influence of changes in them can be hypothesized based on economic theory: a relative increase in the price of substitutes or a relative decrease in the price of complements are expected to increase the willingness to pay to avoid visual pollution and therefore the estimated value of such

damages (assuming the "income effects" of the relative price changes are negligible). Further research would be needed to identify substitutes and complements for visual aesthetic opportunities and to estimate the extent of these effects.

The problem of how to provide information about externalities to people without biasing the survey results which depend on their responses to this information is inherent in the bidding game technique. An example of this problem is the error introduced by using a single set of photographs to provide people with information on visual pollution levels. Randall, Ives, and Eastman found that people's bids for emissions reductions were not statistically significantly less as distance from the power plant increased. One plausible explanation for this is their use of the same information on visual pollution levels for all persons surveyed. If all persons perceived that the visual pollution which they could expect to experience was the same as everyone else's for each emission level from the power plant, then the responses obtained are not surprising.

Finally, the estimates of the value of the visual pollution depend, perhaps significantly, on whether the "equivalent or compensating variation" is estimated and whether any monetary payments are actually made. As noted earlier, the equivalent variation is the maximum amount a person would be willing to pay to obtain a positive externality or avoid a negative externality, while the compensating variation is the amount a person would have to be paid to allow a negative externality or to permit the loss of a positive externality. In this paper, as in the Randall, Ives and Eastman study, the equivalent variation was the measure used. However, the equivalent variation is generally less than the compensating variation. In fact, many of those surveyed by Randall, Ives and Eastman protested the use of this measure for just this reason, although they did not express it in these terms. In practical terms the question of legal liability is at issue here: Do consumers have a legal right to clean air or do producers of electric power have a legal right to use the air to their best advantage? The answer determines whether the equivalent or the compensating variation is the more appropriate measure of the value of visual pollution.

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APPENDIX A

ESTIMATION OF RELATIONSHIPS BETWEEN VISUAL POLLUTION VALUES AND POWER PLANT EMISSIONS

APPENDIX A: ESTIMATION OF RELATIONSHIPS BETWEEN VISUAL
POLLUTION VALUES AND POWER PLANT EMISSIONS

The Randall, Ives, and Eastman⁽¹⁾ survey data for residents and visitors at varying distances from the Four Corners power plant were pooled to get the willingness to pay for abatement of power plant emissions for the two groups: residents and visitors. This pooling is justified on the basis that Randall, Ives, and Eastman reported no "consistent significant differences" between the willingness to pay at the various distances from the plant. This pooling of the survey results gave the three data points for residents and visitors shown in Table A-1.

TABLE A-1: Residents' and Visitors' Bids
for Abatement Compared to the
Zero Abatement Alternative

<u>Level of Abatement of Emissions (1,000 tons of particulates/year)</u>	<u>Resident's Bid (1972 Dollars/ Household/Year)</u>	<u>Visitor's Bid (1972 Dollars/ Visitor Party Day)</u>
0	0	0
70	\$44.50	\$1.34
96	\$71.32	\$2.10

These data were used here to estimate for both residents and visitors equations of the form:

$$B(A) = C \cdot \ln \left[\frac{K}{K-A} \right]$$

where C and K are estimated constants, A is the number of tons of particulate emissions abated annually, and B is the dollar bid.

The variable metric method developed by Fletcher and Powell⁽⁴⁰⁾ and Davidson⁽⁴¹⁾ was used to estimate these non-linear equations.^(42, 43) This method was found to be more accurate than that used by Randall, Ives and Eastman.

The resulting equations relating willingness to pay for reductions in visual pollution to the abatement level are:

- Bid per resident household per year =

$$\$75.15 \ln \left(\frac{156,643}{156,643-A} \right) \quad (A-1)$$

- Bid per visitor party day per year =

$$\$2.52 \ln \left(\frac{169,746}{169,746-A} \right) \quad (A-2)$$

These curves are plotted in Figures 6 and 7 in the text.

As noted in the text these curves were transformed into relationships between the value of visual pollution and power plant emissions by a change in the reference point and the changes in the units on both axes. These changes are described geometrically in the text. Algebraically, substitute (96,000-E) for A to change from abatement of emissions, A, to emissions, E. Then take the difference between this amount, which people would be willing to pay for the emissions compared to having 96,000 tons of particulates per year, and the amount they would be willing to pay for zero power plant emissions, i.e., \$71.32 for residents and \$2.10 for visitors. These changes in equations (A-1) and (A-2) yield the equations (1) and (2) given in the text.

Equations (1) and (2) were then adjusted from 1972 to 1975 dollars using the consumer price index (CPI) for all commodities for equation (1) and the CPI for "reading and recreation" for equation (2). Thus, equation (1) is multiplied by (161.2/125.3) and equation (2) is multiplied by (144.4/122.8).

To get the total value of the visual pollution damages for a given level of power plant emissions in an air quality control region for residents and visitors in 1975 dollars, the following equation was used:

The value of visual pollution in each air quality control region =

$$\begin{aligned} & [\$71.32 - \$75.15 * \ln (\frac{156,643}{60,643+E})] * [\frac{161.2}{125.3}] * \text{HSLDS} \\ & + [\$2.10 - \$2.52 * \ln (\frac{169,746}{73,746+E})] * [\frac{144.4}{122.8}] * \text{RECDAYS} \end{aligned} \quad (\text{A-3})$$

where

E = power plant emissions in tons of particulates per year
(see Appendix C)

HSLDS = the number of resident households in the air quality
control region (see Appendix D)

RECDAYS = recreational visitor party days spent in the air quality
control region in the given year (see Appendix E)

The value of visual pollution avoided due to emissions controls was calculated by taking the difference between the values of equation (A-3) for the maximum possible and the actual emissions levels for the given region in the given year.

APPENDIX B

AIR QUALITY CONTROL
REGIONS IN THE WEST

TABLE B-1: NUMBERS AND NAMES OF AIR QUALITY
CONTROL REGIONS IN THE WEST (38)

<u>State</u>	<u>Number</u>	<u>Name</u>
WA	171	Olympic-Northwest Washington
WA	170	Northern Washington
WA	22	Puget Sound
WA	172	South Central Washington
OR/WA	35	Portland
OR	203	Northwest Oregon
OR	202	Southwest Oregon
OR	200	Central Oregon
OR	201	Eastern Oregon
ID/WA	83	Northern Idaho-Eastern Washington
ID	236	Idaho
ID	49	Metropolitan Boise
ID	173	Eastern Idaho
MT	157	Missoula
MT	154	Great Falls
MT	156	Miles City
MT	50	Billings
MT	155	Helena
WY	52	Metropolitan Cheyenne
WY	245	Wyoming
WY	194	Casper
SD	242	South Dakota
NB	237	Nebraska
CO	163	Yampa
CO	162	San Luis
CO	161	San Isabel
CO	160	Pawnee
CO	159	Grand Mesa
CO	158	Comanche
CO	5	Metropolitan Denver
CO/UT/NM/AZ	89	Four Corners
UT	36	Wasatch Front
UT	243	Utah
NM/TX	46	El Paso-Las Cruces-Alamagordo
NM	44	Albuquerque - Mid Rio Grande

TABLE B-1: Continued

<u>State</u>	<u>Number</u>	<u>Name</u>
NM	226	Upper Rio Grande Valley
NM	227	Northeastern Plains
NM	228	Southwestern Mountains-Augustine Plains
AZ/NV	47	Clark - Mohave
AZ	25	Phoenix - Tucson
AZ/NM	82	Arizona - New Mexico Southern Border
NV	238	Nevada
NV	90	Northwest Nevada
CA	147	North Coast
CA	148	Northeast Plateau
CA	149	Sacramento Valley
CA	10	San Francisco Bay Area
CA	151	San Joaquin Valley
CA	146	North Central Coast
CA	152	South Central Coast
CA	6	Metropolitan Los Angeles
CA	150	San Diego
CA	153	Southeast Desert
CA	145	Great Basin Valleys

APPENDIX C

POWER PLANT EMISSIONS DATA

The emissions figures given in Table C-2 of this Appendix and used in the calculations presented in Tables 4 and 5 in the text were developed at the Los Alamos Scientific Laboratory (LASL).⁽²⁸⁾ The following is a general description of the procedures they used in doing this:

(1) Actual 1975 emissions data for existing plants was obtained from National Emissions Data Service (NEDS) tapes provided to LASL by the U.S. Environmental Protection Agency (EPA).

(2) Emissions for 1985 from plants already operating in 1975 were assumed to remain at 1975 levels as given by NEDS data.

(3) For units to be added to sites where some units were already operating in 1975, emissions per MWe of capacity were assumed to be the same as the 1975 levels for the existing plants at those sites as given by NEDS data.

(4) For new plants at new sites "standard multipliers" for the type of fuel to be burned were developed. These "standard multipliers" were obtained by excluding "outliers" from the 1975 NEDS data for each fuel type and averaging the remaining levels of emissions per MWe of capacity. These multipliers for particulate emissions are given in Table C-1.

TABLE C-1: "Standard Multipliers" Used to
Estimate New Power Plants' Emissions
Levels

<u>Fuel Burned</u>	<u>Tons of Particulates per MWe</u>
Coal	19.93
Oil	2.42
Gas	0.71

TABLE C-2: POWER PLANT EMISSIONS DATA
BY AIR QUALITY CONTROL REGION (39)

<u>State</u>	<u>Air Quality Control Region</u>	Particulate Emissions from Power Plants (tons/yr)	
		<u>Existing in 1975</u>	<u>Proposed for 1985</u>
OR/WA	35	12,328	12,405
OR	201	3,130	3,130
ID	49	0	6,260
MT	156	0	12,896
WY	52	0	8,589
WY	245	19,590	36,242
WY	194	18,550	18,550
CO	163	1,459	10,183
CO	5	9,162	9,162
CO	161	2,128	4,256
UT/AZ/NM/CO	89	35,297	94,362
NM/TX	46	70	126
AZ/NM	82	44	2,297
AZ	25	673	702
NV/AZ	47	5,370	19,135
CA	10	1,125	1,293
CA	146	946	946
CA	152	219	219
CA	6	8,256	8,317
CA	150	757	1,007
CA	153	77	709
WSCC Total		119,181	250,786

APPENDIX D

HOUSEHOLD DATA

TABLE D-1: 1970 Households by Air Quality
Control Region in the West

<u>Air Quality Control Region</u>	<u>County</u>	<u>State</u>	<u>Households*</u>
171	Clallam	WA	11,681
	Grays Harbor	WA	19,952
	Island	WA	8,400
	Jefferson	WA	3,666
	Mason	WA	6,768
	Pacific	WA	5,598
	San Juan	WA	1,514
	Skagit	WA	17,149
	Thurston	WA	25,186
	Whatcom	WA	26,720
	Total		126,634
170	Chelan	WA	14,396
	Douglas	WA	5,268
	Ferry	WA	1,113
	Okanogan	WA	8,486
	Pend Oreille	WA	2,030
	Stevens	WA	5,580
	Total		36,873
22	King	WA	391,759
	Kitsap	WA	32,856
	Pierce	WA	123,421
	Snohomish	WA	81,463
	Total		629,499
172	Benton	WA	20,520
	Franklin	WA	7,879
	Kittitas	WA	3,970
	Klickitat	WA	7,846
	Walla Walla	WA	13,438
	Yakima	WA	46,482
	Total		100,135
35	Benton	OR	15,898
	Clackamas	OR	51,677
	Columbia	OR	9,134
	Lane	OR	68,257
	Linn	OR	22,657
	Marion	OR	47,963
	Multnomah	OR	199,591
	Polk	OR	11,212

* Defined as total number of occupied housing units in County and City Data Book, 1972 (30)

TABLE D-1: Continued

<u>Air Quality Control Region</u>	<u>County</u>	<u>State</u>	<u>Households*</u>
35 (Continued)	Washington	OR	49,173
	Yamhill	OR	12,588
	Clark	WA	41,064
	Cowlitz	WA	22,140
	Lewis	WA	15,282
	Skamania	WA	1,841
	Wahkiakum	WA	1,150
	Total		569,627
203	Clatsop	OR	10,205
	Lincoln	OR	9,365
	Tillamook	OR	6,130
	Total		25,700
202	Coos	OR	18,325
	Curry	OR	4,384
	Douglas	OR	22,560
	Jackson	OR	31,384
	Josephine	OR	12,327
	Total		88,980
200	Crook	OR	3,366
	Deschutes	OR	10,101
	Hood River	OR	4,442
	Jefferson	OR	2,560
	Klamath	OR	16,307
	Lake	OR	2,053
	Sherman	OR	758
	Wasco	OR	6,475
	Total		46,062
201	Baker	OR	5,093
	Gilliam	OR	725
	Grant	OR	2,360
	Harney	OR	2,313
	Malheur	OR	6,964
	Morrow	OR	1,487
	Umatilla	OR	14,593
	Union	OR	6,427
	Wallowa	OR	2,117
	Wheeler	OR	660
	Total		42,739
83	Benewah	ID	2,053
	Kootenai	ID	11,561
	Latah	ID	7,676
	Nez	ID	9,973
	Shoshone	ID	6,340
	Adams	WA	3,553
	Asotin	WA	4,615
	Columbia	WA	1,467

TABLE D-1: Continued

<u>Air Quality Control Region</u>	<u>County</u>	<u>State</u>	<u>Households*</u>
83 (Continued)	Garfield	WA	985
	Grant	WA	12,584
	Lincoln	WA	3,356
	Spokane	WA	93,681
	Whitman	WA	10,728
	Total		<hr/> 168,572
236	Adams	ID	944
	Blaine	ID	1,977
	Boise	ID	578
	Bonner	ID	5,164
	Boundary	ID	1,999
	Camas	ID	211
	Cassia	ID	4,936
	Clearwater	ID	3,360
	Custer	ID	952
	Elmore	ID	4,758
	Gem	ID	2,993
	Gooding	ID	2,818
	Idaho	ID	3,845
	Jerome	ID	3,289
	Lemhi	ID	1,823
	Lewis	ID	1,246
	Lincoln	ID	936
	Minidoka	ID	4,428
	Owyhee	ID	1,872
	Payette	ID	4,145
	Twin Falls	ID	13,729
	Valley	ID	1,150
	Washington	ID	2,580
	Total		<hr/> 69,733
49	Ada County	ID	35,834
	Canyon County	ID	19,266
	Total		<hr/> 55,100
173	Bannock	ID	15,610
	Bear Lake	ID	1,791
	Bingham	ID	7,770
	Bonneville	ID	14,617
	Butte	ID	848
	Caribou	ID	1,837
	Clark	ID	208
	Franklin	ID	2,182
	Fremont	ID	2,487
	Jefferson	ID	3,201
	Madison	ID	2,952
	Oneida	ID	955
	Power	ID	1,428
	Teton	ID	638
	Total		<hr/> 56,524

TABLE D-1: Continued

<u>Air Quality Control Region</u>	<u>County</u>	<u>State</u>	<u>Households*</u>
157	Flathead	MT	12,305
	Lake	MT	4,422
	Lincoln	MT	5,347
	Mineral	MT	897
	Missoula	MT	18,012
	Ravalli	MT	4,738
	Sanders	MT	2,373
	Total		<u>48,094</u>
154	Blaine	MT	1,956
	Cascade	MT	25,292
	Chouteau	MT	2,051
	Glacier	MT	3,005
	Hill	MT	5,225
	Liberty	MT	635
	Pondera	MT	1,998
	Teton	MT	1,943
	Toole	MT	1,872
	Total		<u>43,977</u>
156	Carter	MT	623
	Custer	MT	3,936
	Daniels	MT	1,018
	Dawson	MT	3,368
	Fallon	MT	1,220
	Garfield	MT	535
	McCone	MT	818
	Phillips	MT	1,722
	Powder River	MT	840
	Prairie	MT	4,738
	Richland	MT	3,060
	Roosevelt	MT	2,948
	Rosebud	MT	1,817
	Sheridan	MT	1,815
	Treasure	MT	321
	Valley	MT	3,485
	Wibaux	MT	461
	Total		<u>32,725</u>
50	Big Horn	MT	2,664
	Carbon	MT	2,538
	Fergus	MT	4,026
	Golden Valley	MT	322
	Judith Basin	MT	873
	Musselshell	MT	1,320
	Petroleum	MT	230
	Stillwater	MT	1,587
	Sweet Grass	MT	1,056
	Wheatland	MT	875
	Yellowstone	MT	27,641
	Total		<u>43,132</u>

TABLE D-1: Continued

<u>Air Quality Control Region</u>	<u>County</u>	<u>State</u>	<u>Households*</u>
155	Beaverhead	MT	2,683
	Broadwater	MT	795
	Deer Lodge	MT	4,581
	Gallatin	MT	9,754
	Granite	MT	923
	Jefferson	MT	1,360
	Lewis and Clark	MT	10,826
	Madison	MT	1,696
	Meagher	MT	710
	Park	MT	3,947
	Powell	MT	2,028
	Silver Bow	MT	14,142
	Total		53,445
52	Albany	WY	8,001
	Goshen	WY	3,607
	Laramie	WY	17,866
	Platte	WY	2,247
	Total		31,721
245	Big Horn	WY	3,288
	Campbell	WY	3,729
	Carbon	WY	4,308
	Crook	WY	1,410
	Hot Springs	WY	1,708
	Johnson	WY	1,882
	Lincoln	WY	2,573
	Niobrara	WY	1,075
	Park	WY	5,534
	Sheridan	WY	6,189
	Sublette	WY	1,159
	Sweetwater	WY	5,889
	Teton	WY	1,564
	Uinta	WY	2,049
	Washakie	WY	2,362
	Weston	WY	1,960
	Total		46,679
194	Converse	WY	1,958
	Fremont	WY	8,050
	Natrona	WY	16,193
	Total		26,201
242	Aurora	SD	1,273
	Beadle	SD	6,643
	Bennett	SD	868
	Bon Homme	SD	2,634
	Brookings	SD	6,276
	Brown	SD	11,214
	Brule	SD	1,802
	Buffalo	SD	356

TABLE D-1: Continued

<u>Air Quality Control Region</u>	<u>County</u>	<u>State</u>	<u>Households*</u>
242 (Continued)	Campbell	SD	845
	Charles Mix	SD	3,015
	Clark County	SD	1,864
	Clay County	SD	3,629
	Codington	SD	6,067
	Corson	SD	1,280
	Davison	SD	5,447
	Day	SD	2,774
	Deuel	SD	1,822
	Dewey	SD	1,325
	Douglas	SD	1,383
	Edmunds	SD	1,656
	Faulk	SD	1,183
	Grant	SD	2,752
	Gregory	SD	2,195
	Haakon	SD	861
	Hamlin	SD	1,652
	Hand	SD	1,777
	Hanson	SD	1,134
	Harding	SD	539
	Hughes	SD	3,551
	Hutchinson	SD	3,302
	Total		81,119
237	Adams	NB	10,140
	Antelope	NB	3,016
	Arthur	NB	167
	Banner	NB	349
	Blaine	NB	265
	Boone	NB	2,591
	Box Butte	NB	3,381
	Boyd	NB	1,249
	Brown	NB	1,394
	Buffalo	NB	9,657
	Burt	NB	3,182
	Butler	NB	3,115
	Cass	NB	5,683
	Cedar	NB	3,453
	Chase	NB	1,408
	Cherry	NB	2,280
	Cheyenne	NB	3,534
	Clay	NB	2,749
	Colfax	NB	3,261
	Cuming	NB	3,781
	Custer	NB	4,867
	Dawes	NB	3,033
	Dawson	NB	6,464
	Deuel	NB	970
	Dixon	NB	2,408
	Dodge	NB	11,315
	Dundy	NB	1,603

TABLE D-1: Continued

<u>Air Quality Control Region</u>	<u>County</u>	<u>State</u>	<u>Households*</u>
237 (Continued)	Fillmore	NB	2,804
	Franklin	NB	1,676
	Frontier	NB	1,300
	Furnas	NB	2,517
	Garden	NB	1,049
	Garfield	NB	891
	Gosper	NB	700
	Grant	NB	293
	Greeley	NB	1,277
	Hall	NB	14,054
	Hamilton	NB	2,804
	Harlan	NB	1,558
	Hayes	NB	490
	Hitchcock	NB	1,413
	Holt	NB	4,072
	Hooker	NB	347
	Howard	NB	2,165
	Johnson	NB	1,984
	Kearney	NB	2,190
	Keith	NB	2,754
	Keya Paha	NB	418
	Kimball	NB	1,879
	Knox	NB	3,810
	Lincoln	NB	9,695
	Logan	NB	332
	Loup	NB	294
	McPherson	NB	191
	Madison	NB	8,966
	Merrick	NB	2,781
	Morrill	NB	1,899
	Nance	NB	1,684
	Nemaha	NB	3,028
	Nuckolls	NB	2,535
	Otoe	NB	5,420
	Pawnee	NB	1,602
	Perkins	NB	1,193
	Phelps	NB	3,239
	Pierce	NB	2,713
	Platte	NB	7,973
	Polk	NB	2,211
	Red Willow	NB	4,132
	Richardson	NB	4,419
	Rock County	NB	800
	Saline	NB	4,406
	Saunders	NB	5,453
	Scotts Bluff	NB	11,267
	Seward	NB	4,308

TABLE D-1: Continued

<u>Air Quality Control Region</u>	<u>County</u>	<u>State</u>	<u>Households*</u>
237 (Continued)	Sheridan	NB	2,353
	Sherman	NB	1,553
	Sioux	NB	659
	Stanton	NB	1,796
	Thomas	NB	283
	Thurston	NB	2,084
	Valley	NB	2,018
	Washington	NB	4,099
	Wayne	NB	2,986
	Webster	NB	1,949
	Wheeler	NB	329
	York	NB	4,525
	Total		<hr/> 262,935
163	Grand	CO	1,358
	Jackson	CO	537
	Moffat	CO	2,079
	Rio Blanco	CO	1,474
	Routt	CO	2,159
	Total		<hr/> 7,607
162	Alamosa	CO	3,285
	Conejos	CO	1,980
	Costilla	CO	826
	Mineral	CO	270
	Rio Grande	CO	3,070
	Saguache	CO	1,134
	Totals		<hr/> 10,565
161	Chaffee	CO	3,176
	Custer	CO	412
	El Paso	CO	67,581
	Fremont	CO	7,006
	Huerfano	CO	2,236
	Lake	CO	2,443
	Las Animas County	CO	5,084
	Park	CO	710
	Pueblo	CO	35,373
	Teller	CO	1,127
	Total		<hr/> 125,148
160	Larimer	CO	28,183
	Logan	CO	5,808
	Morgan	CO	6,300
	Phillips	CO	1,471
	Sedgwick	CO	1,161
	Washington	CO	1,848
	Weld	CO	26,664
	Yuma	CO	3,013
	Total		<hr/> 74,448

TABLE D-1: Continued

<u>Air Quality Control Region</u>	<u>County</u>	<u>State</u>	<u>Households*</u>
159	Delta	CO	5,297
	Eagle	CO	2,303
	Garfield	CO	4,923
	Gunnison	CO	2,215
	Hinsdale	CO	49
	Mesa	CO	17,640
	Montrose	CO	5,612
	Ouray	CO	585
	Pitkin	CO	2,069
	San Miguel	CO	610
	Summit	CO	862
	Total		<u>42,165</u>
158	Baca	CO	1,938
	Bent	CO	1,941
	Cheyenne	CO	764
	Crowley	CO	1,083
	Elbert	CO	1,280
	Kiowa	CO	686
	Kit Carson	CO	2,387
	Lincoln	CO	1,605
	Otero	CO	7,277
	Prowers	CO	4,151
	Total		<u>23,112</u>
5	Adams	CO	50,024
	Arapahoe	CO	47,529
	Boulder	CO	40,854
	Clear Creek	CO	1,635
	Denver	CO	185,331
	Douglas	CO	2,410
	Gilpin	CO	481
	Jefferson	CO	68,363
	Total		<u>396,627</u>
89	Apache	AZ	6,832
	Coconino	AZ	12,474
	Navajo	AZ	11,278
	Yavapai	AZ	12,999
	Archuleta	CO	817
	Dolores	CO	510
	La Plata	CO	5,683
	Montezuma	CO	3,965
	San Juan	CO	282
	San Juan	NM	13,269
	Rio Arriba (30%)	NM	1,918
	Sandoval (10%)	NM	414
	McKinley (70%)	NM	6,773
	Valencia (10%)	NM	1,034

TABLE D-1: Continued

<u>Air Quality Control Region</u>	<u>County</u>	<u>State</u>	<u>Households*</u>
89 (Continued)	Emery	UT	1,540
	Garfield	UT	923
	Grand	UT	1,872
	Iron	UT	3,378
	Kane	UT	710
	San Juan	UT	2,206
	Washington	UT	3,834
	Wayne	UT	472
	Total		93,183
36	Davis	UT	23,772
	Salt Lake	UT	134,926
	Tooele	UT	6,078
	Utah	UT	34,473
	Weber	UT	37,252
	Total		236,501
243	Beaver	UT	1,191
	Box Elder	UT	7,642
	Cache	UT	11,798
	Carbon	UT	4,945
	Daggett	UT	174
	Duchesne	UT	1,943
	Juab	UT	1,390
	Millard	UT	2,094
	Morgan	UT	1,054
	Piute	UT	359
	Rich	UT	483
	Sanpete	UT	3,436
	Sevier	UT	3,162
	Summit	UT	1,727
	Uintah	UT	3,433
	Wasatch	UT	1,667
	Total		46,498
46	Dona Ana	NM	18,524
	Lincoln	NM	2,440
	Otero	NM	10,934
	Sierra	NM	2,898
	Brewster	TX	2,331
	Culberson	TX	913
	El Paso	TX	95,843
	Hudspeth	TX	616
	Jeff Davis	TX	455
	Presidio	TX	1,455
	Total		136,409

TABLE D-1: Continued

<u>Air Quality Control Region</u>	<u>County</u>	<u>State</u>	<u>Households*</u>
44	Bernalillo	NM	94,223
	Sandoval (90%)	NM	3,727
	Valencia (40%)	NM	4,134
	Total		<u>102,084</u>
226	Los Alamos	NM	4,461
	Santa Fe	NM	15,300
	Taos	NM	4,811
	Rio Arriba (70%)	NM	4,475
	Total		<u>29,047</u>
227	Colfax	NM	3,794
	Guadalupe	NM	1,346
	Harding	NM	434
	Mora	NM	1,280
	San Miguel	NM	5,506
	Torrance	NM	1,621
	Union	NM	1,629
	Total		<u>15,610</u>
228	Catron	NM	717
	Socorro	NM	2,716
	McKinley (30%)	NM	2,903
	Valencia (50%)	NM	5,167
	Total		<u>11,503</u>
47	Clarke	NV	87,728
	Mohave	AZ	8,626
	Yuma	AZ	17,582
	Totals		<u>113,936</u>
25	Gila	AZ	8,806
	Maricopa	AZ	302,633
	Pima	AZ	110,785
	Pinal	AZ	18,096
	Santa Cruz	AZ	3,817
	Total		<u>444,137</u>
82	Cochise	AZ	17,878
	Graham	AZ	4,325
	Greenlee	AZ	3,022
	Grant	NM	6,242
	Hidalgo	NM	1,350
	Luna	NM	3,536
	Total		<u>36,353</u>

TABLE D-1: Continued

<u>Air Quality Control Region</u>	<u>County</u>	<u>State</u>	<u>Household*</u>
238	Churchill	NV	3,379
	Elko	NV	4,555
	Esmeralda	NV	234
	Eureka	NV	347
	Humboldt	NV	2,145
	Lander	NV	843
	Lincoln	NV	792
	Mineral	NV	2,286
	Nye	NV	1,813
	Pershing	NV	937
	White Pine	NV	3,116
	Total		<u>20,447</u>
90	Carson City	NV	4,837
	Douglas	NV	2,389
	Lyon	NV	2,618
	Storey	NV	246
	Washoe	NV	41,787
	Total		<u>51,877</u>
147	Del Norte	CA	4,707
	Humboldt	CA	32,383
	Lake	CA	7,679
	Mendocino	CA	16,538
	Trinity	CA	2,608
	Siskiyou (50%)	CA	5,642
	Total		<u>69,557</u>
148	Lassen	CA	5,269
	Modoc	CA	2,524
	Shasta (25%)	CA	6,322
	Siskiyou (50%)	CA	5,641
	Total		<u>19,756</u>
149	Butte	CA	34,910
	Colusa	CA	4,136
	El Dorado	CA	15,031
	Glenn	CA	5,723
	Nevada	CA	9,601
	Placer	CA	24,557
	Plumas	CA	4,140
	Sacramento	CA	202,953
	Sierra	CA	874
	Sutter	CA	13,159
	Tehama	CA	9,567
	Yolo	CA	28,316
	Yuba	CA	13,074
	Shasta (75%)	CA	18,968
	Total		<u>385,009</u>
145	Alpine	CA	165
	Inyo	CA	5,536
	Mono	CA	1,382
	Total		<u>7,083</u>

TABLE D-1: Continued

<u>Air Quality Control Region</u>	<u>County</u>	<u>State</u>	<u>Household*</u>
10	Alameda	CA	365,093
	Contra Costa	CA	172,951
	Marin	CA	67,266
	Napa	CA	25,098
	San Francisco	CA	295,174
	San Mateo	CA	185,028
	Santa Clara	CA	322,782
	Solano	CA	51,120
	Sonoma	CA	67,861
	Total		1,552,373
151	Amador	CA	4,037
	Calaveras	CA	4,709
	Fresno	CA	126,752
	Kings	CA	18,731
	Madera	CA	12,756
	Mariposa	CA	2,204
	Merced	CA	30,464
	San Joaquin	CA	92,372
	Stanislaus	CA	62,100
	Tulare	CA	56,490
	Tuolumne	CA	7,498
	Kern (75%)	CA	76,238
	Total		550,841
146	Monterey	CA	71,232
	San Benito	CA	5,460
	Santa Cruz	CA	44,420
	Total		121,112
152	San Luis Obispo	CA	33,926
	Santa Barbara (60%)	CA	50,357
	Total		84,283
6	Orange	CA	436,120
	Ventura	CA	106,469
	Riverside (40%)	CA	60,202
	San Bernardino (40%)	CA	84,554
	Los Angeles (80%)	CA	1,944,658
	Santa Barbara (40%)	CA	33,572
	Total		2,665,574
150	San Diego (90%)	CA	380,490
153	Imperial	CA	21,030
	San Diego (10%)	CA	42,277
	Riverside (60%)	CA	90,302
	San Bernardino (60%)	CA	126,831
	Los Angeles (20%)	CA	486,164
	Kern (25%)	CA	25,412
	Total		792,017

APPENDIX E

RECREATIONAL VISITATION DATA

TABLE E-1: 1975 National Park Service Visitation Data for
Air Quality Control Regions in the West (35)

<u>State</u>	<u>Air Quality Control Region</u>	<u>National Park, National Monument, National Recreation Area, or National Historical Site</u>	<u>1975 Visitor Days (1,000)</u>
WA	171	San Juan Island - NHP	4.60
WA	171	Olympic - NP	1062.86
WA	171	Ross Lake - NRA	---
WA	171/170	North Cascades - NP	173.19
WA	170	Lake Chelan - NRA	---
WA	170	Coulee Dam - NRA	203.80
WA	22	Mount Rainier - NP	1486.28
WA	172	Whitman Mission - NHS	14.11
WA	35	Fort Vancouver - NHS	14.86
OR	203	Fort Clatsop - NMem	7.13
OR	202	Oregon Caves - NM	47.78
OR	200	Crater Lake - NP	156.83
OR	201	None	0
ID	83	Nez Perce - NHP	28.13
ID	236	Craters of the Moon - NM	59.42
ID	49	None	0
ID	173	Yellowstone (part - 5%) - NP	272.11
MT	157	National Bison Range	---
MT	157/154	Glacier (60/40) - NP	2972.62
MT	154	International Peace Park	---
MT/ND	156	Fort Union Trading Post - NHS	0.20
MT	50	Custer Battlefield - NM	19.35
MT	50	Bighorn Canyon (part - 50%) - NRA	75.94
MT	155	Yellowstone (part - 10%) - NP	544.21
MT	155	Big Hole - NB	2.75
WY	52	Fort Laramie - NHS	13.33
WY	245	Grand Tetons - NP	1457.81
WY	245	Devils Tower - NM	30.52
WY	245	Bighorn Canyon (part-50%) - NRA	75.94
WY	245	Flaming Gorge (part) - NRA	---
WY	245	Yellowstone (part -85%) - NP	4625.82
WY	?	John D. Rockefeller Pkw	216.18
WY	?	Fossil Butte - NM	0.47
WY	194	None	0
NB	237	Agate Fossil Beds - NM	0.84

TABLE E-1: Continued

State	Air Quality Control Region	National Park, National Monument, National Recreation Area, or National Historical Site	1975 Visitor Days (1,000)
CO	163	Dinosaur (part - 25%) - NM	42.83
CO	163	Rocky Mountain - NP	1732.78
CO	163	Shadow Mountain - NRA	186.53
CO	162	Great Sand Dunes - NM	83.45
CO	161	None	0
CO	160	None	0
CO	159	Curecanti - NRA	203.33
CO	159	Black Canyon of the Gunnison - NM	85.22
CO	159	Colorado - NM	125.37
CO	158	Bents Old Fort - NHS	3.79
CO	89	Mesa Verde - NP	693.28
CO	89	Yucca House - NM	---
CO	89	Hovenweep - NM	4.69
CO	?	Florissant Fossil Beds - NM	1.84
CO	5	None	0
UT	36	Timpanogos Caves - NM	23.65
UT	89	Zion - NP	1063.09
UT	89	Bryce Canyon - NP	241.29
UT	89	Canyonlands - NP	91.51
UT	89	Arches - NP	133.28
UT	89	Capital Reef - NP	46.90
UT	89	Glen Canyon - NRA	1217.99
UT	89	Cedar Breaks - NM	60.03
UT	89	Natural Bridges - NM	21.63
UT	89	Rainbow Bridge - NM	10.78
UT	243	Golden Spike - NHS	7.10
UT	243	Dinosaur (part) - NM	128.49
UT	243	Flaming Gorge (part) - NRA	---
NM	44	None	0
NM	46	White Sands - NM	58.27
NM	46	Carlsbad Caverns - NP	244.84
NM	82	None	0
NM	89	Aztec Ruins - NM	8.45
NM	89	Chaco Canyon - NM	29.44
NM	89	El Moro - NM	6.87
NM	226	Bandelier - NM	118.39
NM	227	Gran Quivira - NM	3.50
NM	227	Pecos - NM	3.56
NM	227	Fort Union - NHS	1.60
NM	227	Capulin Mountain - NM	5.72
NM	228	Gila Cliff Dwelling - NM	3.47
NM	229	None	0
TX	46	Guadalupe Mountains - NP	16.17
TX	46	Big Bend - NP	735.92

TABLE E-1: Continued

State	Air Quality Control Region	National Park, National Monument, National Recreation Area, or National Historical Site	1975 Visits (1,000)
AZ	25	Oregon Pipe Cactus - NM	79.73
AZ	25	Casa Grande Ruins - NM	8.04
AZ	47	Lake Meade (part - 50%) - NRA	2977.38
AZ	82	Chiricahua - NM	25.29
AZ	82	Tumacacori - NM	4.38
AZ	82	Saguaro - NM	40.06
AZ	82	Fort Bowie - NHS	0.88
AZ	89	Petrified Forest - NP	124.81
AZ	89	Grand Canyon - NP	3805.56
AZ	89	Glen Canyon (part - 10%) - NRA	135.33
AZ	89	Hubble Trading Post - NHS	11.28
AZ	89	Canyon de Chelly - NM	223.05
AZ	89	Grand Canyon - NM	0
AZ	89	Coronado - NMem	8.81
AZ	89	Marble Canyon - NM	---
AZ	89	Montezuma Castle - NM	39.89
AZ	89	Navajo - NM	16.35
AZ	89	Pipe Springs - NM	2.01
AZ	89	Sunset Crater - NM	24.34
AZ	89	Tonto - NM	5.99
AZ	89	Tunzigooot - NM	5.36
AZ	89	Walnut Canyon - NM	7.83
AZ	89	Wapatki - NM	15.19
NV	47	Lake Mead (part - 50%) - NRA	2977.38
NV	90	None	0
NV	238	Death Valley (part - 10%) - NM	56.13
NV	238	Lehman Caves - NM	6.86
NV	238	Valley of Fire	---
CA	6	Channel Islands - NM	58.21
CA	10	John Muir - NHS	3.39
CA	10	Golden Gate - NRA	313.76
CA	10	Point Reyes - NS	623.97
CA	151	Devils Postpile - NM	58.25
CA	146	Pinnacles - NM	101.44
CA	147	Redwood - NP	35.47
CA	148	Lassen Volcano - NP	573.26
CA	148	Lava Beds - NM	27.05
CA	149	Muir Woods - NM	109.04
CA	149	Whiskeytown - NRA	388.28
CA	150	Cabrillo - NM	173.18
CA	151	Yosemite - NP	8496.49
CA	151	Kings Canyon - NP	2834.76
CA	151	Sequoia - NP	2592.84
CA	152	None	0
CA	153	Joshua Tree - NM	646.10
CA	?	Fort Point - NHS	44.11
CA	145	Death Valley (part - 90%) - NM	505.18

TABLE E-2: Recreational Visitor Days and Visitor Party Days in National Park Service Controlled Areas by Air Quality Control Region in the West

<u>State</u>	<u>Air Quality Control Region</u>	<u>Visitor Days (1,000)</u>	<u>Visitor Party Days (1,000)</u>
WA	171	1,154.06	329.73
WA	170	290.40	82.97
WA	22	1,486.28	424.65
WA	172	14.11	4.03
OR/WA	35	14.86	4.25
OR	203	7.13	2.04
OR	202	47.78	13.65
OR	200	156.83	44.81
OR	201	---	---
ID/WA	83	28.13	8.04
ID	236	59.42	16.98
ID	49	---	---
ID	173	272.11	77.75
MT	157	1,783.57	509.59
MT	154	1,189.05	339.73
MT	156	0.20	0.06
MT	50	95.29	27.23
MT	155	546.96	156.27
WY	245	6,190.09	1,768.60
WY	194	---	---
WY	52	13.33	3.81
NB	237	0.84	0.24
CO	163	1,962.14	560.61
CO	162	83.45	23.84
CO	161	---	---
CO	160	---	---
CO	159	413.92	118.26
CO	158	3.79	1.08
CO	5	---	---
UT	243	135.59	38.74
UT	36	23.65	6.76
UT/AZ/NM/CO	89	8,046.22	2,298.92

TABLE E-2: Continued

<u>State</u>	<u>Air Quality Control Region</u>	<u>Visitor Days (1,000)</u>	<u>Visitor Party Days (1,000)</u>
NM	44	---	---
NM/TX	46	1,055.20	301.49
NM	226	118.39	33.83
NM	227	14.38	4.11
NM	228	3.47	0.99
NM	229	---	---
AZ	25	87.77	25.08
AZ/NM	82	70.61	20.17
NV/AZ	47	5,954.76	1,701.36
NV	90	---	---
NV	238	6.86	1.96
CA	6	58.21	16.63
CA	10	941.12	268.89
CA	145	505.18	144.34
CA	146	101.44	28.98
CA	147	35.47	10.13
CA	148	600.31	171.52
CA	149	497.32	142.09
CA	150	173.18	49.48
CA	151	13,924.09	3,978.31
CA	152	---	---
CA	153	646.10	184.60
TOTAL			13,946.60

REFERENCES

1. Randall, Alan, Berry C. Ives, and Clyde Eastman, "Benefits of Abating Aesthetic Environmental Damage from the Four Corners Power Plant, Fruitland, New Mexico," New Mexico State University Agricultural Experiment Station, Bulletin 618, Las Cruces, New Mexico, May 1974.
2. Ayres, Robert U., and Allen V. Kneese, "Production, Consumption and Externalities," American Economic Review, June 1969, pp. 282-297.
3. Bator, Francis M., "The Anatomy of Market Failure," The Quarterly Journal of Economics, August 1958, pp. 251-379
4. Baumol, William J., and Wallace E. Oates, The Theory of Environmental Policy: Externalities, Public Outlays, and Quality of Life, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1975
5. Buchanan, James M. and William Craig Stubblebine, "Externality," Economica, November 1962, pp. 371-384.
6. Coase, R. H., "The Problem of Social Cost," Journal of Law and Economics, October 1960, pp. 1-44.
7. Davis, O.A. and A. B. Whinston, "Externalities, Welfare, and the Theory of Games," Journal of Political Economy, June 1962, pp. 241-262.
8. Davis, O.A. and A. B. Whinston, "On the Distinction between Public and Private Goods," American Economic Review, May 1967, pp. 360-373.
9. Demsetz, Harold, "Toward a Theory of Property Rights," American Economic Review, May 1967 pp. 347-359.
10. Ellis, Howard S. and William Fellner, "External Economies and Diseconomies," American Economic Review, September 1943, pp. 493-511:
11. Furubotn, Eirik G. and Svetozar Pejovich, "Property Rights and Economic Theory: A Survey of Recent Literature," Journal of Economic Literature, December 1972, pp. 1137-1162.
12. Graaff, J.de V., Theoretical Welfare Economics, London, Cambridge University Press, 1957.
13. Haveman, Robert H., "Common Property, Congestion, and Environmental Pollution," Quarterly Journal of Economics, May 1973, pp. 278-287.
14. Head, J.G., and C.S. Shoup, "Public Goods, Private Goods, and Ambiguous Goods," The Economic Journal, September 1969, pp. 567-572.
15. Knight, Frank H., "Some Fallacies in the Interpretation of Social Cost," The Quarterly Journal of Economics, August 1924, pp. 582-606.

REFERENCES - Continued

16. Måler, Karl-Göran, Environmental Economics: A Theoretical Inquiry, published for Resources for the Future, Inc. by The Johns Hopkins University Press, Baltimore and London, 1974.
17. Meade, James E., "External Economies and Diseconomies in a Competitive Situation," The Economic Journal, March 1952, pp. 54-67.
18. Mishan, E.J., "The Relationship Between Joint Products, Collective Goods and External Effects," Journal of Political Economy, May/June 1969, pp. 329-348.
19. Mishan, E.J., "The Postwar Literature on Externalities: An Interpretive Essay," Journal of Economic Literature, March 1971, pp. 1-28.
20. Pigou, A.C., The Economics of Welfare, 4th Edition, London: Macmillan and Co., Ltd., 1932
21. Rothenberg, Jerome, "The Economics of Congestion and Pollution: An Integrated View," American Economic Review, May 1970, pp. 114-121
22. Samuelson, P.A., "Evaluation of Real National Income," Oxford Economic Papers, 1950, pp. 1-29.
23. Samuelson, P. A., "The Pure Theory of Public Expenditures," Review of Economics and Statistics, 1954, pp. 386-389.
24. Samuelson, P. A., "Contrast Between Welfare Conditions for Joint Supply and for Public Goods," Review of Economics and Statistics, February 1969, pp. 26-30.
25. Scitovsky, Tibor, "Two Concepts of External Economies," Journal of Political Economy, 1954, pp. 143-151
26. Scherer, F. M., Industrial Market Structure and Economic Performance, Chicago, Rand McNally & Company, 1970.
27. Erickson, L.E., An Economic Study of a Common Property Problem: The Dungeness Crab Fishery on the Washington Coast, Ph.D. dissertation, University of Michigan, Ann Arbor, Michigan, 1975.
28. Methodology for Tradeoff Analysis of the Costs, Risks and Benefits of Electric Power Production in the West: First Annual Report, Andrew Ford, Editor, Los Alamos Scientific Laboratory, Los Alamos, New Mexico, February 1977.

REFERENCES - Continued

27. U. S. Bureau of the Census, County and City Data Book, 1972 (A Statistical Abstract Supplement), USGPO, Washington, D.C., 1973.
30. U. S. Department of the Interior, National Park Service Work List by Park for the Month of December, 1975, Statistical Unit of the National Park Service, unpublished.
31. U. S. Department of the Interior, Public Use of the National Park System, Fiscal Year Report - 1974, National Park Service, October 1974
32. Various issues of the Survey of Current Business, U.S. Department of Commerce, Social and Economic Statistics Administration, Bureau of Economic Analysis, USGPO, Washington, D.C.
33. Western Systems Coordinating Council, Reply to Federal Power Commission Docket, R-362, "Reliability and Adequacy of Electric Service," Order No. 383-3, April 1, 1976.
34. Office of the Assistant Commissioner for Regional Activities, Office of Air Programs, U.S. Environmental Protection Agency, Federal Air Quality Control Regions, AP-102, USGPO, January 1972.
35. Brookshire, David, Berry Ives, and William Schulze, The Valuation of Aesthetic Preferences, Resource Economics Group, Department of Economics, The University of New Mexico, Albuquerque, New Mexico, 1976.
36. Ralph C. D'Arge, University of Wyoming, and Alan Randall, University of Kentucky, are also conducting further work on the use of bidding games to value externalities.
37. Ramsdell, J. V., B. C. Scott, M. M. Orgill, J. E. Hubbard, D. S. Renne and K. A. McGinnis, Postulated Weather Modifications from Large Energy Centers, BNWL-2162, Battelle-Northwest, Richland, WA, February 1977.
38. Friedman, Milton, A Theory of the Consumption Function, National Bureau of Economic Research, Inc., New York, Princeton University Press, Princeton, N.J., 1957.

REFERENCES - Continued

39. Ferber, Robert, "Research on Household Behavior," American Economic Review, March 1962, pp. 19-63.
40. Fletcher, R. and M. J. D. Powell, "A Rapidly Convergent Descent Method for Minimization," Comput. J., 6:163-168, 1963.
41. Davidon, W.C., "Variable Metric Methods for Minimization," AEC Research and Development Report, ANL 5990 (Rev), 1959.
42. The method is described in E. Polak, Computational Methods in Optimization, A Unified Approach, Academic Press, New York, pp. 56-57, 1971.
43. The computer program used to perform these calculations was written by W. G. Howe, Knolls Atomic Power Laboratory, General Electric Company, Schenectady, New York. Special thanks are due to D.L. Stevens, BNW, for locating this program and T.J. Foley, BNW, for assistance in using it.

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