ECONOMIC ASSESSMENT OF MATERIALS DAMAGE IN THE SOUTH COAST AIR BASIN: A CASE STUDY OF ACID DEPOSITION EFFECTS ON PAINTED WOOD SURFACES USING INDIVIDUAL MAINTENANCE BEHAVIOR DATA

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FINAL REPORT

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ABSTRACT

The purpose of this case study is to examine the economic impact of acid deposition damage to painted wood surfaces in the South Coast Air Basin of Southern California. The analysis brings together four types of information. Estimates of physical damage rates and the distribution of materials are obtained from recently completed studies sponsored by the California Air Resources Board. These data are combined with disaggregate aerometric parameters and survey data on individual maintenance practices. The output of the analysis is an estimate of the annual cost-savings that would be realized for a 10 percent reduction in NO_2 concentrations. The annual cost savings are estimated for individiuals who reside in single family homes and make their own maintenance decisions. The scope of the analysis is further limited to six selected maintenance tasks that involve only painting of wood surfaces.

The data that describe individual maintenance practices are analyzed in two ways. In the physical damage function approach, results of field experiments on physical damage rates are combined with economic data to yield a best estimate of annual cost-savings for the six maintenance tasks of $0.7 million (1988 dollars). Consideration of some of the factors that contribute to uncertainty in this estimate leads to a range of values that fall between $0 and $1 million.

An alternative approach for analyzing the maintenance data is also presented. This approach relies on the estimation of economic damage directly. That is, physical damage rates are not considered. The result of the economic damage function analysis is that annual cost-savings for the six maintenance tasks are $3.6 million. The difference in the estimates of the two approaches is the result of differences in the relationship between changes in the length of the maintenance interval and changes in NO_2 concentrations.

DISCLAIMER

The statements and conclusions of this report are those of the contractor and not necessarily those of the California Air Resources Board. The mention of commercial products, their source or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products.

PREFACE

This report was prepared for the California Air Resources Board under Contract No. A732-062, "Cost of Materials Damage Caused by Acidic Deposition in the South Coast Air Basin." The prime contractor was Mathtech, Inc. Subcontract assistance was provided by Versar, Inc. (ESM Operations) and Opinion Research Corporation. A draft report was submitted in November 1989. The final report was completed as of May 1990.

Mathtech staff performed the economic analyses and prepared the final report. Versar staff developed the spatial grid of aerometric data which is described in Section 5. Opinion Research Corporation designed and conducted the survey of individual maintenance practices which is described in Section 6. Both subcontractors wrote major portions of their respective sections.

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SECTION 1

INTRODUCTION AND SUMMARY

1.1 INTRODUCTION

The Kapiloff Acid Deposition Act was adopted by the California Legislature in 1982. This Act requires the California Air Resources Board (ARB) to assess the causes and effects of acid deposition in California. One of the statutory goals of the Act is to "...determine the present and potential environmental, public health, and economic effects of continued acid deposition...".

The potential effects of acid deposition are diverse. Research is currently underway to assess the impact of acid deposition on lakes, forests, crops, materials, and human health. The results of this research will be useful to those individuals who must weigh the advantages and disadvantages of alternative acid deposition control strategies. This study is concerned with one of these impact categories, materials damage.

1.2 PURPOSE

The purpose of this study is to examine a methodology for the estimation of the materials damage associated with acid deposition in the South Coast Air Basin of Southern California. Previous studies have also addressed this problem and have developed estimates of air pollution damages to materials. However, recent ARB-sponsored research provides more detail about materials damage and materials distribution than was previously available. In addition, new data are collected as part of this study which describe individual maintenance practices and costs. As a result, it is possible to look at the materials damage problem in a new way. In this study, a methodology is developed which is based on the maintenance decisions of individuals. This methodology is applied, as a case study, to a set of specific maintenance tasks in order to develop partial estimates of the economic benefits of an air quality improvement.

1.3 APPROACH

The approach used in this study to estimate the economic impact of acid deposition on materials requires information that is similar to the information used in earlier assessments. A five step procedure is applied:

- Identify the magnitude and distribution of potentially affected materials.
- Model the spatial and temporal distributions of relevant acid deposition measures.
- Predict the rate of physical damage associated with exposure of the material to the modeled concentration of acid deposition. This is the **physical damage function.**[1]
- Describe the impact of changes in acid deposition concentrations on economic behavior.
- Compute the economic impacts of a change in acid deposition concentrations.

The basic assumption is that exposure of materials to acid deposition will lead to more frequent maintenance activities than would be performed in a less polluted environment. The change in the length of a maintenance interval is determined from changes in the rate of physical damage and assumptions about behavior. If the cost of performing a maintenance action is unaffected by changes in acid deposition, then an increase in the maintenance

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[1] Words, phrases or acronyms that appear in bold-face type the first time they are used are included in a Glossary at the end of the report.

interval length will decrease the annual cost of the maintenance action. That is, cost per year goes down. Differences in the annual costs of maintenance actions, for two levels of exposure to acid deposition, are the source of the quantitative estimates of economic impact made in this study.

The major difference between the present study and the earlier efforts is the availability of data on individual maintenance behavior. These data allow the research to consider specific maintenance tasks (e.g., paint wood trim) instead of more general material-use combinations. Furthermore, all observations on maintenance behavior are collected for a specific building. This allows the research to extrapolate per building damage estimates on the basis of building counts. This contrasts with earlier studies in which the extrapolation of results depended on material densities. These differences are described further in Section 2.

1.4 SCOPE OF ANALYSIS

To understand and properly interpret the results of this analysis, it is extremely important to recognize the limitations in scope. The most important limitation is that the analysis does not provide a comprehensive estimate of economic damages for all potentially affected materials. Instead, the study is intended to be a case study of air pollution damage to selected painted wood surfaces. In particular, the estimates are limited to those maintenance actions where only wood is painted. For example, if an individual paints both wood and stucco during a single maintenance action, this observation would not be included in the present analysis. This restriction is necessary because of difficulties in allocating costs and damage rates when multiple materials are affected. As a result, the economic estimates convey information for only a limited set of observations.

The unit of observation for the analysis of damage to painted wood is a specific maintenance action. Data from the survey of individual maintenance behavior are used to describe the following tasks:

- Paint wood trim only.
- Paint wood trim and eaves.
- Paint wood trim, eaves, and sills.
- Paint wood trim, eaves, sills, and walls.
- Paint wood walls only (walls are 100 percent painted wood).
- Paint whole house (walls are 100 percent painted wood).

These tasks are evaluated only for those individuals who reside in single family homes and report that they are responsible for maintenance decisions about their home. This restriction in scope is made to reduce the complexity of the behavioral survey. Other economic decision-makers (e.g., owners of commercial properties) may be affected by different types of incentives when maintenance actions are considered. Consequently, each group of decision-makers should be considered separately. The restriction to single family homes may not be too much of a limitation. The analysis of materials distribution suggests that exposed painted wood surfaces occur primarily in this class of buildings.

Another dimension of scope involves the spatial coverage and attributes of the analysis. With respect to coverage, the analysis considers the South Coast Air Basin. This area includes Los Angeles County, Orange County and the non-desert portions of Riverside and San Bernardino Counties. In order to develop a spatial grid of aerometric data, it is necessary to constrain the study area to the valley area of the basin. The mountain ranges serve as a barrier to credible extrapolation of monitored air pollution data.

The other aspect of spatial scope involves the level of detail available. An advantage of this study relative to many other materials damage assessments is the spatial detail that is available. All of the major components of the analysis are defined for an area that is a **Thomas Brothers map grid.** A Thomas Brothers map grid is a square area that is about 10 km on a side. This level of detail allows one to assess the relative economic impacts for different areas of the basin.

The scope of the analysis is also affected by the type of air quality improvement scenario. The analysis uses NO_2 as a proxy for acid deposition. This is consistent with the results of the physical damage function research. Also, the magnitude of economic impact is reflective of an assumed 10 percent uniform reduction in NO_2 concentrations across the basin. It is important to realize that this scenario represents a much smaller change in environmental quality than has been assumed in some of the earlier assessments of materials damage. In these other studies, estimates are made of the economic impact associated with a change in environmental quality from current levels to a clean level with no man-made contributions of pollution. It is believed that an analysis of incremental change is more credible since little is known about possible thresholds (i.e., non-linearities) in the physical damage functions at low concentrations. The implication of this incremental perspective is that the estimated economic impacts are likely to be much lower than the estimates reported in studies which consider total damage.

The scope of the analysis is also affected by assumptions involving time. In this study, economic impacts are reported as annual values. Thus, the estimates should not be interpreted as discounted present values. All dollar estimates are made in 1988 dollars.

By way of summary, this study examines the materials damage caused by acid deposition for a limited set of decision-makers and maintenance tasks. To place these limitations in perspective, this study focuses on about 200,000 single family homes out of a basin population of 2.2 million single family homes. This is the set of single family residents who painted only wood surfaces the last time they painted and make their own maintenance decisions. It is inappropriate to extrapolate the estimates of damage experienced by this group to other maintenance tasks involving other materials. At the present time, there are neither sufficient data nor analyses to support quantitative relationships between measures of acid deposition and rates of physical damage for other economically significant materials.

1.5 RESULTS OF ANALYSIS

The assessment of materials damage follows the five step procedure described earlier in this section. As mentioned, this procedure is similar to procedures used in earlier assessments. However, the availability of individual maintenance data also permits the analysis to proceed in a slightly different manner. In particular, it is now possible to estimate economic damages without use of a physical damage function. Economic damages may be estimated as a direct function of air pollution levels.

In this report, the approach that relies on physical damage functions is called the **physical damage function approach.** This approach garners the majority of discussion. The approach that does not require physical damage functions is called the **economic damage function approach.** This approach is developed to provide an alternative way of estimating damages when physical damage functions for a material have yet to be determined or are very uncertain.

The results of the physical damage function approach are summarized in Table 1-1. The economic impacts have been aggregated from grids to the county-level to facilitate presentation. A detailed presentation of grid impacts is contained in Section 8. The best estimate of annual cost-savings for the South Coast Air Basin is $0.70 million (1988 dollars). This estimate represents the annual savings that would be realized with a uniform 10 percent reduction in NO_2. The estimate is limited to those individuals who live in single family residences and perform selected maintenance tasks for painted wood surfaces.

Table 1-1

ANNUAL COST-SAVINGS FOR 10 PERCENT REDUCTION IN NO_2
(millions of 1988 dollars)

County	Cost-Savings*
Los Angeles	$0.47
Orange	0.12
Riverside	0.04
San Bernardino	0.07

Total	$0.70

* The range of annual cost-savings, <u>per household</u>, is $0.32 to $0.82 ($/household).

A rigorous, comprehensive quantitative analysis of uncertainty has not been conducted. However, individual sources of uncertainty have been examined. For example, it is possible that uncertainty in the estimates of the probability that individual maintenance actions will be performed could affect the derived economic values by ± 30 percent. Another source of uncertainty involves the marginal impact of the acid deposition variable (NO_2) on physical damage. Given the standard error of the NO_2 coefficient, a 95 percent confidence interval for the coefficient implies a range of economic impacts from $0 to $1.02 million.

The results shown in Table 1-1 are significantly lower than estimates of materials damage that have previously been reported. This is due primarily to considerable differences in the scope of the various studies. Section 8 describes these differences and the discussion in that section suggests that a reconciliation of much of the variation in results can be made.

As mentioned earlier, a second analysis of the data is also conducted. This analysis estimates economic damages without consideration of a physical damage function. This methodology results in an estimate of cost-savings of $3.6 million. This value is about five times greater than the estimate derived under the basic analysis. The difference can be traced to variations in the changes in the maintenance interval length with respect to changes in NO_2 concentrations across the two approaches.

One reason that the economic damage function approach is developed is to determine whether other material/finish combinations can be analyzed, even if physical damage functions have yet to be estimated. For example, the economic damage function approach is applied to painted stucco. However, a preliminary analysis of maintenance of painted stucco walls did not yield statistically significant results.

1.6 CONCLUSIONS

The principal conclusions of the present study include:

- It is possible to develop a methodology for materials damage assessment that is based on individual maintenance behavior. However, the data requirements for a comprehensive estimate of damages are significant.

- The analysis of materials damage based on individual maintenance actions is currently limited by the absence of credible physical damage functions for many materials that are potentially sensitive to air pollution damage.

- The material inventory is a valuable resource. This study does not make full use of all of the information that is available in the material survey. This is due to the fact that the analysis considers discrete maintenance actions as the unit of analysis and not the number of square feet of maintained material.

- The modeling of aerometric data for a grid map is possible in the South Coast Air Basin. However, successful application of the interpolation program to other areas is problematical. The set of available monitoring stations is not likely to be as complete as that found in the South Coast Air Basin.

- The results of the behavioral survey provide some needed answers about people's maintenance practices. Some of the conclusions that can be inferred from these data are: (1) painting is the dominant form of maintenance for currently painted surfaces; (2) the possibility of materials substitution appears to be a non-issue; (3) the decision about what to paint is important for the economic analysis; and (4) visible deterioration is an important factor for 84 percent of those who paint. Peeling and cracking is the most frequently mentioned form of visible deterioration. This has implications for the manner in which the physical damage function research is conducted.

- Statistical analysis of the economic data leads to plausible, but uncertain results. The explanatory power of equations for maintenance cost and maintenance interval length is poor. The estimated equations are not useful as predictors of individual behavior. However, the equations do provide guidance about average, aggregate responses.

- Extrapolation based on building counts can be implemented with greater certainty than extrapolation based on material density. This may reduce the effort required to extend materials damage assessments to other regions.

- The case study analysis examines six maintenance tasks involving painted wood. The analysis indicates that the economic benefits of a uniform 10 percent reduction in NO_2 are not large. On a per household basis, the benefits are less than one dollar. These results are partially a reflection of the limited scope of the case study analysis. However, it should also be recognized that the effect of acid deposition on other economically significant materials has yet to be established. Therefore, it is difficult to gauge how much greater a more comprehensive estimate of benefits would be.

- The disaggregate analysis indicates that the incremental benefits differ across areas of the basin. This has implications for the design of acid deposition control strategies.

- A tentative conclusion that has important implications for the magnitude of economic damages is that not all physical damage necessarily results in economic damage. Our analysis of those individuals who paint their entire homes whenever they paint indicates that these people have longer maintenance interval lengths (than those who paint part of their house) and variations in these intervals are not explained by variations in air pollution.

- The availability of individual maintenance practice data makes it possible to develop more complex models of maintenance behavior. Preliminary estimation of these models yields results that exceed the results obtained with an analysis based on physical damage functions by about a factor of 5.

1.7 RECOMMENDATIONS

On the basis of the work completed for this study, several recommendations may be identified:

- Work should be initiated to develop the data needed to estimate a physical damage function for painted stucco. The material inventory reveals that painted stucco is an important material, especially in the residential sector.

- Additional thought should be given to the problem of measuring damage end-points. The measure of damage should correspond to the manifestation of damage that prompts individuals to take maintenance action.

- One objective that this study was unable to meet involved a better characterization of **critical damage levels**. Originally, the study planned to use pictures of damaged materials to gauge critical damage. However, a pre-test with photographs did not work well. This approach probably deserves a second-look.

- The survey of maintenance practices should be extended to other decision-makers. Landlords of non-single family buildings, commercial building owners, and government agencies also make maintenance decisions. The important question that must be answered, if a more complete assessment of economic impact is to be made, is the extent to which incremental changes in acid deposition are expected to lead to changes in economic behavior for these other decision-makers.

- Alternative models of the maintenance decision are described in this study. These models estimate economic damages directly as a function of air pollution. Estimation of these models does not require quite as much information as the approaches which rely on physical damage functions. Consequently, if economic impacts are to be estimated for other areas, it is worthwhile to consider more fully the credibility of these alternative approaches.

- The Air Resources Board should develop estimates of the costs of implementing and attaining various incremental acid deposition control strategies. Even though materials damage is but one of several effects categories, the relatively small estimates of damage reported in this limited case study, raises the question: Will the benefits of acid deposition control outweigh the costs of control?

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SECTION 2

ECONOMIC ASSESSMENT OF MATERIALS DAMAGE DUE TO AIR POLLUTION

2.1 INTRODUCTION

Economic assessments of the damage to materials from exposure to air pollution have gone through many changes over the last twenty years. Early studies used a framework which assumed economic damage was proportional to physical damage with the proportionality factor equal to an adjusted production value of the affected material. Changes in economic damage were estimated from changes in the rate of physical damage. Implicit in this framework was the assumption that material replacement occured at fixed intervals which represented the normal use-life of the material. This approach is sometimes referred to as the **Value of Lost Material Approach (VLM).**

More recent studies have focused on the types of maintenance or repair activities that occur under various levels of exposure to air pollution. Like the VLM, the modeling of maintenance practices is driven by a physical damage function. However, the possibility of behavioral responses other than replacement are allowed. In particular, maintenance activities such as painting are considered. For this reason, studies of this type have been referred to as the **Cost of Ameliorative/ Preventative Actions (CA/PA).**

This section provides an overview of these two approaches. The discussion emphasizes the data requirements and assumptions that are required to implement both approaches. Following a review of previous studies, the major elements of the approach proposed for this study are defined and compared to earlier studies. The section closes with an Appendix which describes the theory of the measurement of economic benefits for maintenance decisions.

2.2 REVIEW OF LITERATURE

2.2.1 Value of Lost Material Approach (VLM)

Prominent examples of the VLM include Salmon (1970), Midwest Research Institute (1976), Hamilton (1979) and SRI (1981). The steps required to implement the approach generally include:

- Identify the tons of in-place material.
- Identify the amount of material lost per year for current pollution levels and reduced pollution levels using available physical damage functions.
- Calculate the value per ton of in-place material.
- Estimate the economic impact of pollution reduction as the product of value times tons reduced.

Each of these steps is discussed below.

2.2.1.1 Material Identification -- This step involves three distinct data development activities. The first activity is a determination of which materials are to be selected for study. The selection of materials is in part quantitative, but also partly qualitative. Factors like the value of material shipments, exposure potential, sensitivity to air pollution, and expected use-life are used to rank significant materials (Martin Marietta Environmental Systems, 1987).

The second data development activity involves the collection of production data for significant materials. These data are often available in secondary Government publications. Since materials appear on systems (e.g., buildings, bridges) with different use lives, the production data must be collected and summed over a time period that is representative of the relevant use-life. Adjustments are made for net exports; however, no attempt is made to adjust the estimate of in-place materials by losses due, for example, to abandonment of structures containing the significant material.

The third data development activity in this step involves the development of an allocation algorithm. Since the production data are most often national in scope, an analysis of region-specific pollution damages requires an estimate of the amount of material in-place in the affected region. SRI (1981) used multiple allocation criteria (e.g., population, employment) to determine material distribution. However, the absence of an area-specific inventory of in-place materials introduces a major source of uncertainty in the values derived with this approach.

2.2.1.2 Identify Amount of Material Lost -- The second element of the VLM is the evaluation of physical damage at various levels of air pollution. This is accomplished through the use of physical damage functions. A physical damage function is a mathematical relationship which explains variations in some measure of physical damage in terms of a set of explanatory factors, including air pollution.

The data needed to estimate these functions is usually obtained in one of two ways. The first way involves controlled laboratory exposures. In this approach, materials of interest are exposed to pre-selected levels of the relevant air pollutant with other potentially important factors held fixed at known levels. The advantage of this type of experiment is that statistical results concerning marginal impacts can be given a cause and effect interpretation. A disadvantage of this type of experiment is that the exposure trials are frequently carried out at concentrations significantly above ambient levels. This is done to accelerate the onset of damage. However, exposure at high concentrations may not permit extrapolation of effects to ambient levels.

The other form of experiment used to develop physical damage functions uses data collected in the field. These experiments collect information on material damage (e.g., weight loss/exposed panel) and environmental variables at or near the exposure site. Although ambient data are collected, the field studies suffer from several problems. The first problem is that the statistical relations show only associations. They cannot be given a cause and effect interpretation in the absence of other supporting information. A second problem is that the exposure period needed to collect useful data is generally quite long. Consequently, field studies can be expensive to implement.

A problem that exists for both field studies and laboratory exposures is that the convenient measure of damage (e.g., weight loss) does not always correspond to the type of damage to which individuals respond. A good example of this is the paint damage functions. The measure of damage most frequently used in paint damage function research is erosion. However, information obtained in the present study indicates that peeling and cracking of paint is the form of damage that prompts people to repaint. More work is required to confront this inconsistency.

2.2.1.3 Value of In-place Material -- The value of basic, raw material can be obtained from a variety of secondary Government publications. Typically, prices are stated on a unit weight basis and reflect production site values. For purposes of the economic assessment, the in-place material value is needed. Consequently, the value of the material must be adjusted to reflect labor installation costs for various material systems.

2.2.1.4 Valuation of Damage -- The final step in the VLM is the calculation of economic damages. The hypothesis of the approach is that fewer pounds (or other weight measure) of the affected materials will have to be replaced when air quality improves. With fewer pounds of material required to upgrade the system to a like-new status the value of the pounds reduced is a measure of the cost savings associated with the pollution reduction.

The only trace of a behavioral assumption in this approach involves the replacement interval. The replacement interval is fixed at the normal use-life of the material system. Use-life data are average values and are often taken from tax depreciation guidelines.[1] This introduces a potential bias if use lives differ by area because of differences in air pollution exposure.

2.2.1.5 Summary -- The VLM was used in the early assessments of economic damage primarily because the data needed to implement the approach were available. However, concern about the limitations associated with allocation algorithms led to the conclusion that detailed materials inventories would markedly improve the credibility of the assessments. Furthermore, there was criticism of the implicit behavioral assumption that maintenance actions were limited to material replacement at the end of standard use-life intervals. Because of these criticisms, models based on ameliorative/preventative actions were developed which generalized the behavioral assumptions and were designed to use detailed materials inventory data.

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[1] In some cases, life-cycle costs are computed (Weber and Lippiat, 1984). Proper application of this method requires information on the lifetime over which maintenance/replacement decisions will be made as well as the current maintenance status of the affected material.

2.2.2 Costs of Ameliorative/Preventative Actions (CA/PA)

Among the studies that have adopted a Cost of Ameliorative/ Preventative Action (CA/PA) framework and utilize detailed material inventory data are TRC (1981), TRC (1985), and Horst et al. (1986).

The CA/PA approach bases estimates of economic benefits on the costs associated with ameliorative/preventative actions taken to mitigate the effects of air pollutants. This approach introduces two new concepts that provide a more realistic framework of analysis than was possible with the VLM. These concepts are **prevailing practice** and **critical damage level.**

Prevailing practice refers to the principal current strategies used by individuals to adjust to the adverse effects of air pollution. For example, in the case of damage to painted trim, the prevailing practice might be identified as a five-year repainting schedule. Prevailing practice is an important concept because it incorporates into the analysis data that reflect the typical response of the average individual to perceived air pollution damage. This provides a potentially more realistic description of economic behavior than the VLM. In this latter case, no attempt is made to affirm that the behavior postulated (material replacement at fixed intervals) is consistent with actual behavior. Given that measures of economic benefits are to be based on individuals' willingness to pay, as evidenced by the economic choices they make, the usefulness of the prevailing practice concept is evident.

The second concept introduced in the CA/PA approach is the critical damage level. The critical damage level is reached when damage to the material necessitates repair or replacement action in order to maintain the integrity of the material. Although each individual may have a unique, personal critical damage level, exogenous information such as "good engineering practice" is usually developed to define a generic critical damage level for all individuals. Naturally, different material systems may have different critical damage levels. One implication of this is that analyses which rely on critical damage levels generally find it advantageous to use detailed information about material/use combinations. This is accomplished by conducting detailed materials inventories of the materials at risk.

To highlight the implementation of the CA/PA approach, three studies are described below. These studies use essentially the same information. However, the assumptions made in each study differ slightly. These models will then be compared to the model proposed for this study, with the comparison emphasizing the evolution of the CA/PA model over time. To focus the discussion, the presentation will be in terms of damage to painted surfaces.

TRC (1981) conducted a study of materials damage associated with air pollution in the Boston area. Although the study describes in detail important components of the damage assessment such as materials inventory, exposure, and physical damage functions, the emphasis of the current discussion will be on the assumptions used to develop the economic damage estimates.

Define the following terms:

$P_{\ell s}$ = the concentration of a pollutant at location ℓ for air quality scenario S. The current situation is represented by S=0. The comparative scenario is represented by S=1.

$D_m(P_{\ell s})$ = the amount of physical damage for material m when exposed to pollutant $P_{\ell s}$. This variable represents the physical damage function. The units are in μm/yr.

Z_{mo} = the critical damage level for material m at pollution scenario o (current conditions). The units are in μm.

$L_{m\ell S}$ = the length of the maintenance interval for material m at location ℓ and air quality scenario S. The units are in years.

$M_{m\ell b}$ = the area of material m exposed at location ℓ for building type b. The units are in square feet.

C_m = the unit cost of a maintenance action for material m. The units are in \$/sq.ft.

Figure 2-1 shows how these variables are combined to yield an economic estimate of materials damage associated with air pollution. On the left-hand side of the figure, Box 1 shows $M_{m\ell b}$, the area of material m. This variable is multiplied by C_m (Box 2), the unit maintenance cost for the material. The product ($M_{m\ell b}*C_m$) is the expenditure required to complete a single maintenance action.

Boxes 3, 4, and 5 show the information needed to predict the length of the maintenance interval. The basic assumption is that people choose to perform maintenance when the critical damage level is reached. This relationship is formalized by the equation:

$$Z_{m0} = L_{m\ell 0} \cdot D_m(P_{\ell 0}) \qquad (2.1)$$

TRC (1981) assumed $L_{m\ell 0}$. Then, for given $P_{\ell 0}$ and damage function D_m, they solved for Z_{m0}. Furthermore, Z_{m0} is assumed to be constant across pollution concentrations. Therefore, if $P_{\ell 0}$ improves to $P_{\ell 1}$ ($P_{\ell 1} < P_{\ell 0}$), damage rates will fall (i.e., $\partial D/\partial P > 0$) and the length of the maintenance interval will increase to $L_{m\ell 1}$ to keep Z_{m0} constant. The computation of the maintenance interval length is shown in Box 6.

The expenditure and interval information are brought together in Box 7. The value of expenditures divided by the length of the maintenance interval (M•C/L) yields an estimate of the

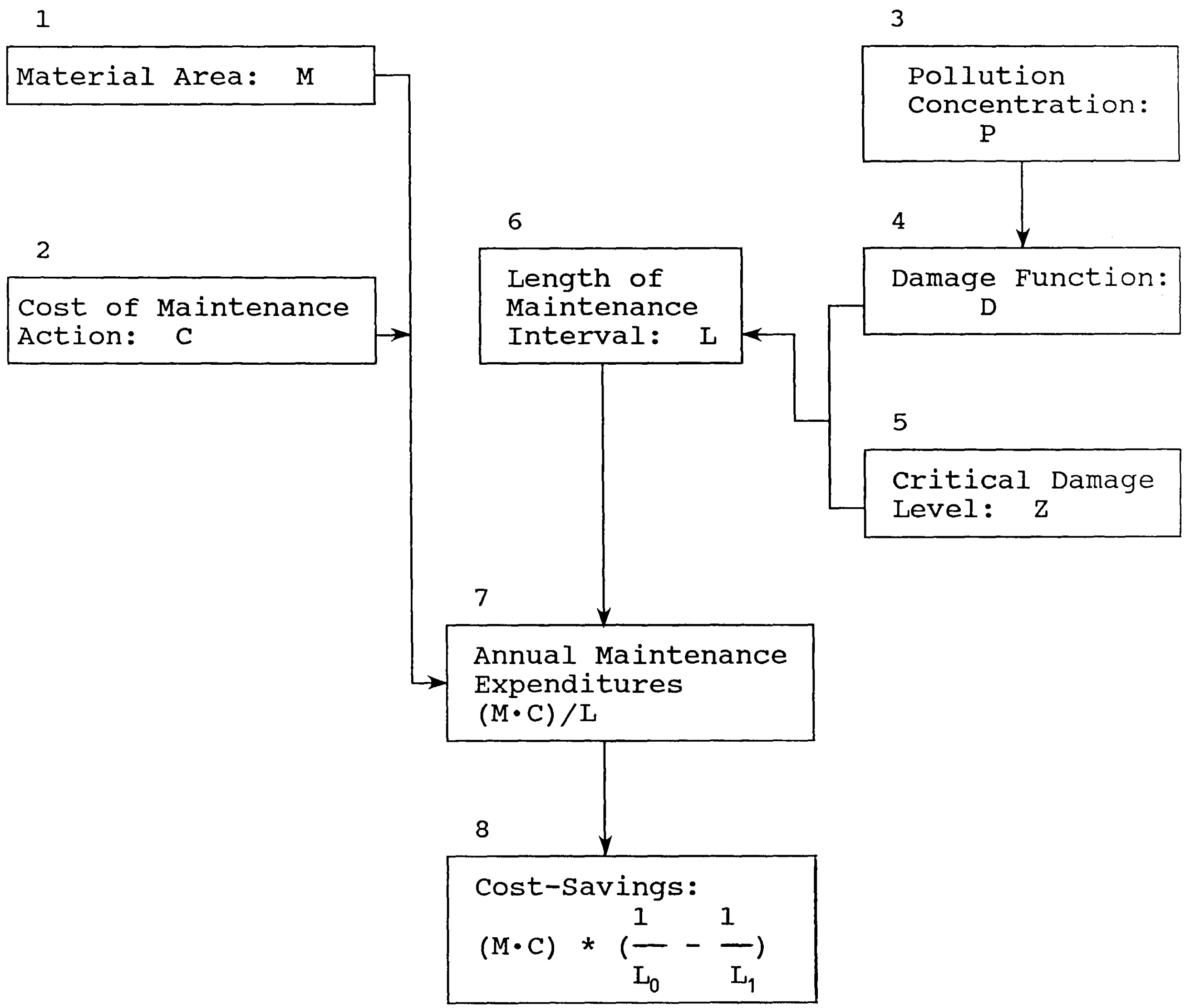

Figure 2-1. Overview of CA/PA Methodology in TRC (1981).

annual cost of the maintenance action. If the denominator increases from L_0 to L_1 in response to a reduction in air pollution concentrations from $P_{\ell 0}$ to $P_{\ell 1}$, then the annual cost of the maintenance action will be reduced. The difference in the annual cost of the maintenance action is the measure of economic damage avoided (cost-savings) associated with the improvement. This calculation is shown in Box 8.

TRC (1985) used an approach similar to their earlier work. The principal refinement was to survey paint contractors to determine L_0 in a more quantitative manner. The survey indicated that the average maintenance interval for repainting residential homes in the study area (the South Coast Air Basin) was about seven years.

In TRC (1985), it was discovered that the use of exogenously determined critical damage levels in combination with the physical damage functions produced too low of estimates for the maintenance intervals. Therefore, they assumed that the maintenance interval remained fixed at seven years at all levels of pollution and calculated damages based on the proportion of damage assignable to pollution. Implicit in this approach is the assumption that the critical damage level changes with changes in air pollution.

Horst et al. (1986) examined the damages to building materials associated with acid deposition in the Northeast quadrant of the United States. In this study, critical damage levels were developed from outside sources of information on a material by material basis. For the given critical damage levels, and physical damage functions evaluated at current pollution levels, an estimate of maintenance intervals under current conditions could be made. This is L_0. Under the assumption that maintenance action is initiated at the same level of critical damage, it is possible to derive an estimate of L_1 in a manner similar to TRC

(1981). The difference between TRC (1981) and Horst et al. (1986) is that L_0 is derived in the later study, not assumed.

2.3 FRAMEWORK FOR PRESENT ANALYSIS

The basic approach developed for the present study requires the same type of data as described above for the CA/PA methodology. These data include measures of ambient concentration by area, material distribution, physical damage functions, maintenance costs, and maintenance intervals. However, there are two significant changes in the units of these variables as compared to the earlier CA/PA studies.

- The maintenance activity is valued on a per house basis instead of a square foot basis. This permits extrapolation based on building counts instead of material densities.
- The data on costs and maintenance intervals are collected from those individuals who actually make the decision to perform the maintenance. This information permits a better accounting of what is being painted, whether maintenance intervals change with what is being painted, who is doing the painting, the costs of painting by who is painting, which factors influenced the painting decision, etc.

The development of a complete census of residential buildings was undertaken to facilitate the extrapolation of damage estimates. TRC (1985) recommended that extrapolations be based on building counts instead of the materials densities which had been used in their study. The reason for the recommendation is that there is greater variability in the density of buildings of various types across the basin than there is in the amount of exposed material per building. In response to this recommendation, the ARB sponsored a study to access data tapes containing complete counts of residences by area. These data were collected and tabulated by Valley Research Corporation (1989), and are briefly described in Section 3 of this report.

Data concerning individual maintenance decisions were collected as part of the present study. Horst et al. (1986) recommended that data on actual behavioral responses should be collected to gain a better understanding of the factors that lead people to undertake maintenance. The advantage of having individual responses available for the analysis is that it becomes possible to identify a set of well-defined, homogeneous maintenance tasks. This is important if the economic analysis is to be consistent with the physical damage functions.

Figure 2-2 shows the steps used in the present study to estimate economic damages. The left-hand side of the figure shows three types of data. Box 1 contains the unit cost estimates for completing a given maintenance task. The cost estimates are determined from individual responses to the behavioral survey and reflect variations in household decisions and residence attributes. Box 2 contains estimates of the probability that a specific maintenance task will be performed. These data are also developed from the behavioral survey. The third box on the left side of Figure 2-2 is the number of single family homes. These data are location-specific to small rectangular grids throughout the basin. The product of the first three boxes gives the total expenditure for a maintenance task by location. This is shown in Box 4.

It is important to understand that the magnitude of this expenditure is directly related to the probability of performing the maintenance task. In the present study, the analysis is restricted to a set of single family residents who make their own maintenance decisions about painted wood surfaces. The maintenance tasks are further limited to those tasks where only painted wood is maintained. Tasks that involve multiple materials are not considered. This assumption reduces the probability

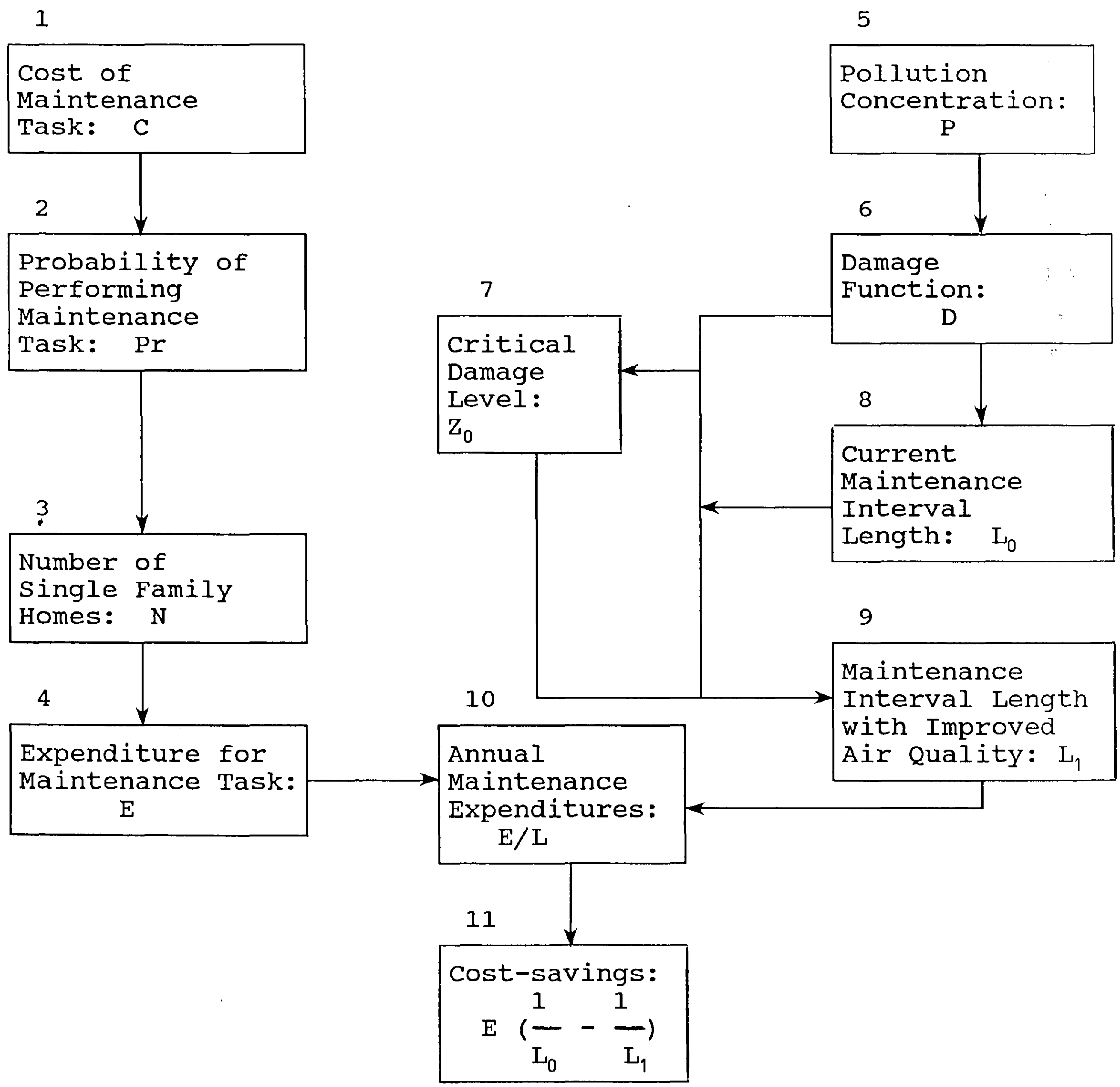

Figure 2-2. Overview of Methodology for Current Study

that a particular maintenance action will be included in the analysis. However, the assumption is necessary because it is difficult to allocate costs across different materials (that have different rates of damage) when more than one material is painted as part of a single maintenance action.

The right-hand side of Figure 2-2 is also different from Figure 2-1, although here, the same type of data are being used. The key elements include a damage function (Box 5) which depends on pollutant concentrations (Box 6), a critical damage level (Box 7), and a maintenance interval length (Box 8). The difference from Figure 2-1 is that the length of the maintenance interval under current environmental conditions is known from the behavioral survey. Therefore, it is not necessary to predict or to assume L_0. Under the assumption that Z_{m0} remains constant for different levels of pollution, it is possible to predict L_1, the length of the maintenance interval with improved air quality in the same way as was described in Figure 2-1. This is shown in Box 9. The annual expenditures are computed by dividing total expenditures by the length of the maintenance interval, and is shown in Box 10.

Finally, the cost-savings of the air pollution improvement is calculated as the difference in the annual costs under the two concentration levels. This calculation is shown in Box 11.

Figure 2-3 provides an overview of the major components of the present study. Sources of data, the outputs produced by each component, and the section of the report which describes each output are shown in the figure.

In addition to the physical damage function approach described above, this study also extends the basic CA/PA methodology by taking advantage of the individual responses concerning maintenance that are available from the behavioral survey. The economic damage function approach attempts to establish a direct statistical association between the length of the maintenance interval and ambient air pollution. Basically, such a specification indirectly incorporates information provided by the physical damage function research. The advantage of this approach is that it permits analysis of damages to materials for which physical damage functions have yet to be developed. In fact, an attempt is made in this study to extend the basic analysis from painted wood to painted stucco. The discussion of this extension is provided in Section 8.

Type of Data		Outputs	Discussion
A. Materials Distribution	1.	Square footage of material by material type/finish	Section 3
	2.	Count of single family residences by area	Section 3
	3.	Average size/age of single family residences by area	Section 3
B. Physical Damage Function	1.	Statistical equation for damage to painted wood	Section 4
C. Aerometric Data	1.	Distribution of aerometric data by area under baseline conditions	Section 5
	2.	Hypothetical uniform percent reduction scenario	Section 5
D. Behavioral Survey	1.	Maintenance practice data	Section 6
	2.	Probability of performing a specific maintenance task	Section 6
	3.	Cost information for specific maintenance practices	Section 7
	4.	Economic estimates	Section 8

Figure 2-3. Major Components of Study

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APPENDIX 2-A

ECONOMIC ASSESSMENT OF MATERIALS DAMAGE: THEORY

2.A.1 INTRODUCTION

Measurement of the economic benefits associated with an increase in economic welfare depends on the **willingness to pay** by individuals to be in a preferred state of the world. With a reduction in air pollution, the welfare of individuals may be improved in a variety of ways. Better air quality can lead to reductions in mortality risk, fewer acute and chronic morbidity incidents, as well as such non-health impacts as reduced materials damage. This section presents an overview of the theory underlying the measurement of economic benefits due to reduced materials damage brought about by a reduction in air pollution. The discussion is intended to be general in nature, rather than specific to the present case study.

The presentation of the material is graphical. However, the discussion is technical and certain difficult concepts of applied welfare economics are used extensively. For this reason, some readers may wish to turn to Section 3. For these readers, the message of the Appendix is two-fold. First, the measure of CA/PA cost-savings (for an air quality improvement) developed in this report is an overestimate of the true level of cost-savings. Second, it is shown that the CA/PA cost-savings will underestimate the benefits of the air quality improvement. These relationships occur because of the partial focus of the analysis and because of the use of cost-savings rather than economic surplus as a measure of benefits.

2.A.2 DEFINITIONS

The economic process involves the conversion of society's stock of resources into goods and services, and the sale of these goods and services in markets. This activity generates economic benefits by allowing people to consume and produce desired combinations of goods and services. Of particular interest here is the fact that changes in acid deposition levels can alter the benefits enjoyed by economic decision-makers through impacts on markets for maintenance (e.g., painting) and building services.

The benefits of a welfare improvement reflect the willingness to pay by the affected individual to be in the preferred situation rather than the current state. For consumers, this value can be approximated by the area under an ordinary demand curve and above the price line. This area is known as **consumers' surplus**. It represents a measure of what consumers would be willing to pay over and above what they do pay.

An analagous concept for producers is **producers' surplus.** This measure of welfare is defined to be the area above the supply curve of the producer and below the price line. Since this measure of economic surplus ultimately flows back to members of society, as income to fixed factors, producers' surplus is considered to be as much a benefit as consumers' surplus.

The concepts of consumers' and producers' surpluses are closely tied to demand and supply curves. Consequently, an action which affects demand or supply in a market will likely lead to a net impact on the surplus measures. A comparison of economic surplus with and without the action identifies the economic benefits associated with the action.[1]

2.A.3 ECONOMIC BENEFITS OF AIR QUALITY IMPROVEMENTS

Ideally, changes in welfare associated with air quality improvements would be determined directly in the market for air quality. Unfortunately, no such market exists. Because of the public good nature of the air resource (i.e., individuals cannot privately consume the good), a demand curve of the usual type cannot be observed.

However, it is possible to observe how air quality influences the behavior of individuals in other markets. In this section, markets related to building maintenance are examined. With a reduction in air pollution, the hypothesis is that fewer units of maintenance will be required to maintain a given level of building services. As used here, the term "building services" reflects both quality and quantity dimensions. Thus, high quality housing of a given size provides more building service than a comparably sized house of lower quality.

The economic effect of air pollution can be illustrated graphically as shown in Figure 2-A-1. The figure shows the demand and supply conditions for building services of type i. For example, in the present study, this would be the building services market for single family residences. The demand curve, D_B, in the figure represents the market demand for building services as a function of the price of the service. The curve $S_B(P_B, P_M^0, AQ^0)$ represents the market supply of building services given an initial level of air pollution AQ^0 and price of the input "maintenance" of

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[1] The theory of welfare measurement is complex. Just, Hueth and Schmitz (1982) provide a fairly rigorous statement of the issues involved. Freeman (1979) describes some of the problems faced in measuring the benefits of environmental improvements.

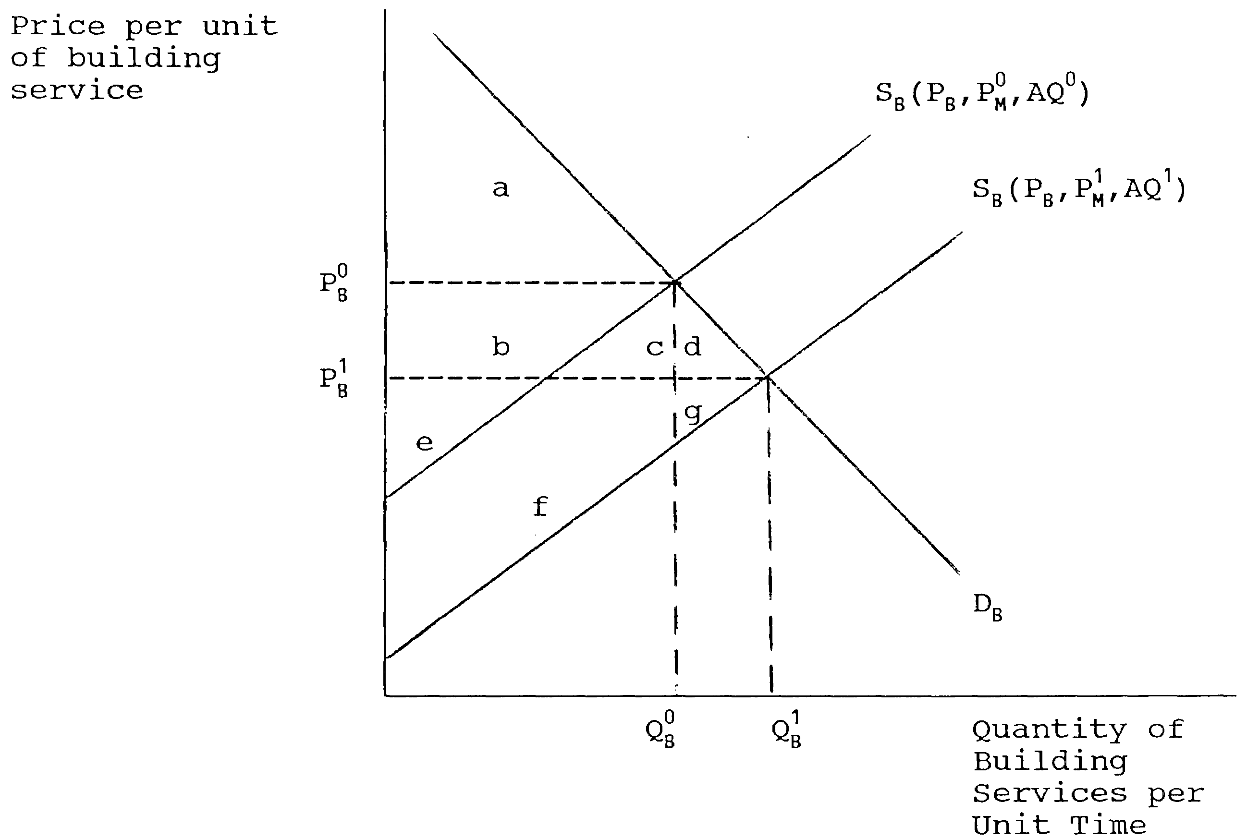

Figure 2-A-1. Welfare Impacts in the Building Services Market

P_M^0. (The maintenance market is discussed below.) The supply curve depends on air pollution because of pollution's effect on maintenance costs, where maintenance activities are an input into the production of building services. Equilibrium in the market occurs at price P_B^0, and quantity Q_B^0, where the supply and demand curves intersect.

If air pollution is reduced to AQ^1 through some exogenous action, there would be a decrease in the quantity of maintenance required to supply a given level of building service. In this case, the supply price for building services would decline. This is shown by the rightward shift of the supply curve from $S_B(P_B, P_M^0, AQ^0)$ to $S_B(P_B, P_M^1, AQ^1)$. With this change, a new equilibrium will be reached at price P_B^1 and quantity Q_B^1 in the building services market.

The economic <u>benefits</u> of the pollution reduction from AQ^0 to AQ^1 are given by the sum of areas c+d+f+g in Figure 2-A-1. This area is the change in consumers' surplus (area b+c+d) plus the change in producers' surplus (area e+f+g - area b+e). Area c+f represents the cost-savings in supplying the original level of building services Q_B^0. Area d+g is the increase in surplus that results from the increase in the equilibrium quantity of building services from Q_B^0 to Q_B^1.

One of the inputs used to produce building services is maintenance activities. The market for maintenance activities is shown in Figure 2-A-2. The demand side of the maintenance activities market is represented by the building landlords (e.g., in the present case, those homeowners who make maintenance decisions) who are on the supply side of the building services market. The supply side of the maintenance activities market consists of building maintenance firms. These maintenance firms may be landlords who do their own maintenance.

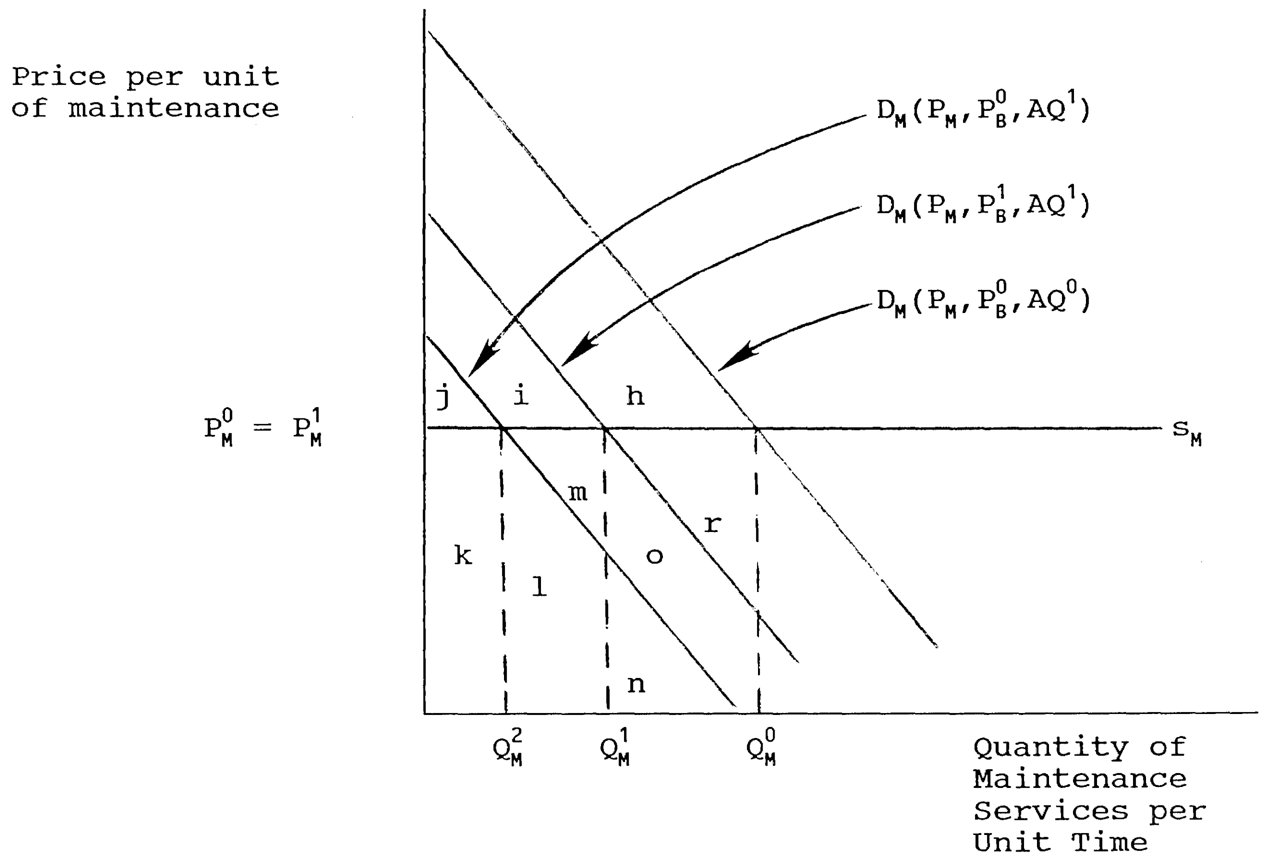

Figure 2-A-2. Welfare Impacts in the Maintenance Services Market

In the maintenance market, the supply of maintenance is represented by the supply curve S_M. The demand for maintenance is initially $D_M(P_M, P_B^0, AQ^0)$. The demand for maintenance is a derived demand arising from the landlords' profit maximizing decisions in the building services market. The demand for maintenance depends on air quality (better air quality requires less maintenance per unit time) and it is this dependence that leads to the effect of air pollution on the supply side of the building services market.

At air pollution level AQ^0, the equilibrium in the market for maintenance occurs at price P_M^0 and quantity Q_M^0. With a reduction in air pollution to AQ^1, the hypothesis is that the demand for maintenance will first shift from $D_M(P_M, P_B^0, AQ^0)$ to $D_M(P_M, P_B^0, AQ^1)$. However, because of the new lower equilibrium price in the building services market, the demand for maintenance eventually is represented by $D_M(P_M, P_B^1, AQ^1)$. This establishes a new equilibrium in the market for maintenance activities at P_M^1 and Q_M^1. The horizontal supply curve S_M results in P_M^1 being equal to P_M^0. However, the decline in air pollution leads to Q_M^1 being less than Q_M^0.

Note that if the price adjustment in the building services market from P_B^0 to P_B^1 is not considered, then the quantity of maintenance will be Q_M^2, which is less than Q_M^1. This inequality results because the price reduction in the building services market will lead to an increase in the quantity of building services demanded from Q_B^0 to Q_B^1. In turn, the reduction in maintenance from Q_M^0 to Q_M^2 that occurs because of the pollution reduction, is partially offset by the increase in maintenance from Q_M^2 to Q_M^1 to support the increase in the quantity of building services.

In the CA/PA approach, economic welfare changes are approximated by area l+m+n+o+r. That is, the CA/PA methodology fails to account for demand side adjustments in the building services market. However, in Figure 2-A-2, area l+m+n+o+r exceeds area n+o+r. This latter area is the measure of cost-savings when adjustments in the building services market are taken into account.

Furthermore, the measure of cost-savings in the building services market when the original level of building services is provided is represented by area c+f. Since area c+f is less than area c+f+d+g, and the latter area is a measure of the change in economic surplus, this implies that

$$c+f+d+g > c+f = l+m+n+o+r > n+o+r \; .$$

In words, the CA/PA methodology yields an estimate of cost-savings that exceeds the actual savings in maintenance costs, but understates the benefits of the air quality improvement. These relationships occur for two reasons: 1) the use of cost-savings rather than economic surplus as the benefit measure; and 2) the failure to consider demand side effects in the building services market.

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SECTION 3

MATERIALS INVENTORY

3.1 INTRODUCTION

A comprehensive survey of materials distribution was conducted by Valley Research Corporation (1989) for the Air Resources Board. The inventory of materials covered residential structures, non-residential structures, and infrastructure. Telephone surveys, field validation, aerial photography, and secondary data sources were utilized. Specific materials were identified by finish and component. Average values for each material were computed for the basin as a whole and conditional on the age and size of the structure (for single family residences). The population of buildings by building type and area was obtained from tax assessor data bases maintained by county governments.

The basic unit of analysis for the inventory sampling was a map-book. A map-book is a geographical area which contains multiple parcels for all land-use types. In the South Coast Air Basin, there are approximately 4,000 map-books. In this study, a major part of the data development activity involved assignment of mapbooks to Thomas Brothers map grids. This step was necessary to establish a consistent basis for integrating the inventory data with the behavioral survey and aerometric data.

Valley Research Corporation provided Mathtech with four types of information:

- Summary statistics of exterior surface composition for single family residences and non-single family parcels.
- Predictive equations for estimating material areas by material type/use given mean liveable space, age of house, and size of house.

- Map-book statistics of land parcels (i.e., counts of parcels) by use-type.
- Codes which assign map-books to Thomas Brothers map grids.

Each of these outputs is discussed below.

3.2 SUMMARY STATISTICS OF MATERIALS DISTRIBUTION

Detailed data tables were developed by Valley Research Corporation (1989) which identified the average areas and percent contributions of specific material finish combinations in the South Coast Air Basin. For single family residences, painted wood accounted for the greatest proportion of the total exterior area. The percent contribution for painted wood was estimated at 16.4 percent. Other prominent material-finish items for single family residences were painted stucco (14.8 percent); asphalt/ fiberglass-shingle/composition roofing (13.2 percent); bare concrete (10.9 percent); and bare wood shingle (7.1 percent).

The distribution of materials was also reported by building component. Separate components identified included: Roof, roof features, soffit, basic wall, primary and secondary windows, primary and secondary doors, wall attachments, ground cover, minor structures, and fencing. These data allow one to estimate, for example, the average area of painted wood (material/finish), on painted windows (component) for the representative single family home in the basin.

The statistics described above were reported for 14 different cells. The cells included: basin-wide estimates; estimates for Los Angeles County alone, estimates for a composite of Orange, Riverside, and San Bernardino counties; estimates for Los Angeles County classified by age and size of home.

Statistics for non-single family residences were summarized by material/finish and use code. These data focused on building components only, and excluded secondary building features and ground components. Counts of enumeration items were also provided by Valley Research Corporation.

The data represent a valuable resource. There is more detail available than can possibly be used at present in the economic analysis. However, the information does help the economic analysis in several ways:

- The material/finish statistics indicate which materials are most prominent in the South Coast Air Basin.
- The statistics on the distribution of materials by components help to identify where the dominant materials are used on representative houses.

As a result of the materials inventory, the behavioral survey was designed with the following features:

- The focus of the analysis would be limited to painted wood and painted stucco.
- The economic analysis would focus on single family residences. Painted wood and stucco surfaces are most often found on this building type.

3.3 PREDICTIVE EQUATIONS

The availability of detailed inventory data for individual single family residences permits additional statistical analysis of the material data. For example, one might ask whether the total area of a building component can be predicted from a variable such as mean liveable space. If such a statistical association can be established, this would provide a quick way for predicting component material areas outside the sample. In turn, the available data on material composition by component could be used to predict the area of a particular material/finish combination for a specific component. This is the type of data needed to assess maintenance costs when maintenance costs are stated on a $/square foot basis.

Valley Research Corporation estimated simple linear and proportional regressions between component areas and mean liveable space for single family homes in Los Angeles County. The equations generally explained between 30 and 60 percent of the variation in component area. However, it was decided that these predictive equations would not be used for the economic analysis. The reason for this is that the composition of the predicted areas is for a representative structure. That is, for example, the summary statistics reveal how much painted wood appears on primary windows on average. This is unconditional. For the economic analysis, it is more appropriate to know the average area of painted wood on primary windows conditional on painted wood being present. Consequently, the economic analysis does not use the material surface area statistics developed by Valley Research Corporation. Instead, the unit of analysis is a specific maintenance action. The advantage of defining costs on a per action per house basis is that it permits extrapolation based on building counts to be implemented in a straightforward fashion. As discussed immediately below, Valley Research Corporation also provided Mathtech with counts of buildings by type, area, size and age for Los Angeles County and by type and area for the other three counties in the basin.

3.4 COUNT OF SINGLE FAMILY RESIDENCES

Valley Research Corporation also collected data on the population of buildings by building type for separate map-book areas in the South Coast Air Basin. Table 3-1 summarizes the count of parcels by use type and county. The economic analysis is limited to consideration of single family homes. As mentioned earlier, this use type contains a majority of the painted wood and painted stucco surfaces and these are the two dominant

Table 3-1

COUNT OF BUILDINGS BY USE TYPE

Los Angeles County

No. of Map-books	2,942
Single Family Residence	1,414,872
Small Multi-Family Residence	67,954
Large Multi-Family Residence	61,246
Residential Condominium	41,559
Small Non-Residential Parcel	25,559
Large Non-Residential Parcel	119,604
Major Properties	22,662
Vacant	126,680
Unknown	3,027
Total	1,883,163

Composite County

	Orange	Riverside	San Bernardino	Total
No. of Map-Books	344	338	231	913
Single Family Residence	434,013	159,826	240,278	834,117
Multi-Family Residence	26,152	2,658	5,711	34,521
Reidential Condominium	5,093	735	4,718	10,546
Non-Residential Parcel	38,685	8,570	25,859	73,114
Mobile Home	356	21,038	681	22,075
Agricultural Parcel	526	9,757	2,597	12,880
Vacant	38,782	92,952	73,884	205,618
Unknown	110	6,609	1,051	7,770
Total	508,897	302,145	354,779	1,200,641

Source: Valley Research Corporation (1989).

material-use combinations. Furthermore, consideration of single family residences alone is also helpful in reducing the complexity of the behavioral survey. It is likely that owners of commercial and industrial buildings will have different decision criteria concerning maintenance than will homeowners.

The data on single family residences is reported on a map-book basis. Since homes in different areas may differ in age and size and these two variables may, in turn, influence the distribution of materials, Valley Research Corporation also provided average estimates of the age and size composition of single family homes in each map-book. This information is contained on a file named **RESTAT**. These data allow the economic analysis to consider the age and size impacts as part of the extrapolation calculation. In fact, as shown in Section 8, the behavioral survey data are used to predict the maintenance interval length as a function of age of house and the maintenance action cost as a function of size and age of house. As a result, economic damages may be computed on an area by area basis and within basin variations in economic damages separately identified.

3.5 CONVERSION OF MAPBOOKS TO THOMAS BROTHERS MAP GRID CODES

The RESTAT file provides information on the age and size distribution of single family homes by mapbook. In order to link the RESTAT data to the air quality and behavioral survey data, it was necessary to assign each mapbook area to a unique Thomas Brothers map grid.

This task was accomplished using look-up tables provided to Mathtech by Valley Research Corporation. Separate tables were available for each of the four counties in the study area. Table 3-2 is a sample of one page of the tables. Note that in the table, several mapbook areas may fall within the boundaries of a single Thomas Brothers map grid. For example, mapbooks 11, 13,

Table 3-2

MAPBOOK AND THOMAS BROTHERS MAPBOOK CODES
1987 INDEX TO ORANGE COUNTY

MAP BOOK	TBM PAGE NO.	MAP BOOK	TBM PAGE NO.	MAP BOOK	TBM PAGE NO.
01	16	93	18	188	22
02	17	94	17	195	20
03	17	95	20	198	22
04	22	96	15	199	19
05	23	97	15	200	14
07	22	98	15	203	14
08	23	99	16	215	15
10	22	100	16	217	14
11	23	101	16	222	14
13	23	103	24	224	14
14	23	104	24	231	16
15	23	105	18	232	16
16	23	107	21	233	16
17	1	108	22	234	11
18	1	109	22	241	14
19	1	110	25	242	9
22	2	111	26	244	9
23	26	112	26	250	11
24	26	114	30	251	11
25	26	117	31	253	12
28	6	119	28	255	11
29	6	120	32A	258	10
30	5	121	37	260	9
31	6	123	38	262	9
32	6	124	38	263	9
33	6	125	29D	267	11
34	11	126	10	268	12
35	11	127	10	269	6
36	11	128	11	271	11
37	11	129	11	272	11
39	17	130	14	276	4
41	17	131	15	277	5
43	19	132	15	280	5
45	31	133	15	281	6
47	31	134	9	283	6
48	31	135	10	284	6
49	31	136	10	285	6
50	31	137	16	287	5
52	33	139	27	288	5
53	34	140	22	289	5
56	35	141	27	292	6
57	39	142	21	293	6
58	39	143	21	296	2
60	39	144	22	298	1
64	2	145	20	300	1
66	5	146	20	303	2
69	9	148	30	304	2
70	10	149	30	306	3
71	10	151	26	308	3
72	11	153	26	312	4
73	11	155	27	315	4
77	13	156	27	319	2
79	10	157	26	320	3
82	11	159	26	322	3
83	11	163	20	323	8
85	13	165	21	326	4
86	14	167	21	334	7
89	16	169	22	336	7
90	16	178	20	337	6

Source: Table provided by Valley Research Corporation.

14, 15 and 16 all fall within Thomas Brothers map grid 23. However, the entries in the table do not show the possibility of a single mapbook cutting across map grid boundaries. For Orange, Riverside and San Bernardino Counties, mapbooks always fell within a single Thomas Brothers map grid. However, for Los Angeles County, the mapbook areas often crossed over multiple map grids.

This creates a problem. Since the distribution of homes within a mapbook is not known, it is not possible to apportion homes across mapbooks except through an assumption of uniformity. Alternatively, it could be assumed that all homes in the mapbook are located in the first grid area listed. This is equivalent to no apportionment. This latter approach was adopted because it led to fewer coding problems. Since the map grids were listed in ascending numerical order for a single mapbook, this has the effect of moving the homes toward the north and west boundaries of a mapbook area. Quantitatively, it is not believed that this will result in a serious bias in the assessment of the joint distribution of home location and air quality exposure.

The process described above is straightforward if one is summing building counts across map-books. However, in order to derive average size and age values at the Thomas Brothers grid level, weighted averages of the map book values were computed. The weights were the proportions of single family homes in the map book relative to the total count in the grid.

Figure 3-1 shows the location of the Thomas Brothers map grids in the South Coast Air Basin. The grids are numbered sequentially for each county. For example, grid 12 appears in four places, once for each of the four counties. Grids appearing outside of the study region are not included as numbered grids in the figure.

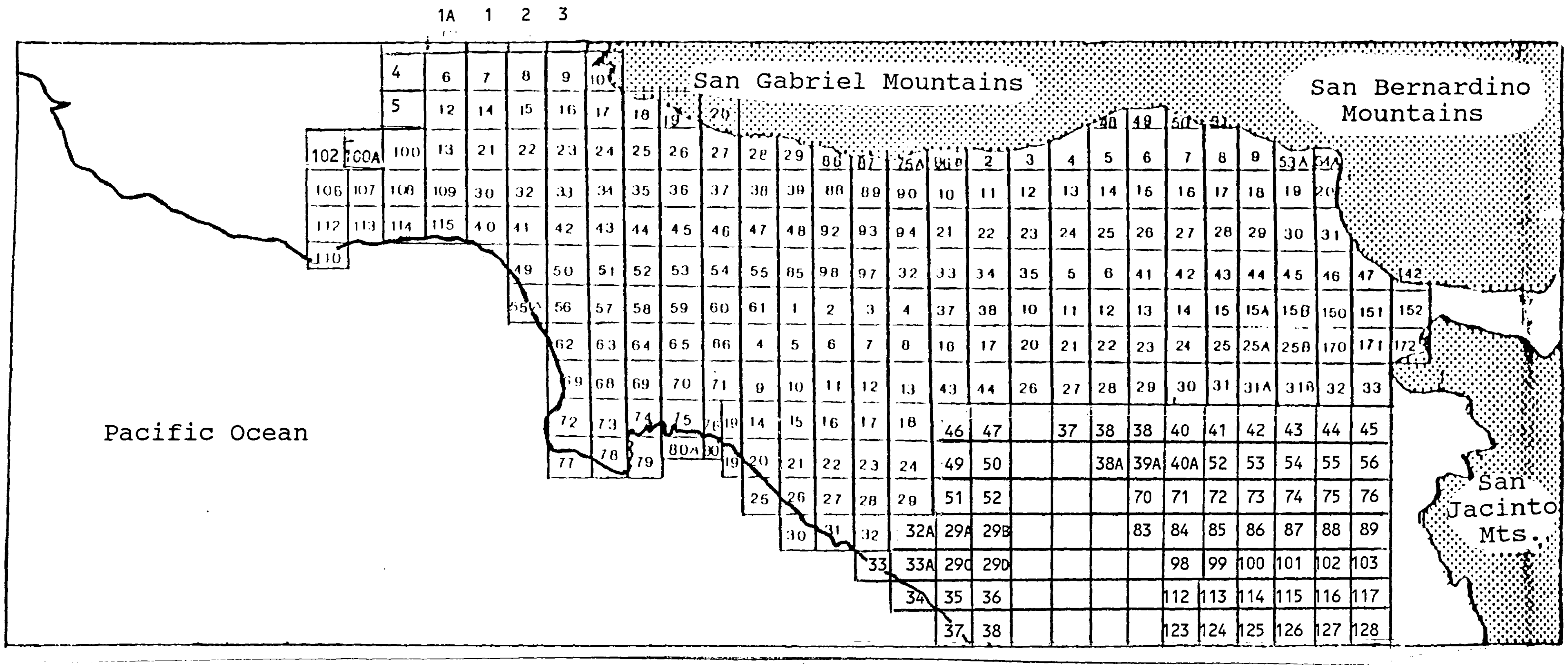

Figure 3-1. Thomas Brothers Grid Map System for the South Coast Air Basin Study Region

3.6 SUMMARY

The materials inventory developed by Valley Research Corporation provides estimates of the distribution of materials and the composition of components for buildings in the South Coast Air Basin. Because of limitations in the physical damage function research, only part of the inventory information can be used in an economic analysis at this time. Additional limitations are associated with the design of the behavioral survey. Future analyses should be designed to take greater advantage of the detail available in this inventory.

A potentially useful statistic that was not reported by Valley Research Corporation is the average area of a specific material/finish by component conditional on the presence of the material. This measure of area would be more appropriate for use with maintenance practice data collected from individual households.

REFERENCE

Valley Research Corporation (1989). Development of an Inventory of Materials Potentially Sensitive to Ambient Atmospheric Acidity in the South Coast Air Basin. Report prepared for the California Air Resources Board under Contract No. A6079-32, March.

SECTION 4

PHYSICAL DAMAGE FUNCTIONS

4.1 INTRODUCTION

EMSI (1989), with the assistance of Professor Ron Henry of the University of Southern California, developed statistical damage functions from weight loss and aerometric data collected at four sites in California. Three of the sites were located in the South Coast Air Basin. These field sites were located in Burbank, Long Beach, and Upland. A fourth site, in Salinas, was used as a background site. Damage occurring at the Salinas site was assumed to represent the damage that would occur under natural conditions. Damage functions were estimated for four materials:

- Zinc (bare)
- Nickel (bare)
- Paint coatings without carbonate extender
- Paint coatings with some carbonate extender.

Damage functions for other potentially relevant materials such as unpainted and painted stucco were not developed because of the absence of field data on damage rates. It should be noted that the damage functions for the paint coatings are based on the exposure of metallic panels covered with paint typically used to coat wood substrates. This combination is used because it is difficult to obtain accurate measures of paint weight loss when painted wood panels are used. For this study, the damage functions for these panels are evaluated as if they represented painted wood surfaces.

The end-points of physical damage were based on weight loss data and on Atmospheric Corrosion Rate Monitor (**ACRM**) measurements. Both types of data are useful. Weight loss data are frequently used as the dependent variable in a physical damage regression because it is one possible indicator of damage that may be perceived by individuals. The ACRM data reflect a specific physical process and may be measured with less error and without drastically affecting each exposed coupon every time a measurement is taken. In the present work, ACRM data were used by EMSI in a Principal Components Analysis to unravel some of the statistical associations between ACRM measurements and various aerometric variables. Furthermore, it is shown that there is a good correlation between the nickel ACRM measurements and the weight loss of zinc and nickel. Thus, the results of the Principal Components Analysis can be used to define a set of explanatory variables for a regression analysis explaining variations in weight loss for these two materials. The correlation of ACRM nickel measurements with paint weight loss data was smaller than for the metals. However, a weight loss paint damage function (for the paint with some carbonate extender) was also estimated for the set of variables that emerged from the Principal Components Analysis.[1]

4.2 DATA ANALYSIS

On the basis of the Principal Components Analysis, three variables were selected as potential explanatory variables:

- Ozone (daily averages measured in ppb), O_3
- Nitrogen dioxide (daily averages measured in ppb), NO_2
- Relative Humidity (measured as fraction of time humidity exceeds 60 percent), T_{60}

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[1] See EMSI (1989) for a discussion of this analysis and a description of the exposure regimen.

Cross-products of these variables were also considered. A constant term was included to reflect contributions to rates of damage other than those controlled for in the damage functions. The dependent variables for the damage functions were weight loss rates (in grams/square meter/year).

Tables 4-1(a) and 4-1(b) report the results of the damage function analysis. Table 4-1(a) includes data points from Southern California sites only. Consequently, the results should be used for prediction purposes only for current ambient levels of the independent variables. The second table contains the regression results for a data set that includes average values for the background site located in Salinas. These damage functions may be used to predict weight loss rates at relatively low pollution levels, although the confidence interval for expected weight loss is likely to be large at low concentrations.

For the economic analysis, it was determined that only the damage functions for the paint coatings would be used. This decision was based on the fact that bare nickel and zinc were not economically significant materials. A review of data contained in the materials inventory of the South Coast Air Basin (Valley Research, 1989) showed no nickel inventory for structures and

Table 4-1(a)

DAMAGE FUNCTIONS FOR SELECTED MATERIALS AT SOUTHERN CALIFORNIA SITES
(Dependent Variable: weight loss rate in grams/square meter/year)

	Zinc	Nickel	Paint with Carbonate
Constant	10.410 (2.980)*	8.79 (2.240)	-5.716 (2.465)
O_3**	-0.341 (0.103)	-0.331 (0.077)	--
NO_2**	-0.154 (0.052)	-0.124 (0.039)	0.149 (0.049)
T_{60}	--	--	19.140 (4.890)
$O_3 \times T_{60}$	0.187 (0.050)	0.118 (0.037)	--
$NO_2 \times T_{60}$	--	--	-0.328 (0.103)
$O_3 \times NO_2$	0.005 (0.002)	0.005 (0.001)	--
S(Y)***	0.768	0.576	0.579
R^2	0.560	0.518	0.572
NOBS	29	29	29

* Numbers in parentheses are standard errors
** O_3 and NO_2 values are in ppb.
*** Standard error of dependent variable

Source: EMSI (1989).

Table 4-1(b)

DAMAGE FUNCTIONS FOR SELECTED MATERIALS AT ALL CALIFORNIA SITES
(Dependent Variable: weight loss rate in grams/square meter/year)

	Zinc	Nickel	Paint with Carbonate
Constant	-1.174 (1.051)*	-0.118 (0.736)	-0.031 (1.120)
O_3**	0.033 (0.020)	-0.057 (0.029)	--
NO_2**	--	--	0.033 (0.017)
T_{60}	5.252 (1.457)	3.307 (1.053)	3.980 (1.090)
O_3 x NO_2	--	0.002 (0.001)	--
S(Y)***		0.998	0.674 0.708
R^2	0.326	0.354	0.351
NOBS	30	30	30

* Numbers in parentheses are standard errors
** O_3 and NO_2 values are in ppb.
*** Standard error of dependent variable

Source: EMSI (1989).

limited amounts of bare (unpainted) zinc.[2] Therefore, the remainder of this section focuses on the paint damage functions shown in the last two columns of Tables 4-1(a) and 4-1(b). These equations will be the focus of our demonstration of alternative methodologies for assessing the economic value of materials damage due to air pollution exposure.

A closer examination of the paint damage function in Table 4-1(a) reveals a possible problem for the economic analysis. Take the partial derivative of the equation with respect to NO_2:

$$\frac{\partial\ (weight\ loss\ rate)}{\partial\ NO_2} = 0.149 - 0.328 * (T_{60})$$

This shows that the relationship between changes in NO_2 and changes in weight loss rate depends on the level of T_{60}. In fact, for levels of T_{60} commonly found in the South Coast Air Basin (around 0.60), the partial derivative is negative. This implies that increases in NO_2 concentrations lead to lower weight loss rates. This result is not expected based on physical principles. The explanation for this result is a specification

[2] Bare galvanized steel and bare chain link fencing accounts for only about 3.5 percent of the material surface area in the South Coast Air Basin. (Valley Research Corporation, 1989). Furthermore, using critical damage levels reported in Horst et al. (1986), the predicted maintenance interval length for zinc, using the damage function in Table 4-1(a) and current values of the independent variables, is in excess of 20 years. This is near the normal replacement interval for zinc material systems. Consequently, incremental changes in air quality may not significantly alter economic behavior.

error. This could be an incorrect functional expression, excluded relevant explanatory factor, or other estimation problem.[3]

Because of the problem with the relationship between NO_2 and weight loss rate changes in the paint damage function of Table 4-1(a), the economic analysis is based on, and limited by, the single paint damage function shown in Table 4-1(b). This function is linear in NO_2, so that the partial derivative of weight loss rate with respect to NO_2 is a constant and equal to the coefficient of NO_2. This coefficient of NO_2 is statistically different from zero at standard levels of confidence, although the equation as a whole explains only 35 percent of the variation in the weight loss data.

There are several features of the paint equation in Table 4-1(b) that should be noted; especially with respect to prospects for a credible economic analysis:

- The equation is not intended to represent the physical deterioration process. The damage function is designed to show statistical association. Consequently, the economic analysis cannot rely on the damage function results to show cause and effect.

- NO_2 should be considered a proxy for components of photochemical smog that are the causative damage factors. These components include nitric acid vapors, organic acids, and acidic particles such as sulfates. For the economic analysis, this has the important implication that small changes in NO_2 are reflective of similar changes in the pollutants that constitute acidic deposition. This may not be true. The formation of acid deposition is a complex process.

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[3] An F-test was conducted to determine whether or not both terms involving NO_2 had coefficients that were statistically different from zero. The null hypothesis of no relation was easily rejected. See Kmenta (1971) for a discussion of this test-statistic.

- The effect of NO_2 on weight loss rate is for a representative square meter. For the economic analysis, this implies that the joint effect of deposition and location of the affected material on a structure is ignored.

- The damage function is specific to paints typically used to coat wood. This implies that the demonstration of alternative valuation methodologies is most appropriate for an assessment of the cost-savings associated with wood painting only.

- The paints used in the field exposure experiments were paints that had large market shares in California. The damage function for paint in Table 4-1(b) is for a paint that contained some carbonate extender. This implies that an economic analysis based on the damage function in Table 4-1(b) should be limited to those surfaces that are painted with a paint composition that includes the carbonate extender (No statistically significant coefficient for pollution was estimated for the paint sample without the calcium carbonate extender). It will be assumed that 50 percent of painted wood surfaces use a paint composition similar to that on the exposed coupons.

- Although the damage functions in Table 4-1(b) are designed to allow weight loss rate predictions at low pollution levels, it is thought to be prudent to limit changes in NO_2 to marginal changes. The implication of this for the economic analysis is that the scenario involves small percentage changes from current levels.

- The physical end point, weight loss rate, may be inappropriate as a measure of the perceived damage to which individuals respond when making home maintenance decisions. The economic analysis must distinguish among factors that influence the decision to paint as a maintenance action. The damage function is best applied in those situations where visible deterioration is an important factor in re-painting decisions.

These limitations of the damage function analyses do not preclude an economic analysis based on the damage functions. However, the limitations do significantly narrow the scope of what materials/surfaces can be considered in the economic analysis.

Based on the types of limitations described above, these improvements are warranted for future work:

- Consider the collection of environmental data for those pollutants believed to be directly involved in the degradation of materials.
- Consider the use of scale structures for assessing deposition and damage. The material inventory information is sufficiently detailed to take advantage of site-specific damage rate estimates.
- Expand the field experiments to include the economically significant materials. It seems especially important to begin the design of an experiment to measure damage to painted and unpainted stucco.
- Develop methods for measuring damage in quantitative terms which relate to people's perceptions of damage. For paint, the dominant types of deterioration to which people respond are peeling, cracking, and blistering, not weight loss per se.

REFERENCES

EMSI (1989). Investigation of the Effects of Acid Deposition on Materials. Report prepared for the California Air Resources Board under Contract Nos. A4-110-32 and A5-137-32, June.

Horst, R.L., Jr. et al. (1986). A Damage Function Assessment of Building Materials: The Impact of Acid Deposition. Report prepared by Mathtech, Inc. for the U.S. Environmental Protection Agency under Contract No. 68-01-7033, May.

Kmenta, J. (1971). Elements of Econometrics. Macmillan Publishing Co., New York.

Valley Research Corporation (1989). Development of an Inventory of Materials Potentially Sensitive to Ambient Atmospheric Acidity in the South Coast Air Basin. Report prepared for the California Air Resources Board under Contract No. A6-079-32, March.

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SECTION 5

SPATIAL DISTRIBUTION OF AEROMETRIC DATA IN THE SOUTH COAST AIR BASIN

5.1 INTRODUCTION

A study of pollutant levels and relative humidity values was performed to assist in the assessment of pollutant damage to materials in the South Coast Air Basin of California. Aerometric data were processed for use with the California Air Resources Board (ARB) damage functions and materials inventory and in conjunction with telephone survey responses by area residents. Ozone, NO_2 and time of wetness were the parameters chosen for study on the basis of the damage functions. Time of wetness data were calculated from relative humidity data. It was necessary to develop spatial averages of the parameters for use in the study. These were obtained by interpolating point source data (monitored values) over the region of interest. A receptor grid was developed and integrated with an interpolation program from ARB to provide the spatial averages in a grid compatible with the rest of the study.

The pollutant data set was a compilation of monitored data provided by the ARB. Ozone and NO_2 annual values were examined for the years 1980 through 1987. The humidity statistic of interest was the time of wetness. Humidity data was provided by the National Climatic Data Center, with additional site data provided by Ron Henry of the University of Southern California. The time of wetness was defined as the percent of time that the relative humidity value was greater than 60, the same definition used for the damage functions. The time of wetness study was limited to two years, 1986 and 1987.

Since trends of damage and the effects of long term exposure were of interest, annual averages were used in the study. Multiple years of data were examined to show trends and the effects of long term exposure. Spatial averages were needed for the products of NO_2, ozone and time of wetness, in addition to those for the individual parameters.[1] Based on test cases, it was determined that similar results were obtained for the average of the products as were obtained for the product of the averages. Therefore, at each location, an average of the products can be estimated using the product of the averages. The use of annual averages for the individual aerometeric parameters simplified the procedure and increased the data base, since shorter term average data was not readily available in all cases.

5.2 DATA DEVELOPMENT

The pollutant data values used for processing in this study were annual average ozone and NO_2 values as available from the Aerometric Data Division of the California Air Resources Board for the years 1980 through 1987. The data were compiled from ARB's available monitored data from sites in the South Coast Air Basin. The relative humidity data were provided, on an hourly basis, for two years (1986 and 1987) by the National Climatic Data Center. Data from additional sites were provided by Ron Henry, providing better coverage of the total basin for interpolation purposes.

Each aerometric parameter was processed separately. It was determined that this method would reasonably approximate studying the combined effect of the pollutants. In order to process the data in this manner, it was necessary to show that the sum of the products of NO_2 and ozone values reasonably approximated the

[1] As shown in Section 4, some of the physical damage functions were specified with cross-product terms.

product of the sums of the same values. Also, it was necessary to show that the product of the annual average pollutant value and the annual average percent of wetness was representative of the average of the daily pollutant values multiplied by the daily percentage of wetness. In each case data from one coastal site and two inland sites were examined on a short term basis to check for the desired representativeness.

The data from three sites (Pasadena, Fontana and Long Beach) were examined for two years (1986 and 1987) to determine if the product of the hourly sums was representative of the sum of the hourly products for the two pollutants. The two results were similar (see Table 5-1), thus allowing pollutants to be processed separately. The results of the interpolation program runs can be combined to provide a representive value of the cross product of the two pollutants.

Table 5-1

SUM OF PRODUCTS VS. PRODUCT OF SUMS, OZONE AND NO_2 DATA

		Sum of Products	Product of Sums
Pasadena	86	16.532	16.515
	87	13.753	12.785
Fontana	86	13.304	13.671
	87	11.710	11.880
Long Beach	86	9.090	9.546
	87	6.478	7.201

One coastal site (Long Beach) and two inland sites (Riverside and Los Angeles) were used for the relative humidity/pollutant relationship test. The annual average statistic was defined as the sum of all hourly pollutant values for the year divided by the number of hours of available pollutant data multiplied by the time of wetness. The time of wetness is the percent of time during the year (during valid relative humidity readings) that the humidity was greater than sixty. The daily average statistic was defined as the sum over all days of the product of the pollutant average and the daily wetness percentage divided by the number of days of data. Combinations of annual average pollutant and time of wetness data were compared to combinations of daily averages because the damage functions developed for ARB were based on daily averages.

Due to the similarity of the results (see Table 5-2) for the annual and daily statistics for the two years examined (1986 and 1987), it was determined that the annual average computed values could be used for this study. It is not clear that combining annual averages would give the same result as combining hourly averages. Therefore, caution should be exercised in combining annual average pollutant data with annual time of wetness data for use with damage functions which are based on hourly data.

5.3 THE INTERPOLATION PROGRAM

The program used to predict concentrations at receptor locations was provided by Paul Allen from the California Air Resources Board. The associated data files containing site names and locations and mountain barrier line segments were provided along with the program. The program was modified for use in the damage study. Data files containing applicable annual values and stations were created to run with the program for this particular application.

Table 5-2

HOURLY VS. DAILY COMPUTATION OF POLLUTANT AVERAGES WITH PERCENT WETNESS

		OZONE (in ppm)	
		ANNUAL STATISTIC	DAILY STATISTIC
Long Beach	86	.0123	.0121
	87	.0110	.0111
Riverside	86	.0145	.0131
	87	.0152	.0131
Los Angeles	86	.0159	.0170
	87	.0163	.0179
		NO_2 (in ppm)	
		ANNUAL STATISTIC	DAILY STATISTIC
Long Beach	86	.0363	.0334
	87	.0285	.0265
Riverside	86	.0138	.0131
	87	.0123	.0115
Los Angeles	86	.0494	.0482
	87	.0422	.0417

The program contains a model that interpolates values from the given point sources to each of the receptors, using a $1/r^2$ distance weighting scheme. The line segments depicting existing mountains act as walls between sources and receptors, prohibiting a source from influencing a receptor across a mountain barrier.

5.4 THE RECEPTOR GRID

An important element of the analysis involves the modeling of ozone, NO_2, and relative humidity levels for a spatial grid which corresponds to the Thomas Brothers map grid. In order to complete this task, it was necessary to define the boundaries (e.g., in terms of UTM coordinates) for each Thomas Brothers grid.

Initially, it was believed that each Thomas Brothers map grid was of uniform size. In this case, knowledge of the UTM (or latitude, longitude values) for one corner of one Thomas Brothers grid would be sufficient to define the grid for the entire basin. A wall map of the Thomas Brothers grid map system was purchased and measurements made of each grid square dimension. It was immediately noticed that variations existed in the grid dimensions. While the variations were not large, failure to account for them could lead to cumulative, significant errors. On average, the east-west dimension of each grid was about 12.9 km. However, some grids were as small as 11.9 km in this direction. The average north-south grid length was 11.96 km with the smallest north-south dimension being 11.44 km.

Because of these variations, each grid dimension was separately measured and used as input data for the air quality modeling. In addition, it was necessary to provide a base point on the grid map in terms of latitude and longitude. Two points were identified. Washington Boulevard and Atlantic Boulevard intersect in the City of Commerce at 34°00'11" North Latitude and 118°10'01" West Latitude. Also, a monitoring station located at 12122 Diane Street in Garden Grove is located at 33°46'30" North Latitude and 117°54'48" West Longitude. These two points were used to ensure that accurate measurements of the grid dimensions had been obtained and to predict the geographic locations of the center of each Thomas Brothers grid map.

5.5 COMPUTATIONS

The $1/r^2$ interpolation program was run for each of the eight years (1980-87) of available ozone data to determine the ozone concentration at the center of each grid box. Eight runs for the same years were made using the available NO_2 data. The two years of available relative humidity data (1986-87) were processed to determine the percent of time that the relative humidity was greater than sixty. This relative humidity statistic, known as the time of wetness, was input to the program for all available sites to obtain a percent time of wetness at the grid box centers. Additional time of wetness data for two sites for the year 1986 were provided by Ron Henry from his damage studies. The location of these extra sources provided better coverage of the total area for interpolation purposes. Yearly files containing the interpolation program outputs were created as final results. The results were also examined spatially to determine scopes of influence and trends.

5.6 RESULTS

The interpolation program was run for each of the eight years of NO_2 and ozone annual data. The highest and lowest values for each set of pollutant results are shown in Table 5-3. The entries in Table 5-3 indicate that the range of air pollution concentrations is of order two to three across the basin, on an annual average basis. This variation is important if statistically significant impacts of air pollution on maintenance decisions are to be determined.

Figure 5-1 shows the location of the receptor grids in the South Coast Air Basin. The grid numbers shown in the figure correspond to areas for which unique aerometric data have been

Table 5-3

HIGHEST AND LOWEST POLLUTANT VALUES FROM RESULTS

	OZONE (ppm)	
	LOW	HIGH
1980	0.0172	0.0445
1981	0.0181	0.0391
1982	0.0159	0.0372
1983	0.0200	0.0366
1984	0.0190	0.0386
1985	0.0194	0.0405
1986	0.0200	0.0422
1987	0.0197	0.0405
	NO_2 (ppm)	
	LOW	HIGH
1980	0.0267	0.0678
1981	0.0327	0.0682
1982	0.0317	0.0601
1983	0.0287	0.0589
1984	0.0268	0.0570
1985	0.0258	0.0599
1986	0.0274	0.0609
1987	0.0286	0.0539

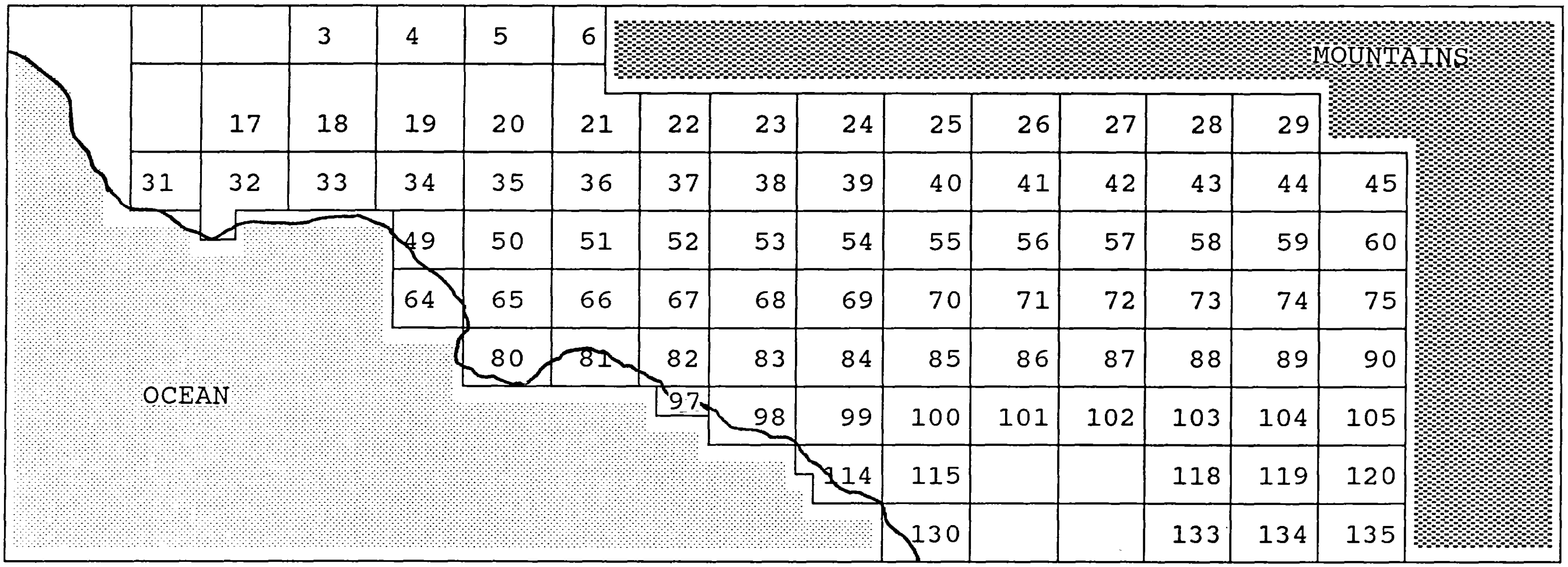

Figure 5-1. Location of Receptor Grid in South Coast Air Basin

modeled. Note that these grid areas generally represent a combination of four Thomas Brothers Map Grids (see e.g., Figure 3-1). As a result, the aerometric data are modeled for areas that are about 20 km square. However, near basin boundaries the grid areas may be smaller. All modeled concentration values are estimated for the center point of the grids shown in Figure 5-1. The concentration values associated with each grid square are shown in Table 5-4 for 1986. An entry of -999.9 indicates that the grid is in the ocean, in the mountains, or otherwise outside the boundaries for which air quality concentrations are modeled.

Table 5-4 also contains the predicted values for time-of-wetness in 1986. A summary of results for the remaining years is provided in Appendix A of this section. The Appendix also includes graphical displays of isopleths for the modeled data. The isopleth map for ozone in 1980 shows the location of monitoring stations in the South Coast Air Basin. These monitors are the source of data for the interpolation program.

An examination of the NO_2 results for all years (1980-87) reveals an overall decrease in values. The reductions are more pronounced in the western portion of the basin. The pocket of high values is seen in the northwestern to north central portion of the basin. The lowest values consistently appear on the central coastal area of the basin. An examination of the ozone results reveals no obvious trends. The high concentration values appear in the northeastern/eastern portion of the basin. The low ozone concentrations tend to occur in the western coastal areas.

5.7 APPLICATION TO ECONOMIC ANALYSIS

Maintenance decisions are likely affected by the cumulative exposure of materials to air pollution. A complete assessment of economic damages would necessarily consider the pattern of exposure and the possible effect of short-term peaks. This

Table 5-4

MODELED AEROMETRIC DATA FOR SOUTH COAST AIR BASIN
(Annual Averages, 1986)

Grid	NO_2	O_3	Time of Wetness
1	-999.9000	-999.9000	-999.9000
2	-999.9000	-999.9000	-999.9000
3	0.0345	0.0280	0.4263
4	0.0363	0.0270	0.4312
5	0.0496	0.0269	0.4321
6	0.0508	0.0268	0.4258
7	-999.9000	-999.9000	-999.9000
8	-999.9000	-999.9000	-999.9000
9	-999.9000	-999.9000	-999.9000
10	-999.9000	-999.9000	-999.9000
11	-999.9000	-999.9000	-999.9000
12	-999.9000	-999.9000	-999.9000
13	-999.9000	-999.9000	-999.9000
14	-999.9000	-999.9000	-999.9000
15	-999.9000	-999.9000	-999.9000
16	-999.9000	-999.9000	-999.9000
17	0.0370	0.0290	0.4237
18	0.0325	0.0276	0.4246
19	0.0309	0.0273	0.4180
20	0.0550	0.0268	0.4133
21	0.0530	0.0269	0.4552
22	0.0509	0.0299	0.5348
23	0.0499	0.0332	0.5544
24	0.0498	0.0389	0.5293
25	0.0452	0.0323	0.4937
26	0.0426	0.0329	0.5016
27	0.0421	0.0371	0.5246
28	0.0415	0.0422	0.5515
29	0.0422	0.0402	0.5471
30	-999.9000	-999.9000	-999.9000
31	0.0471	0.0259	0.7153
32	0.0468	0.0256	0.7307
33	0.0459	0.0254	0.7501
34	0.0429	0.0258	0.7683
35	0.0482	0.0244	0.7643
36	0.0609	0.0200	0.5584
37	0.0517	0.0266	0.5853
38	0.0497	0.0301	0.5792
39	0.0521	0.0295	0.5364
40	0.0462	0.0307	0.4884
41	0.0420	0.0327	0.4992
42	0.0380	0.0333	0.5185
43	0.0399	0.0354	0.5537

Table 5-4 (continued)

Grid	NO_2	O_3	Time of Wetness
44	0.0424	0.0357	0.5360
45	0.0436	0.0340	0.5156
46	-999.9000	-999.9000	-999.9000
47	-999.9000	-999.9000	-999.9000
48	-999.9000	-999.9000	-999.9000
49	0.0448	0.0239	0.7993
50	0.0439	0.0225	0.7850
51	0.0523	0.0214	0.6759
52	0.0507	0.0244	0.6467
53	0.0453	0.0254	0.6173
54	0.0478	0.0278	0.5743
55	0.0466	0.0290	0.5321
56	0.0407	0.0316	0.4999
57	0.0337	0.0327	0.4878
58	0.0394	0.0329	0.4648
59	0.0422	0.0332	0.4890
60	0.0436	0.0330	0.5028
61	-999.9000	-999.9000	-999.9000
62	-999.9000	-999.9000	-999.9000
63	-999.9000	-999.9000	-999.9000
64	0.0442	0.0228	0.8036
65	0.0469	0.0228	0.7552
66	0.0518	0.0202	0.6893
67	0.0492	0.0231	0.6800
68	0.0455	0.0244	0.6506
69	0.0455	0.0264	0.6293
70	0.0451	0.0291	0.6012
71	0.0432	0.0311	0.5040
72	0.0405	0.0315	0.4711
73	0.0414	0.0319	0.4424
74	0.0429	0.0320	0.4667
75	0.0439	0.0320	0.4917
76	-999.9000	-999.9000	-999.9000
77	-999.9000	-999.9000	-999.9000
78	-999.9000	-999.9000	-999.9000
79	-999.9000	-999.9000	-999.9000
80	0.0484	0.0234	0.7036
81	0.0499	0.0220	0.6857
82	0.0466	0.0232	0.6803
83	0.0420	0.0302	0.6688
84	0.0426	0.0263	0.6975
85	0.0426	0.0263	0.6976
86	0.0404	0.0316	0.4668
87	0.0429	0.0320	0.4626
88	0.0430	0.0320	0.4628
89	0.0435	0.0321	0.4719

Table 5-4 (continued)

Grid	NO_2	O_3	Time of Wetness
90	0.0441	0.0323	0.4852
91	-999.9000	-999.9000	-999.9000
92	-999.9000	-999.9000	-999.9000
93	-999.9000	-999.9000	-999.9000
94	-999.9000	-999.9000	-999.9000
95	-999.9000	-999.9000	-999.9000
96	-999.9000	-999.9000	-999.9000
97	0.0274	0.0254	0.6861
98	0.0268	0.0252	0.6874
99	0.0371	0.0261	0.7187
100	0.0444	0.0254	0.7150
101	0.0442	0.0255	0.7160
102	0.0441	0.0321	0.4665
103	0.0441	0.0321	0.4665
104	0.0440	0.0323	0.4695
105	0.0443	0.0323	0.4748
106	-999.9000	-999.9000	-999.9000
107	-999.9000	-999.9000	-999.9000
108	-999.9000	-999.9000	-999.9000
109	-999.9000	-999.9000	-999.9000
110	-999.9000	-999.9000	-999.9000
111	-999.9000	-999.9000	-999.9000
112	-999.9000	-999.9000	-999.9000
113	-999.9000	-999.9000	-999.9000
114	0.0390	0.0258	0.7068
115	0.0391	0.0258	0.7060
116	-999.9000	-999.9000	-999.9000
117	-999.9000	-999.9000	-999.9000
118	0.0426	0.0328	0.4747
119	0.0442	0.0328	0.4727
120	0.0454	0.0328	0.4756
121	-999.9000	-999.9000	-999.9000
122	-999.9000	-999.9000	-999.9000
123	-999.9000	-999.9000	-999.9000
124	-999.9000	-999.9000	-999.9000
125	-999.9000	-999.9000	-999.9000
126	-999.9000	-999.9000	-999.9000
127	-999.9000	-999.9000	-999.9000
128	-999.9000	-999.9000	-999.9000
129	-999.9000	-999.9000	-999.9000
130	0.0415	0.0257	0.6943
131	-999.9000	-999.9000	-999.9000
132	-999.9000	-999.9000	-999.9000
133	0.0442	0.0296	0.5744
134	0.0412	0.0313	0.5547
135	0.0414	0.0323	0.4761

degree of complexity was beyond the scope of the present project. Instead, the data were reviewed on a year by year basis, for a selection of locations, to determine a representative year. Based on this review, 1986 was selected. Consequently, in the economic analysis that follows, levels of damage, and changes in economic damage are computed as if the predicted values for 1986 represent the long-term average values across all years.

The data described in this section are representative of a state of the world given current air quality regulations and enforcement practices. For the economic analysis, it is necessary to define a comparative scenario of air quality levels. The comparative scenario can take one of several forms:

- A scenario in which all man-made contributions to air pollution concentrations would be eliminated. This approach would lead to an estimate of economic damages associated with current conditions.
- A scenario in which a specific control strategy was modeled. This approach would lead to an estimate of economic benefits. Different areas of the basin can experience different changes in concentrations.
- A scenario in which all areas in the basin are assumed to experience an identical percentage change in air quality concentrations.

In this study, the third option is selected. The economic values developed in this study are associated with a uniform 10 percent reduction in acidic deposition (as represented by NO_2) concentrations. Although implementation of an actual control strategy would likely reduce concentrations by different amounts in different areas, the analysis of a uniform reduction, for spatially disaggregate grids, provides information about the distribution of cost-savings relative to a known environmental improvement scenario.

5.8 SUMMARY

A major element of this study involves the integration of several data sets at a spatially disaggregate level. This section has described the data and models used to develop a grid-based map of aerometric values in the South Coast Air Basin. The process has been aided by the fact that a fairly dense network of monitors exists in the basin and that much previous work has been done in the development of the necessary software.

One implication of this observation is that it may be difficult to get the same level of detail and precision if the methodology were to be tried for other areas. The South Coast Air Basin is somewhat unique in the amount of information that is available for the type of research described in this section.

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APPENDIX 5-A

MODELED AEROMETRIC DATA FOR
SOUTH COAST AIR BASIN

Annual Averages 1980 to 1987

1980 FINAL RESULTS

REC	NO2	O3
1	-999.9000	-999.9000
2	-999.9000	-999.9000
3	0.0526	0.0341
4	0.0535	0.0320
5	0.0605	0.0289
6	0.0624	0.0287
7	-999.9000	-999.9000
8	-999.9000	-999.9000
9	-999.9000	-999.9000
10	-999.9000	-999.9000
11	-999.9000	-999.9000
12	-999.9000	-999.9000
13	-999.9000	-999.9000
14	-999.9000	-999.9000
15	-999.9000	-999.9000
16	-999.9000	-999.9000
17	0.0540	0.0344
18	0.0520	0.0340
19	0.0516	0.0344
20	0.0678	0.0282
21	0.0607	0.0282
22	0.0561	0.0325
23	0.0422	0.0318
24	0.0453	0.0305
25	0.0484	0.0354
26	0.0471	0.0429
27	0.0450	0.0425
28	0.0446	0.0419
29	0.0454	0.0427
30	-999.9000	-999.9000
31	0.0536	0.0247
32	0.0544	0.0242
33	0.0555	0.0238
34	0.0569	0.0235
35	0.0578	0.0239
36	0.0610	0.0240
37	0.0563	0.0271
38	0.0475	0.0286
39	0.0470	0.0284
40	0.0485	0.0344
41	0.0457	0.0428
42	0.0403	0.0410
43	0.0435	0.0404
44	0.0459	0.0445
45	0.0471	0.0403
46	-999.9000	-999.9000
47	-999.9000	-999.9000
48	-999.9000	-999.9000
49	0.0580	0.0211
50	0.0599	0.0192
51	0.0521	0.0172
52	0.0553	0.0231
53	0.0513	0.0228

54	0.0491	0.0256
55	0.0474	0.0293
56	0.0440	0.0353
57	0.0461	0.0331
58	0.0446	0.0382
59	0.0460	0.0404
60	0.0472	0.0390
61	-999.9000	-999.9000
62	-999.9000	-999.9000
63	-999.9000	-999.9000
64	0.0590	0.0196
65	0.0574	0.0200
66	0.0527	0.0176
67	0.0513	0.0211
68	0.0490	0.0212
69	0.0481	0.0221
70	0.0469	0.0250
71	0.0467	0.0323
72	0.0467	0.0340
73	0.0461	0.0365
74	0.0467	0.0377
75	0.0475	0.0374
76	-999.9000	-999.9000
77	-999.9000	-999.9000
78	-999.9000	-999.9000
79	-999.9000	-999.9000
80	0.0540	0.0212
81	0.0513	0.0197
82	0.0470	0.0218
83	0.0435	0.0216
84	0.0442	0.0230
85	0.0442	0.0230
86	0.0467	0.0342
87	0.0468	0.0367
88	0.0471	0.0392
89	0.0475	0.0380
90	0.0481	0.0374
91	-999.9000	-999.9000
92	-999.9000	-999.9000
93	-999.9000	-999.9000
94	-999.9000	-999.9000
95	-999.9000	-999.9000
96	-999.9000	-999.9000
97	0.0273	0.0195
98	0.0267	0.0193
99	0.0369	0.0229
100	0.0464	0.0236
101	0.0462	0.0237
102	0.0469	0.0394
103	0.0469	0.0395
104	0.0477	0.0384
105	0.0481	0.0374
106	-999.9000	-999.9000
107	-999.9000	-999.9000
108	-999.9000	-999.9000
109	-999.9000	-999.9000
110	-999.9000	-999.9000
111	-999.9000	-999.9000
112	-999.9000	-999.9000
113	-999.9000	-999.9000

114	0.0389	0.0232
115	0.0392	0.0232
116	-999.9000	-999.9000
117	-999.9000	-999.9000
118	0.0444	0.0396
119	0.0469	0.0384
120	0.0478	0.0380
121	-999.9000	-999.9000
122	-999.9000	-999.9000
123	-999.9000	-999.9000
124	-999.9000	-999.9000
125	-999.9000	-999.9000
126	-999.9000	-999.9000
127	-999.9000	-999.9000
128	-999.9000	-999.9000
129	-999.9000	-999.9000
130	0.0421	0.0228
131	-999.9000	-999.9000
132	-999.9000	-999.9000
133	0.0464	0.0330
134	0.0414	0.0363
135	0.0432	0.0365

1981 FINAL RESULTS

REC	NO2	O3
1	-999.9000	-999.9000
2	-999.9000	-999.9000
3	0.0522	0.0315
4	0.0534	0.0319
5	0.0615	0.0285
6	0.0631	0.0277
7	-999.9000	-999.9000
8	-999.9000	-999.9000
9	-999.9000	-999.9000
10	-999.9000	-999.9000
11	-999.9000	-999.9000
12	-999.9000	-999.9000
13	-999.9000	-999.9000
14	-999.9000	-999.9000
15	-999.9000	-999.9000
16	-999.9000	-999.9000
17	0.0541	0.0314
18	0.0514	0.0320
19	0.0508	0.0317
20	0.0682	0.0259
21	0.0620	0.0277
22	0.0578	0.0312
23	0.0520	0.0300
24	0.0516	0.0292
25	0.0498	0.0344
26	0.0485	0.0378
27	0.0469	0.0391
28	0.0463	0.0391
29	0.0472	0.0382
30	-999.9000	-999.9000
31	0.0546	0.0255
32	0.0549	0.0252
33	0.0551	0.0248
34	0.0543	0.0244
35	0.0522	0.0242
36	0.0670	0.0280
37	0.0588	0.0276
38	0.0539	0.0281
39	0.0514	0.0268
40	0.0498	0.0334
41	0.0471	0.0376
42	0.0419	0.0368
43	0.0449	0.0375
44	0.0473	0.0361
45	0.0487	0.0360
46	-999.9000	-999.9000
47	-999.9000	-999.9000
48	-999.9000	-999.9000
49	0.0564	0.0232
50	0.0583	0.0223
51	0.0574	0.0183
52	0.0572	0.0249
53	0.0547	0.0232

54	0.0519	0.0267
55	0.0499	0.0312
56	0.0454	0.0343
57	0.0452	0.0325
58	0.0452	0.0352
59	0.0472	0.0357
60	0.0487	0.0355
61	-999.9000	-999.9000
62	-999.9000	-999.9000
63	-999.9000	-999.9000
64	0.0576	0.0224
65	0.0571	0.0219
66	0.0550	0.0181
67	0.0543	0.0219
68	0.0513	0.0224
69	0.0506	0.0252
70	0.0495	0.0303
71	0.0477	0.0335
72	0.0465	0.0333
73	0.0467	0.0346
74	0.0479	0.0351
75	0.0490	0.0349
76	-999.9000	-999.9000
77	-999.9000	-999.9000
78	-999.9000	-999.9000
79	-999.9000	-999.9000
80	0.0552	0.0222
81	0.0540	0.0202
82	0.0515	0.0213
83	0.0472	0.0226
84	0.0477	0.0247
85	0.0477	0.0247
86	0.0465	0.0333
87	0.0475	0.0354
88	0.0480	0.0373
89	0.0486	0.0360
90	0.0494	0.0354
91	-999.9000	-999.9000
92	-999.9000	-999.9000
93	-999.9000	-999.9000
94	-999.9000	-999.9000
95	-999.9000	-999.9000
96	-999.9000	-999.9000
97	0.0333	0.0240
98	0.0327	0.0240
99	0.0422	0.0246
100	0.0504	0.0242
101	0.0502	0.0242
102	0.0484	0.0375
103	0.0483	0.0375
104	0.0486	0.0365
105	0.0494	0.0356
106	-999.9000	-999.9000
107	-999.9000	-999.9000
108	-999.9000	-999.9000
109	-999.9000	-999.9000
110	-999.9000	-999.9000
111	-999.9000	-999.9000
112	-999.9000	-999.9000
113	-999.9000	-999.9000

114	0.0441	0.0243
115	0.0443	0.0243
116	-999.9000	-999.9000
117	-999.9000	-999.9000
118	0.0463	0.0369
119	0.0484	0.0366
120	0.0496	0.0362
121	-999.9000	-999.9000
122	-999.9000	-999.9000
123	-999.9000	-999.9000
124	-999.9000	-999.9000
125	-999.9000	-999.9000
126	-999.9000	-999.9000
127	-999.9000	-999.9000
128	-999.9000	-999.9000
129	-999.9000	-999.9000
130	0.0468	0.0240
131	-999.9000	-999.9000
132	-999.9000	-999.9000
133	0.0490	0.0318
134	0.0451	0.0342
135	0.0459	0.0350

1982 FINAL RESULTS

REC	NO2	O3
1	-999.9000	-999.9000
2	-999.9000	-999.9000
3	0.0474	0.0267
4	0.0485	0.0265
5	0.0549	0.0256
6	0.0562	0.0255
7	-999.9000	-999.9000
8	-999.9000	-999.9000
9	-999.9000	-999.9000
10	-999.9000	-999.9000
11	-999.9000	-999.9000
12	-999.9000	-999.9000
13	-999.9000	-999.9000
14	-999.9000	-999.9000
15	-999.9000	-999.9000
16	-999.9000	-999.9000
17	0.0483	0.0276
18	0.0467	0.0266
19	0.0463	0.0262
20	0.0601	0.0257
21	0.0567	0.0242
22	0.0522	0.0253
23	0.0486	0.0306
24	0.0417	0.0372
25	0.0461	0.0276
26	0.0447	0.0305
27	0.0434	0.0364
28	0.0430	0.0350
29	0.0433	0.0356
30	-999.9000	-999.9000
31	0.0506	0.0222
32	0.0510	0.0218
33	0.0515	0.0214
34	0.0521	0.0213
35	0.0523	0.0218
36	0.0600	0.0220
37	0.0546	0.0230
38	0.0499	0.0273
39	0.0498	0.0261
40	0.0472	0.0248
41	0.0436	0.0298
42	0.0395	0.0323
43	0.0428	0.0327
44	0.0435	0.0340
45	0.0446	0.0334
46	-999.9000	-999.9000
47	-999.9000	-999.9000
48	-999.9000	-999.9000
49	0.0523	0.0191
50	0.0529	0.0173
51	0.0512	0.0189
52	0.0535	0.0214
53	0.0496	0.0217

54	0.0491	0.0241
55	0.0477	0.0267
56	0.0421	0.0297
57	0.0357	0.0317
58	0.0415	0.0324
59	0.0436	0.0331
60	0.0448	0.0327
61	-999.9000	-999.9000
62	-999.9000	-999.9000
63	-999.9000	-999.9000
64	0.0525	0.0176
65	0.0521	0.0183
66	0.0510	0.0159
67	0.0507	0.0194
68	0.0479	0.0200
69	0.0475	0.0223
70	0.0467	0.0264
71	0.0447	0.0292
72	0.0421	0.0305
73	0.0430	0.0317
74	0.0443	0.0320
75	0.0452	0.0318
76	-999.9000	-999.9000
77	-999.9000	-999.9000
78	-999.9000	-999.9000
79	-999.9000	-999.9000
80	0.0509	0.0193
81	0.0503	0.0176
82	0.0481	0.0191
83	0.0443	0.0206
84	0.0449	0.0223
85	0.0449	0.0223
86	0.0421	0.0306
87	0.0444	0.0322
88	0.0446	0.0336
89	0.0451	0.0328
90	0.0456	0.0323
91	-999.9000	-999.9000
92	-999.9000	-999.9000
93	-999.9000	-999.9000
94	-999.9000	-999.9000
95	-999.9000	-999.9000
96	-999.9000	-999.9000
97	0.0322	0.0255
98	0.0317	0.0257
99	0.0403	0.0230
100	0.0471	0.0217
101	0.0470	0.0217
102	0.0446	0.0338
103	0.0446	0.0338
104	0.0452	0.0331
105	0.0459	0.0324
106	-999.9000	-999.9000
107	-999.9000	-999.9000
108	-999.9000	-999.9000
109	-999.9000	-999.9000
110	-999.9000	-999.9000
111	-999.9000	-999.9000
112	-999.9000	-999.9000
113	-999.9000	-999.9000

114	0.0419	0.0225
115	0.0421	0.0225
116	-999.9000	-999.9000
117	-999.9000	-999.9000
118	0.0425	0.0337
119	0.0446	0.0334
120	0.0455	0.0331
121	-999.9000	-999.9000
122	-999.9000	-999.9000
123	-999.9000	-999.9000
124	-999.9000	-999.9000
125	-999.9000	-999.9000
126	-999.9000	-999.9000
127	-999.9000	-999.9000
128	-999.9000	-999.9000
129	-999.9000	-999.9000
130	0.0442	0.0222
131	-999.9000	-999.9000
132	-999.9000	-999.9000
133	0.0459	0.0285
134	0.0416	0.0310
135	0.0421	0.0322

1983 FINAL RESULTS

REC	NO2	O3
1	-999.9000	-999.9000
2	-999.9000	-999.9000
3	0.0454	0.0263
4	0.0465	0.0258
5	0.0506	0.0263
6	0.0516	0.0264
7	-999.9000	-999.9000
8	-999.9000	-999.9000
9	-999.9000	-999.9000
10	-999.9000	-999.9000
11	-999.9000	-999.9000
12	-999.9000	-999.9000
13	-999.9000	-999.9000
14	-999.9000	-999.9000
15	-999.9000	-999.9000
16	-999.9000	-999.9000
17	0.0461	0.0268
18	0.0451	0.0258
19	0.0449	0.0254
20	0.0545	0.0267
21	0.0515	0.0261
22	0.0482	0.0282
23	0.0455	0.0295
24	0.0388	0.0284
25	0.0429	0.0305
26	0.0377	0.0325
27	0.0380	0.0365
28	0.0366	0.0360
29	0.0378	0.0366
30	-999.9000	-999.9000
31	0.0466	0.0247
32	0.0469	0.0242
33	0.0475	0.0237
34	0.0486	0.0228
35	0.0499	0.0222
36	0.0589	0.0210
37	0.0491	0.0261
38	0.0463	0.0276
39	0.0465	0.0267
40	0.0441	0.0299
41	0.0361	0.0327
42	0.0364	0.0340
43	0.0364	0.0338
44	0.0384	0.0350
45	0.0401	0.0345
46	-999.9000	-999.9000
47	-999.9000	-999.9000
48	-999.9000	-999.9000
49	0.0467	0.0216
50	0.0454	0.0202
51	0.0471	0.0237
52	0.0491	0.0250
53	0.0465	0.0259

54	0.0458	0.0269
55	0.0440	0.0299
56	0.0391	0.0329
57	0.0351	0.0344
58	0.0379	0.0339
59	0.0393	0.0342
60	0.0405	0.0338
61	-999.9000	-999.9000
62	-999.9000	-999.9000
63	-999.9000	-999.9000
64	0.0453	0.0206
65	0.0461	0.0215
66	0.0463	0.0200
67	0.0473	0.0234
68	0.0458	0.0239
69	0.0448	0.0257
70	0.0433	0.0296
71	0.0415	0.0324
72	0.0393	0.0325
73	0.0396	0.0329
74	0.0403	0.0331
75	0.0411	0.0330
76	-999.9000	-999.9000
77	-999.9000	-999.9000
78	-999.9000	-999.9000
79	-999.9000	-999.9000
80	0.0462	0.0226
81	0.0459	0.0212
82	0.0445	0.0227
83	0.0420	0.0237
84	0.0423	0.0254
85	0.0423	0.0254
86	0.0393	0.0326
87	0.0410	0.0329
88	0.0409	0.0330
89	0.0411	0.0330
90	0.0415	0.0330
91	-999.9000	-999.9000
92	-999.9000	-999.9000
93	-999.9000	-999.9000
94	-999.9000	-999.9000
95	-999.9000	-999.9000
96	-999.9000	-999.9000
97	0.0293	0.0249
98	0.0287	0.0250
99	0.0375	0.0257
100	0.0441	0.0256
101	0.0440	0.0257
102	0.0407	0.0331
103	0.0407	0.0331
104	0.0412	0.0331
105	0.0420	0.0329
106	-999.9000	-999.9000
107	-999.9000	-999.9000
108	-999.9000	-999.9000
109	-999.9000	-999.9000
110	-999.9000	-999.9000
111	-999.9000	-999.9000
112	-999.9000	-999.9000
113	-999.9000	-999.9000

114	0.0389	0.0254
115	0.0391	0.0253
116	-999.9000	-999.9000
117	-999.9000	-999.9000
118	0.0393	0.0335
119	0.0405	0.0334
120	0.0414	0.0334
121	-999.9000	-999.9000
122	-999.9000	-999.9000
123	-999.9000	-999.9000
124	-999.9000	-999.9000
125	-999.9000	-999.9000
126	-999.9000	-999.9000
127	-999.9000	-999.9000
128	-999.9000	-999.9000
129	-999.9000	-999.9000
130	0.0412	0.0250
131	-999.9000	-999.9000
132	-999.9000	-999.9000
133	0.0423	0.0301
134	0.0385	0.0319
135	0.0389	0.0328

1984 FINAL RESULTS

REC	NO2	O3
1	-999.9000	-999.9000
2	-999.9000	-999.9000
3	0.0420	0.0289
4	0.0431	0.0279
5	0.0501	0.0259
6	0.0511	0.0254
7	-999.9000	-999.9000
8	-999.9000	-999.9000
9	-999.9000	-999.9000
10	-999.9000	-999.9000
11	-999.9000	-999.9000
12	-999.9000	-999.9000
13	-999.9000	-999.9000
14	-999.9000	-999.9000
15	-999.9000	-999.9000
16	-999.9000	-999.9000
17	0.0434	0.0291
18	0.0412	0.0287
19	0.0405	0.0287
20	0.0543	0.0239
21	0.0513	0.0260
22	0.0488	0.0299
23	0.0453	0.0309
24	0.0463	0.0291
25	0.0428	0.0309
26	0.0397	0.0349
27	0.0402	0.0386
28	0.0401	0.0380
29	0.0405	0.0386
30	-999.9000	-999.9000
31	0.0467	0.0248
32	0.0468	0.0244
33	0.0469	0.0239
34	0.0463	0.0232
35	0.0450	0.0231
36	0.0570	0.0230
37	0.0490	0.0265
38	0.0464	0.0283
39	0.0487	0.0270
40	0.0437	0.0301
41	0.0389	0.0356
42	0.0384	0.0355
43	0.0399	0.0357
44	0.0408	0.0370
45	0.0418	0.0361
46	-999.9000	-999.9000
47	-999.9000	-999.9000
48	-999.9000	-999.9000
49	0.0467	0.0216
50	0.0467	0.0200
51	0.0524	0.0199
52	0.0479	0.0246
53	0.0462	0.0259

54	0.0462	0.0269
55	0.0444	0.0292
56	0.0401	0.0328
57	0.0362	0.0347
58	0.0397	0.0353
59	0.0411	0.0358
60	0.0420	0.0353
61	-999.9000	-999.9000
62	-999.9000	-999.9000
63	-999.9000	-999.9000
64	0.0467	0.0204
65	0.0478	0.0209
66	0.0499	0.0190
67	0.0472	0.0227
68	0.0449	0.0245
69	0.0445	0.0259
70	0.0436	0.0284
71	0.0423	0.0314
72	0.0404	0.0332
73	0.0409	0.0339
74	0.0418	0.0343
75	0.0424	0.0342
76	-999.9000	-999.9000
77	-999.9000	-999.9000
78	-999.9000	-999.9000
79	-999.9000	-999.9000
80	0.0477	0.0220
81	0.0481	0.0207
82	0.0451	0.0217
83	0.0412	0.0236
84	0.0417	0.0256
85	0.0417	0.0256
86	0.0404	0.0333
87	0.0418	0.0338
88	0.0420	0.0340
89	0.0423	0.0341
90	0.0427	0.0342
91	-999.9000	-999.9000
92	-999.9000	-999.9000
93	-999.9000	-999.9000
94	-999.9000	-999.9000
95	-999.9000	-999.9000
96	-999.9000	-999.9000
97	0.0274	0.0240
98	0.0268	0.0240
99	0.0364	0.0262
100	0.0433	0.0270
101	0.0432	0.0272
102	0.0421	0.0341
103	0.0421	0.0341
104	0.0424	0.0342
105	0.0427	0.0341
106	-999.9000	-999.9000
107	-999.9000	-999.9000
108	-999.9000	-999.9000
109	-999.9000	-999.9000
110	-999.9000	-999.9000
111	-999.9000	-999.9000
112	-999.9000	-999.9000
113	-999.9000	-999.9000

114	0.0381	0.0262
115	0.0383	0.0262
116	-999.9000	-999.9000
117	-999.9000	-999.9000
118	0.0409	0.0347
119	0.0420	0.0345
120	0.0428	0.0346
121	-999.9000	-999.9000
122	-999.9000	-999.9000
123	-999.9000	-999.9000
124	-999.9000	-999.9000
125	-999.9000	-999.9000
126	-999.9000	-999.9000
127	-999.9000	-999.9000
128	-999.9000	-999.9000
129	-999.9000	-999.9000
130	0.0405	0.0256
131	-999.9000	-999.9000
132	-999.9000	-999.9000
133	0.0428	0.0308
134	0.0397	0.0330
135	0.0399	0.0341

1985 FINAL RESULTS

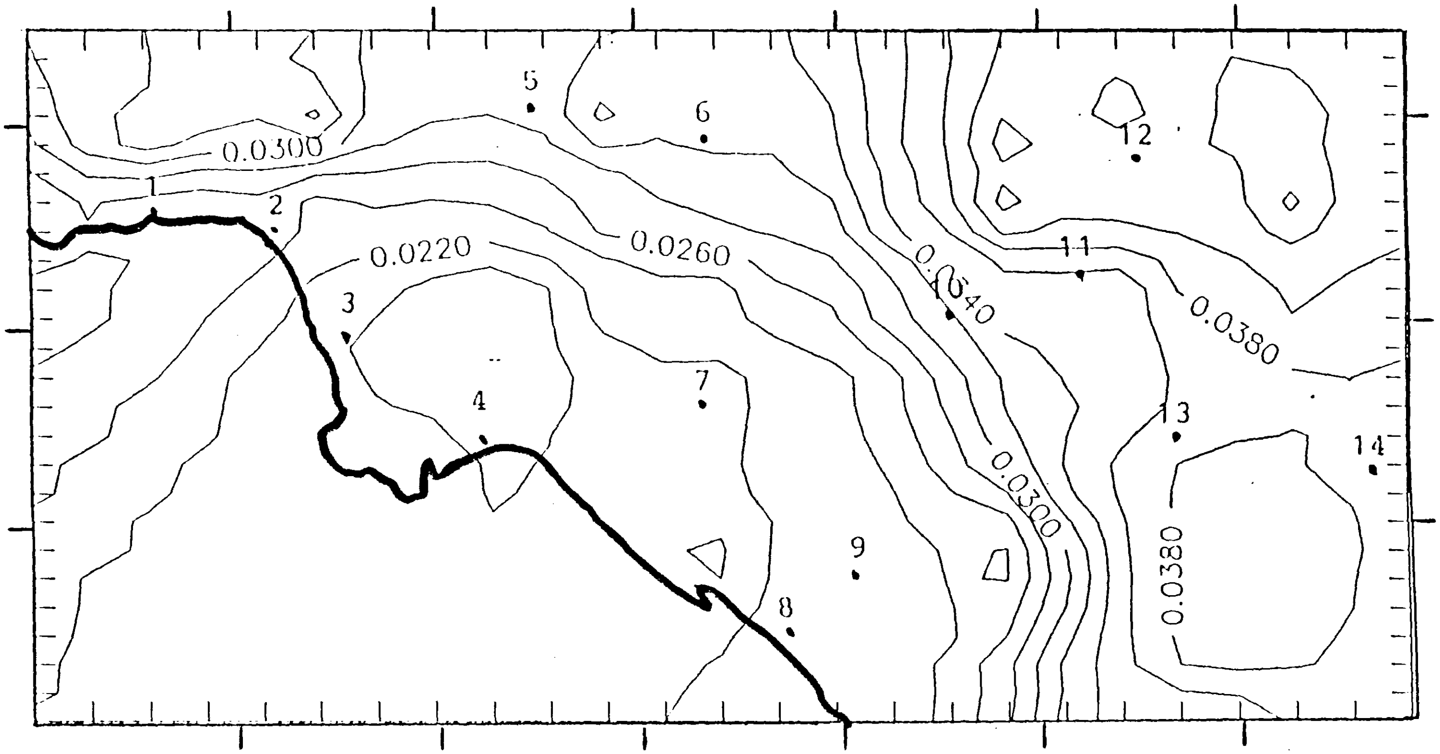
REC	NO2	O3
1	-999.9000	-999.9000
2	-999.9000	-999.9000
3	0.0417	0.0287
4	0.0429	0.0280
5	0.0510	0.0272
6	0.0520	0.0269
7	-999.9000	-999.9000
8	-999.9000	-999.9000
9	-999.9000	-999.9000
10	-999.9000	-999.9000
11	-999.9000	-999.9000
12	-999.9000	-999.9000
13	-999.9000	-999.9000
14	-999.9000	-999.9000
15	-999.9000	-999.9000
16	-999.9000	-999.9000
17	0.0435	0.0293
18	0.0406	0.0285
19	0.0398	0.0281
20	0.0553	0.0262
21	0.0526	0.0271
22	0.0502	0.0307
23	0.0496	0.0308
24	0.0487	0.0367
25	0.0434	0.0313
26	0.0393	0.0337
27	0.0401	0.0372
28	0.0406	0.0371
29	0.0414	0.0391
30	-999.9000	-999.9000
31	0.0457	0.0258
32	0.0452	0.0254
33	0.0439	0.0249
34	0.0394	0.0248
35	0.0463	0.0239
36	0.0599	0.0210
37	0.0511	0.0266
38	0.0493	0.0289
39	0.0507	0.0293
40	0.0443	0.0302
41	0.0382	0.0341
42	0.0378	0.0353
43	0.0397	0.0353
44	0.0418	0.0405
45	0.0430	0.0372
46	-999.9000	-999.9000
47	-999.9000	-999.9000
48	-999.9000	-999.9000
49	0.0436	0.0223
50	0.0443	0.0194
51	0.0513	0.0200
52	0.0498	0.0243
53	0.0453	0.0260

54	0.0469	0.0282
55	0.0452	0.0300
56	0.0402	0.0333
57	0.0360	0.0360
58	0.0397	0.0359
59	0.0419	0.0373
60	0.0430	0.0362
61	-999.9000	-999.9000
62	-999.9000	-999.9000
63	-999.9000	-999.9000
64	0.0443	0.0203
65	0.0463	0.0214
66	0.0496	0.0209
67	0.0477	0.0232
68	0.0443	0.0247
69	0.0443	0.0272
70	0.0440	0.0305
71	0.0427	0.0328
72	0.0406	0.0337
73	0.0413	0.0347
74	0.0425	0.0351
75	0.0433	0.0349
76	-999.9000	-999.9000
77	-999.9000	-999.9000
78	-999.9000	-999.9000
79	-999.9000	-999.9000
80	0.0471	0.0234
81	0.0480	0.0227
82	0.0451	0.0233
83	0.0406	0.0329
84	0.0413	0.0278
85	0.0413	0.0278
86	0.0406	0.0338
87	0.0425	0.0346
88	0.0427	0.0357
89	0.0432	0.0352
90	0.0437	0.0349
91	-999.9000	-999.9000
92	-999.9000	-999.9000
93	-999.9000	-999.9000
94	-999.9000	-999.9000
95	-999.9000	-999.9000
96	-999.9000	-999.9000
97	0.0264	0.0282
98	0.0258	0.0280
99	0.0359	0.0288
100	0.0433	0.0285
101	0.0432	0.0288
102	0.0436	0.0358
103	0.0436	0.0358
104	0.0434	0.0353
105	0.0438	0.0348
106	-999.9000	-999.9000
107	-999.9000	-999.9000
108	-999.9000	-999.9000
109	-999.9000	-999.9000
110	-999.9000	-999.9000
111	-999.9000	-999.9000
112	-999.9000	-999.9000
113	-999.9000	-999.9000

114	0.0377	0.0285
115	0.0379	0.0284
116	-999.9000	-999.9000
117	-999.9000	-999.9000
118	0.0418	0.0357
119	0.0435	0.0354
120	0.0446	0.0352
121	-999.9000	-999.9000
122	-999.9000	-999.9000
123	-999.9000	-999.9000
124	-999.9000	-999.9000
125	-999.9000	-999.9000
126	-999.9000	-999.9000
127	-999.9000	-999.9000
128	-999.9000	-999.9000
129	-999.9000	-999.9000
130	0.0403	0.0278
131	-999.9000	-999.9000
132	-999.9000	-999.9000
133	0.0432	0.0320
134	0.0402	0.0341
135	0.0405	0.0350

54	0.0448	0.0269	0.6595
55	0.0446	0.0288	0.6284
56	0.0380	0.0311	0.5437
57	0.0292	0.0325	0.5121
58	0.0358	0.0324	0.4864
59	0.0388	0.0326	0.5136
60	0.0402	0.0323	0.5298
61	-999.9000	-999.9000	-999.9000
62	-999.9000	-999.9000	-999.9000
63	-999.9000	-999.9000	-999.9000
64	0.0376	0.0226	0.7834
65	0.0401	0.0225	0.7573
66	0.0430	0.0197	0.6769
67	0.0441	0.0229	0.6669
68	0.0422	0.0244	0.6763
69	0.0424	0.0262	0.6769
70	0.0423	0.0288	0.6560
71	0.0401	0.0309	0.5354
72	0.0370	0.0312	0.4905
73	0.0379	0.0319	0.4622
74	0.0394	0.0320	0.4875
75	0.0404	0.0317	0.5158
76	-999.9000	-999.9000	-999.9000
77	-999.9000	-999.9000	-999.9000
78	-999.9000	-999.9000	-999.9000
79	-999.9000	-999.9000	-999.9000
80	0.0420	0.0231	0.7145
81	0.0426	0.0216	0.6741
82	0.0417	0.0236	0.6687
83	0.0396	0.0346	0.6831
84	0.0401	0.0268	0.7124
85	0.0401	0.0268	0.7124
86	0.0369	0.0313	0.4859
87	0.0399	0.0324	0.4832
88	0.0397	0.0336	0.4832
89	0.0402	0.0328	0.4939
90	0.0408	0.0322	0.5103
91	-999.9000	-999.9000	-999.9000
92	-999.9000	-999.9000	-999.9000
93	-999.9000	-999.9000	-999.9000
94	-999.9000	-999.9000	-999.9000
95	-999.9000	-999.9000	-999.9000
96	-999.9000	-999.9000	-999.9000
97	0.0290	0.0258	0.7006
98	0.0286	0.0253	0.7023
99	0.0362	0.0267	0.7190
100	0.0410	0.0260	0.7180
101	0.0409	0.0261	0.7181
102	0.0410	0.0338	0.4892
103	0.0410	0.0338	0.4891
104	0.0408	0.0331	0.4933
105	0.0414	0.0324	0.5007
106	-999.9000	-999.9000	-999.9000
107	-999.9000	-999.9000	-999.9000
108	-999.9000	-999.9000	-999.9000
109	-999.9000	-999.9000	-999.9000
110	-999.9000	-999.9000	-999.9000
111	-999.9000	-999.9000	-999.9000
112	-999.9000	-999.9000	-999.9000
113	-999.9000	-999.9000	-999.9000

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average Ozone 1980

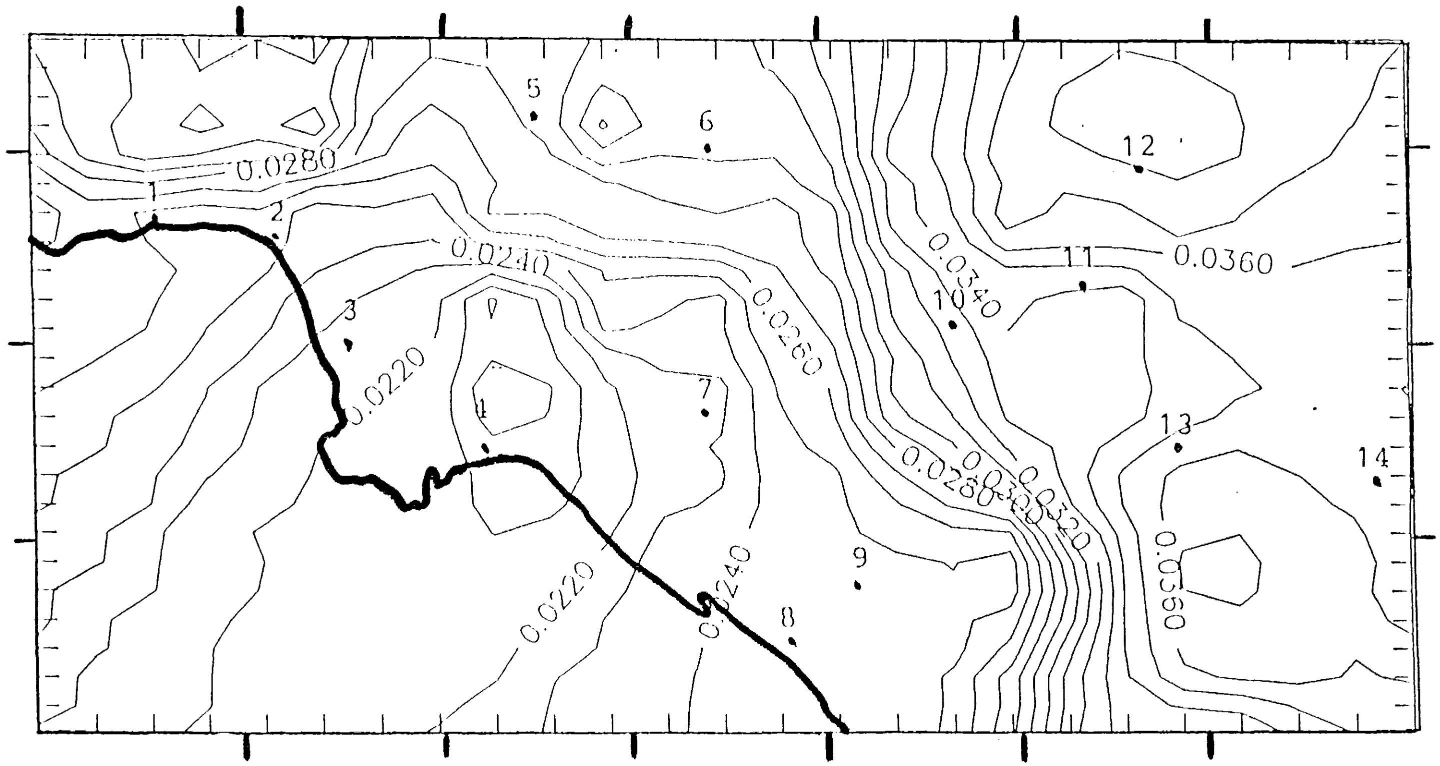


LEGEND:

1 Malibu
2 Santa Monica
3 Los Angeles
4 Long Beach
5 Pasadena
6 Azusa
7 Anaheim
8 Laguna Beach
9 El Toro
10 Norco
11 Riverside
12 San Bernardino
13 Perris
14 Hemet

Scale: 1":26.6 Km

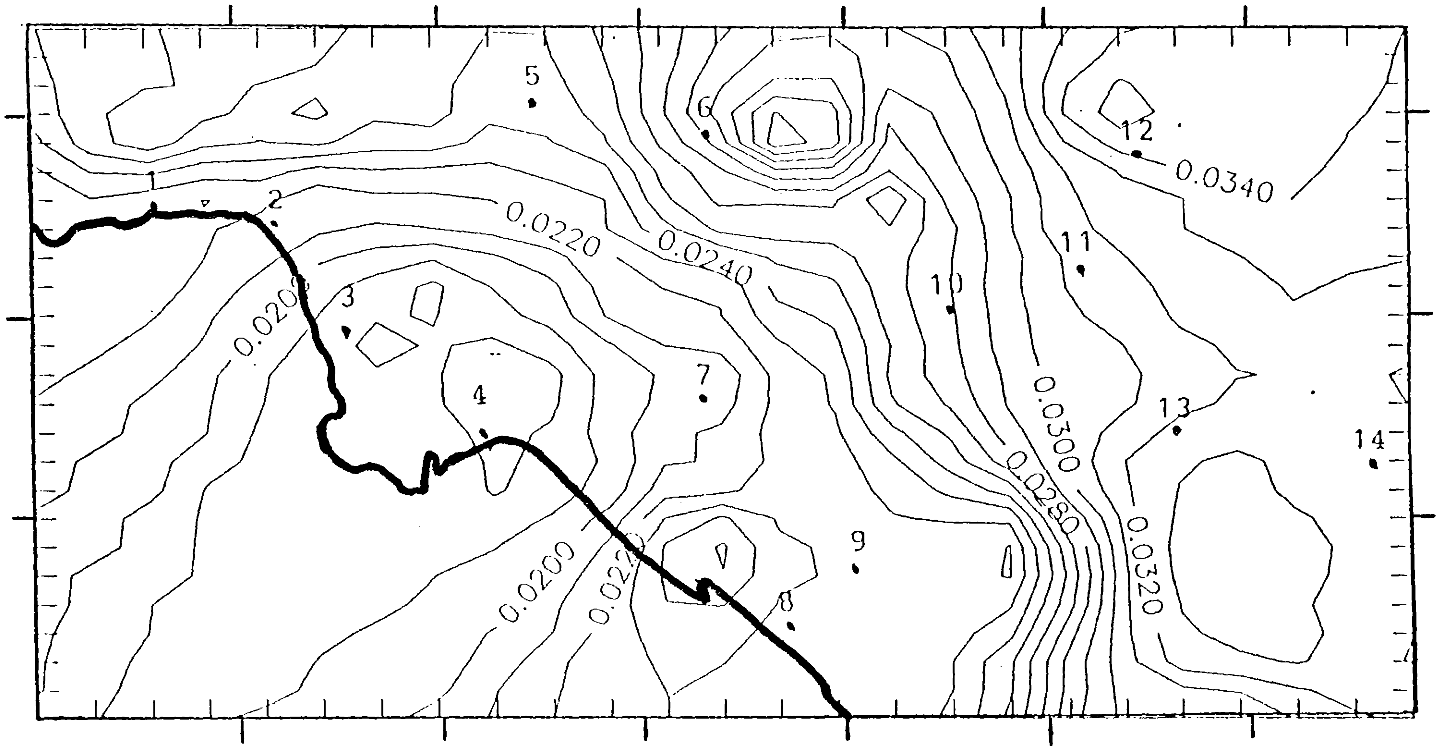
SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average Ozone 1981



LEGEND:	1	Malibu	8	Laguna Beach
	2	Santa Monica	9	El Toro
	3	Los Angeles	10	Norco
	4	Long Beach	11	Riverside
	5	Pasadena	12	San Bernardino
	6	Azusa	13	Perris
	7	Anaheim	14	Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average Ozone 1982

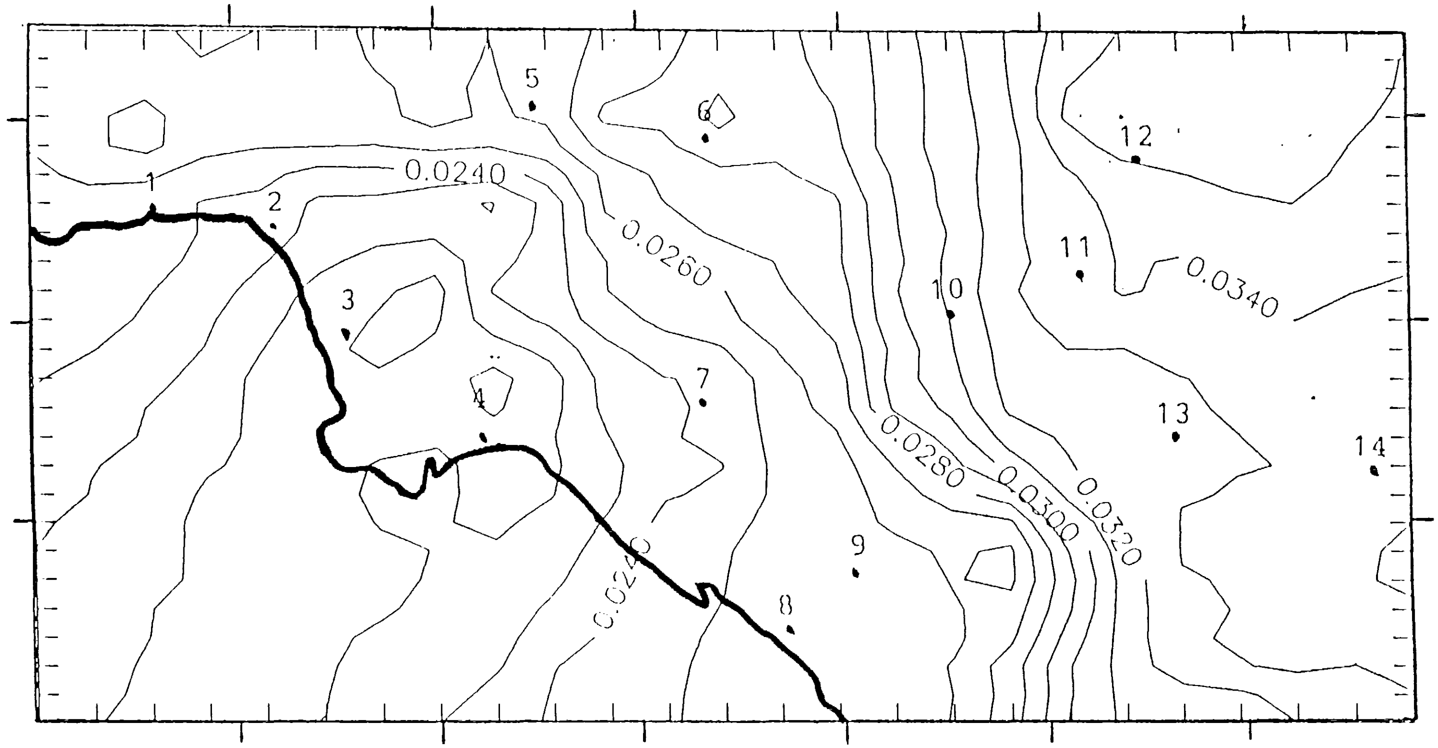


LEGEND:

1	Malibu	8	Laguna Beach
2	Santa Monica	9	El Toro
3	Los Angeles	10	Norco
4	Long Beach	11	Riverside
5	Pasadena	12	San Bernardino
6	Azusa	13	Perris
7	Anaheim	14	Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average Ozone 1983

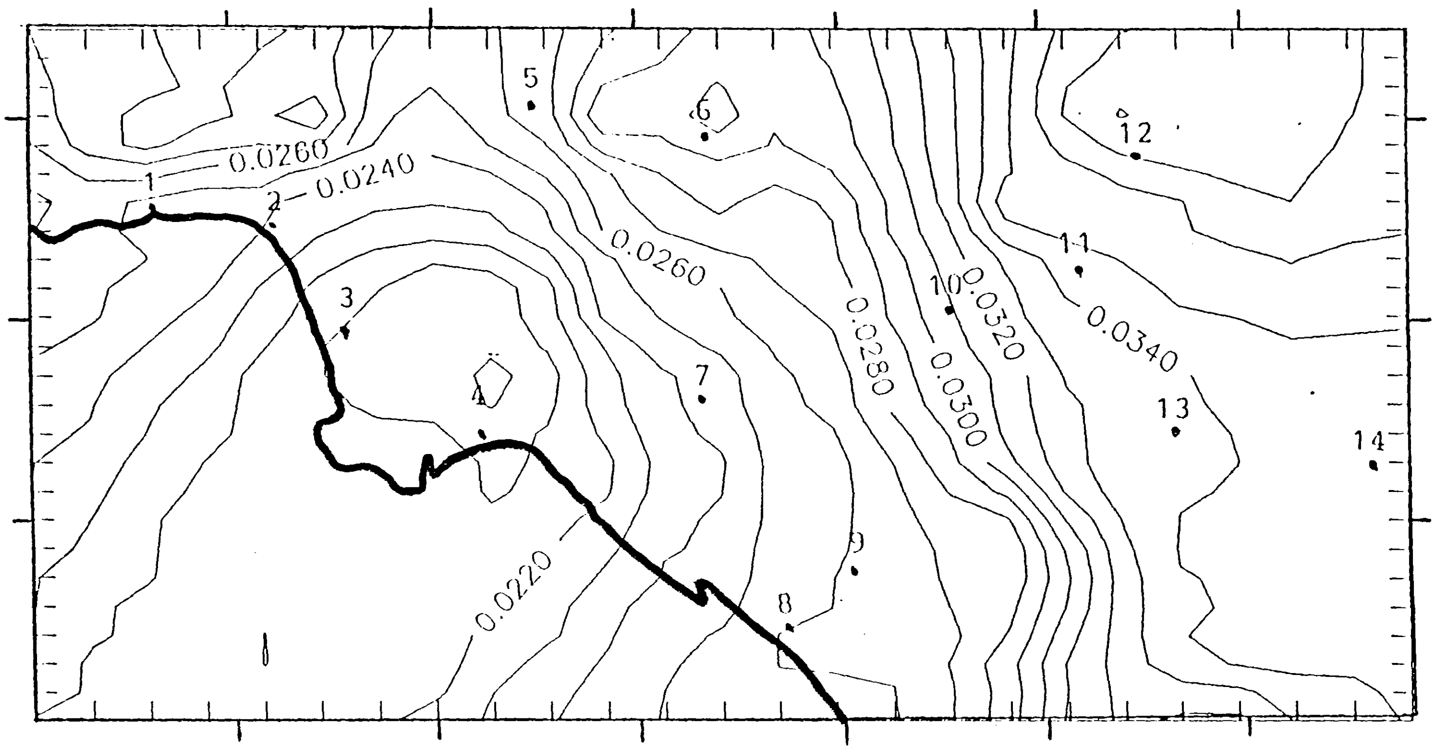


LEGEND:

1	Malibu	8	Laguna Beach
2	Santa Monica	9	El Toro
3	Los Angeles	10	Norco
4	Long Beach	11	Riverside
5	Pasadena	12	San Bernardino
6	Azusa	13	Perris
7	Anaheim	14	Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average Ozone 1984

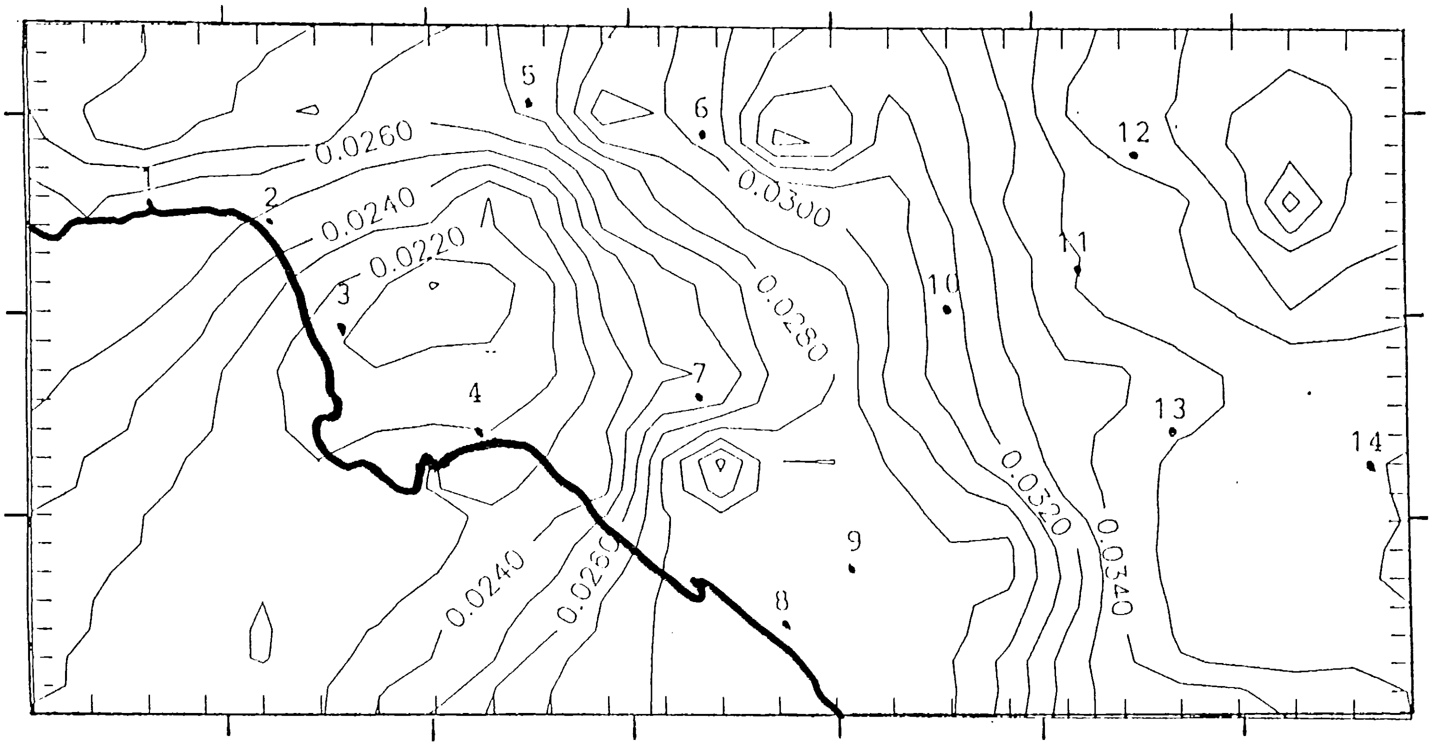


LEGEND:

1	Malibu	8	Laguna Beach
2	Santa Monica	9	El Toro
3	Los Angeles	10	Norco
4	Long Beach	11	Riverside
5	Pasadena	12	San Bernardino
6	Azusa	13	Perris
7	Anaheim	14	Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average Ozone 1985

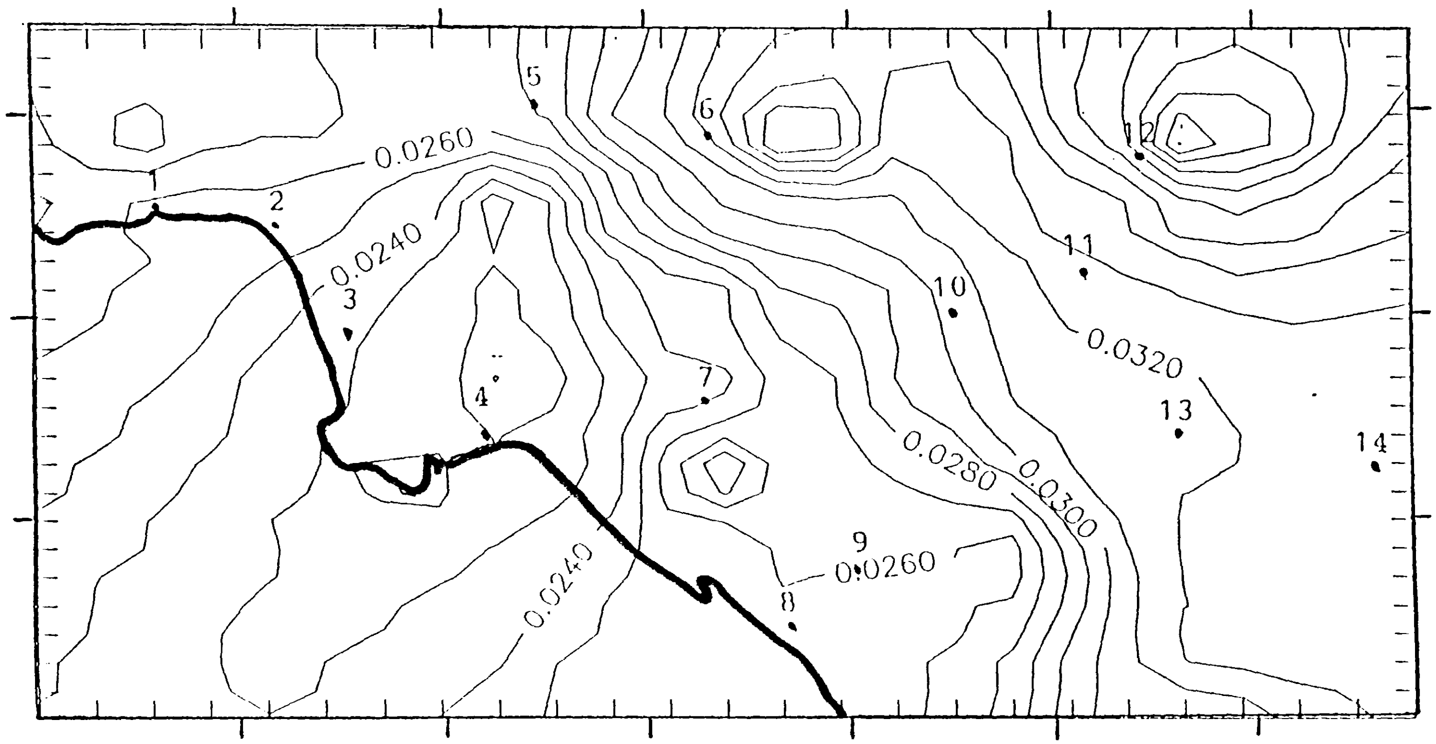


LEGEND:

1	Malibu	8	Laguna Beach
2	Santa Monica	9	El Toro
3	Los Angeles	10	Norco
4	Long Beach	11	Riverside
5	Pasadena	12	San Bernardino
6	Azusa	13	Perris
7	Anaheim	14	Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average Ozone 1986

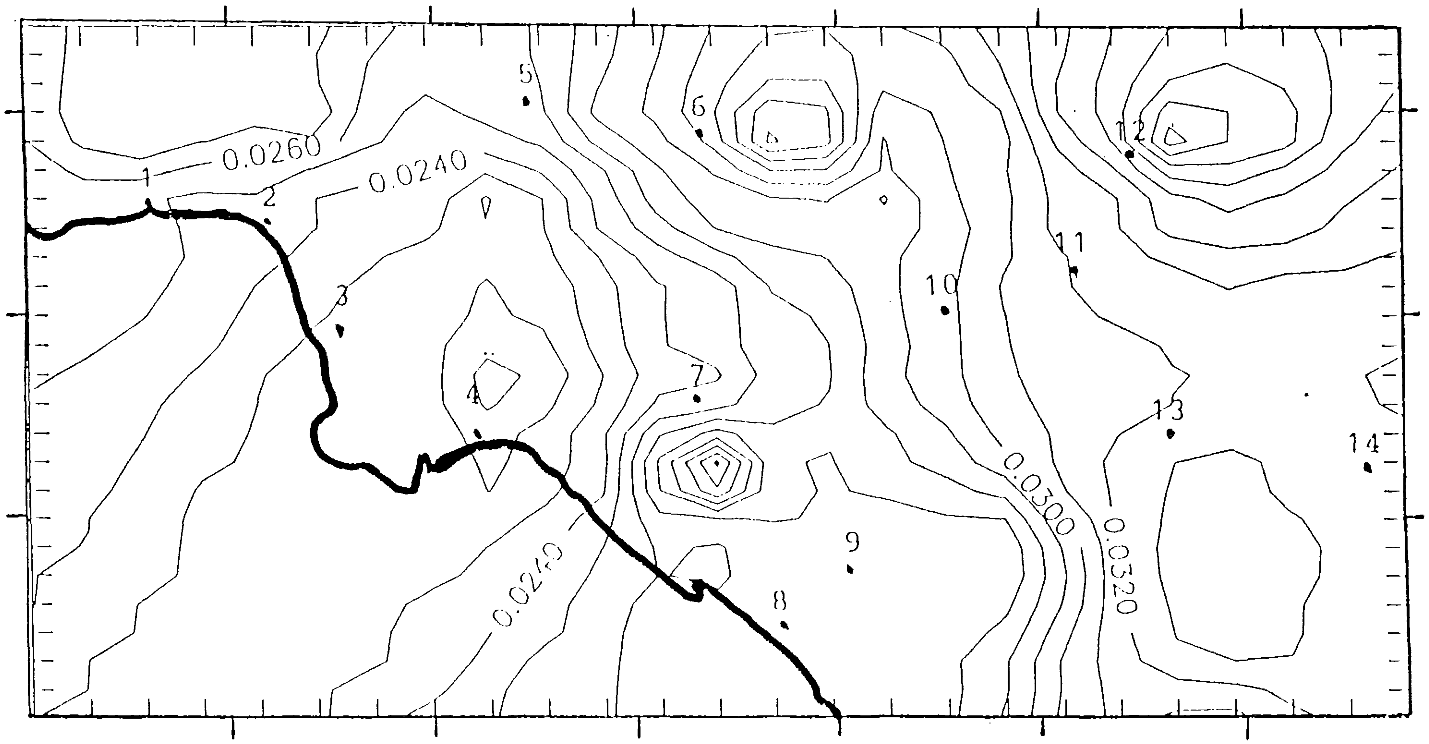


LEGEND:

1	Malibu	8	Laguna Beach
2	Santa Monica	9	El Toro
3	Los Angeles	10	Norco
4	Long Beach	11	Riverside
5	Pasadena	12	San Bernardino
6	Azusa	13	Perris
7	Anaheim	14	Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average Ozone 1987

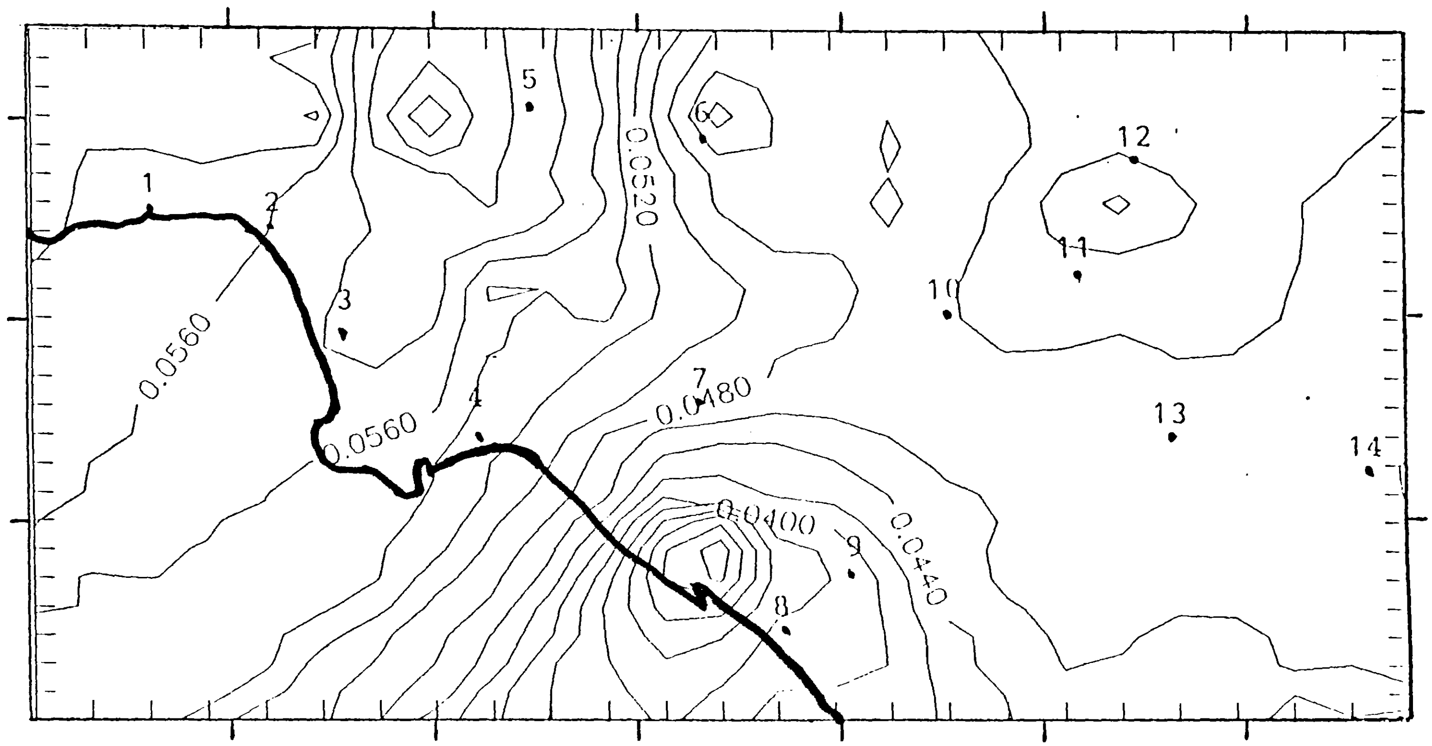


LEGEND:

1 Malibu
2 Santa Monica
3 Los Angeles
4 Long Beach
5 Pasadena
6 Azusa
7 Anaheim
8 Laguna Beach
9 El Toro
10 Norco
11 Riverside
12 San Bernardino
13 Perris
14 Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average NO_2 1980

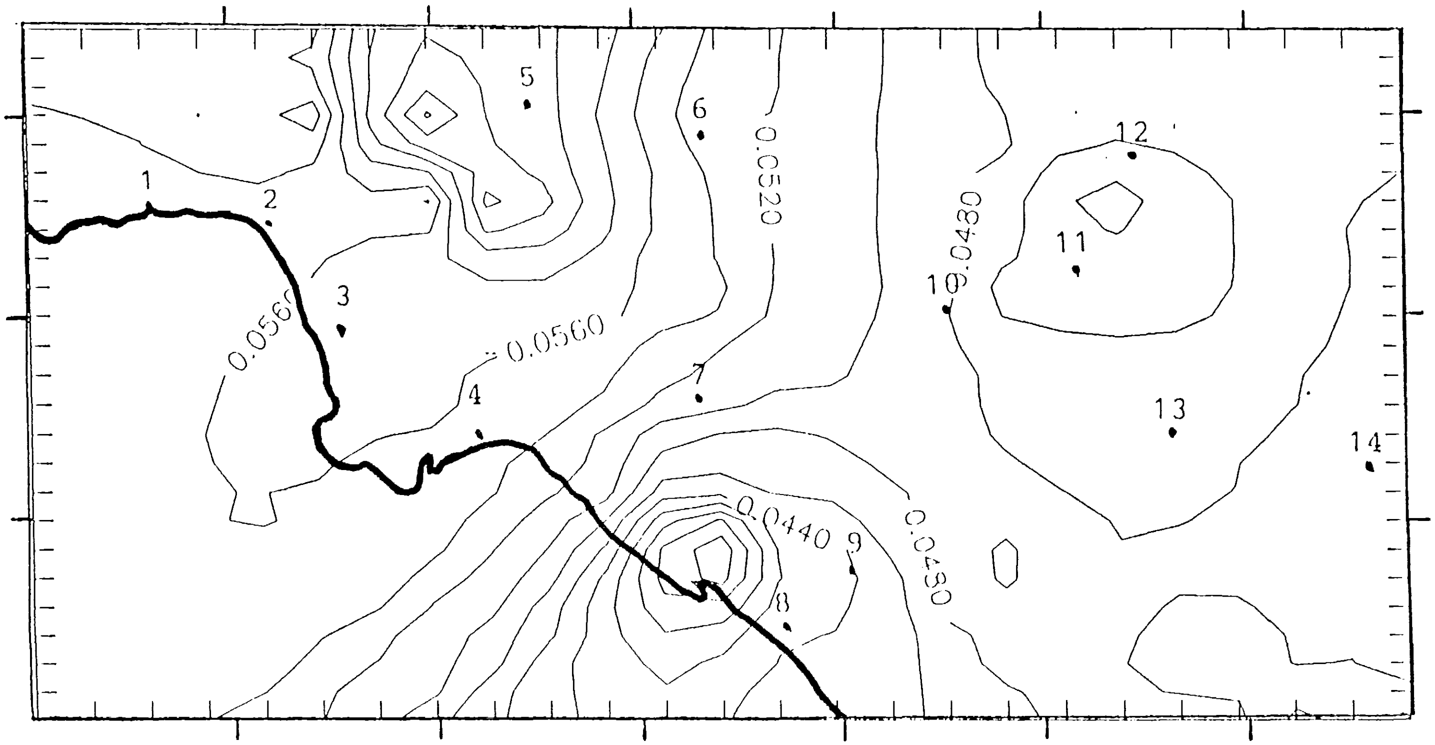


LEGEND:

1	Malibu	8	Laguna Beach
2	Santa Monica	9	El Toro
3	Los Angeles	10	Norco
4	Long Beach	11	Riverside
5	Pasadena	12	San Bernardino
6	Azusa	13	Perris
7	Anaheim	14	Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average NO_2 1981



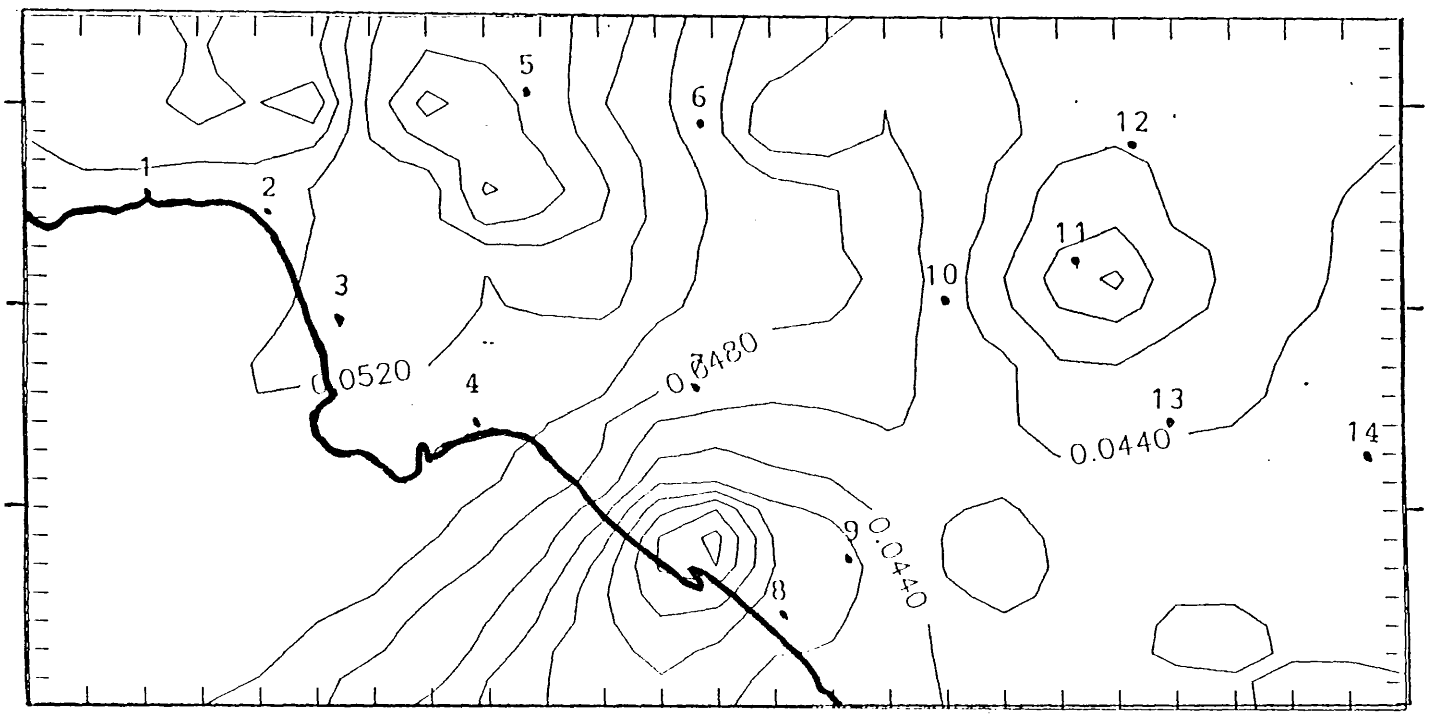
LEGEND:

1 Malibu
2 Santa Monica
3 Los Angeles
4 Long Beach
5 Pasadena
6 Azusa
7 Anaheim
8 Laguna Beach
9 El Toro
10 Norco
11 Riverside
12 San Bernardino
13 Perris
14 Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS

Annual Average NO_2 1982

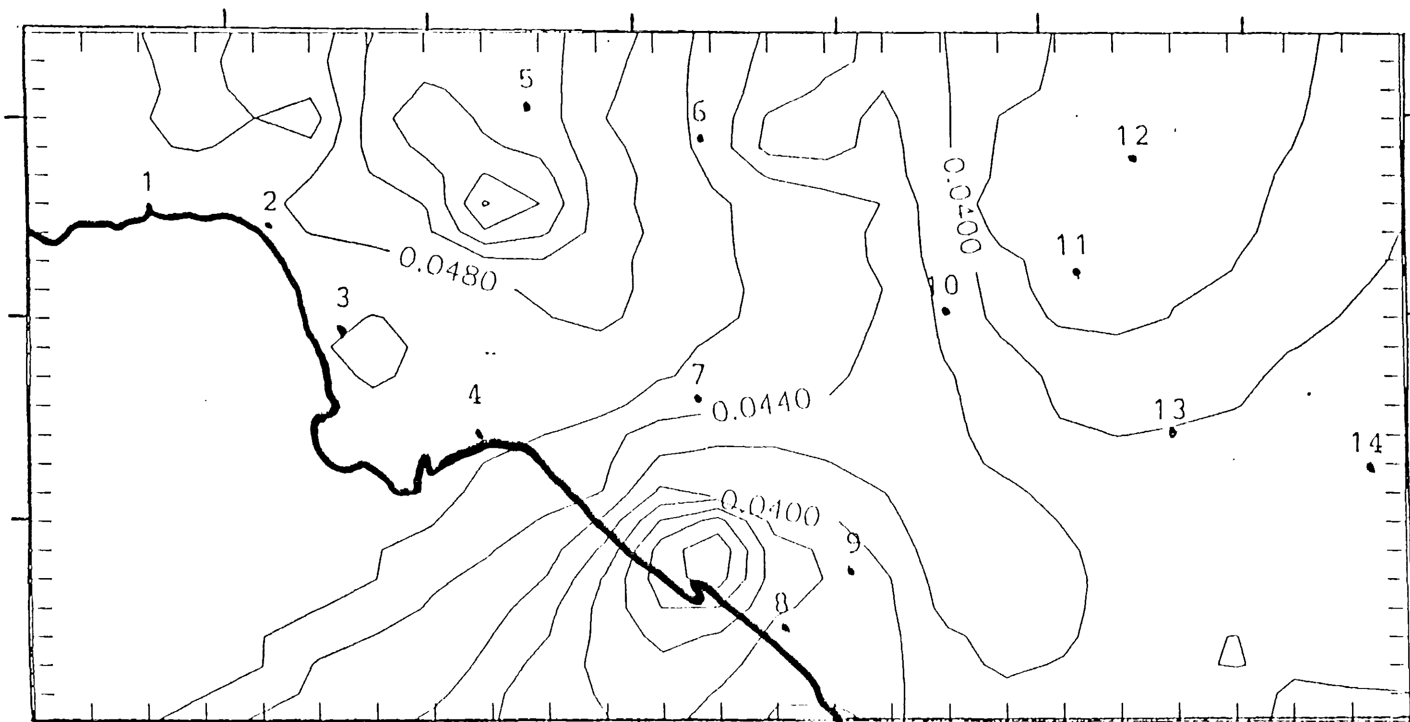


LEGEND:

1	Malibu	8	Laguna Beach
2	Santa Monica	9	El Toro
3	Los Angeles	10	Norco
4	Long Beach	11	Riverside
5	Pasadena	12	San Bernardino
6	Azusa	13	Perris
7	Anaheim	14	Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average NO_2 1983

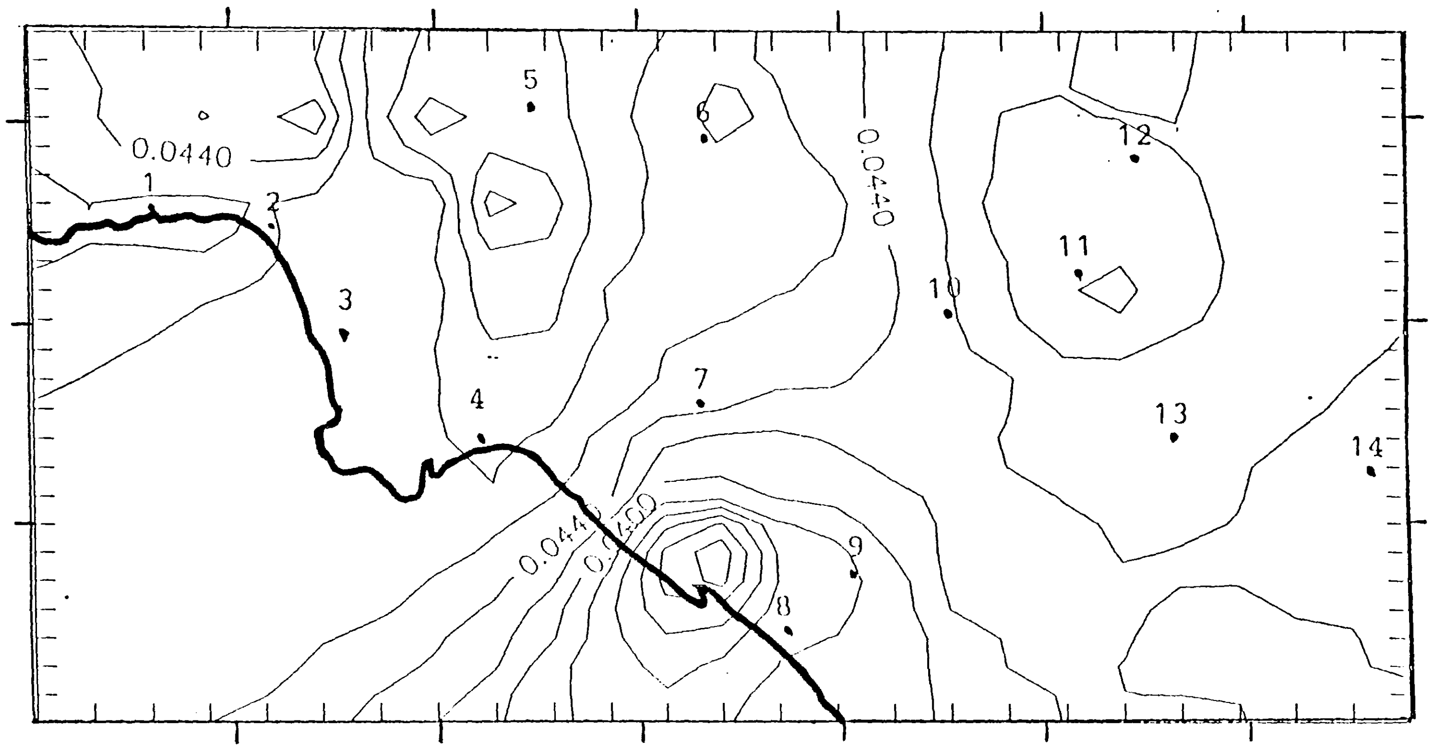


LEGEND:

1	Malibu	8	Laguna Beach
2	Santa Monica	9	El Toro
3	Los Angeles	10	Norco
4	Long Beach	11	Riverside
5	Pasadena	12	San Bernardino
6	Azusa	13	Perris
7	Anaheim	14	Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average NO_2 1984

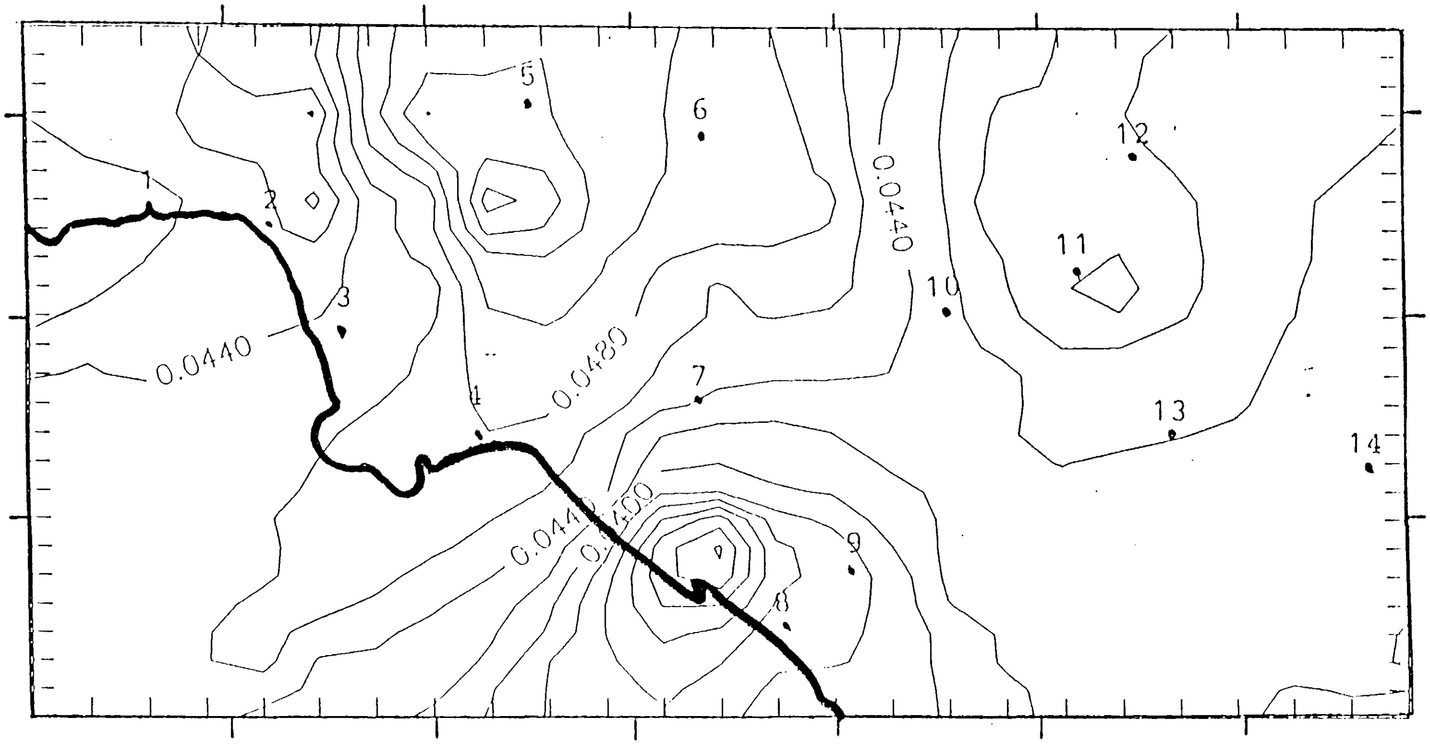


LEGEND:

1	Malibu	8	Laguna Beach
2	Santa Monica	9	El Toro
3	Los Angeles	10	Norco
4	Long Beach	11	Riverside
5	Pasadena	12	San Bernardino
6	Azusa	13	Perris
7	Anaheim	14	Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average NO_2 1985

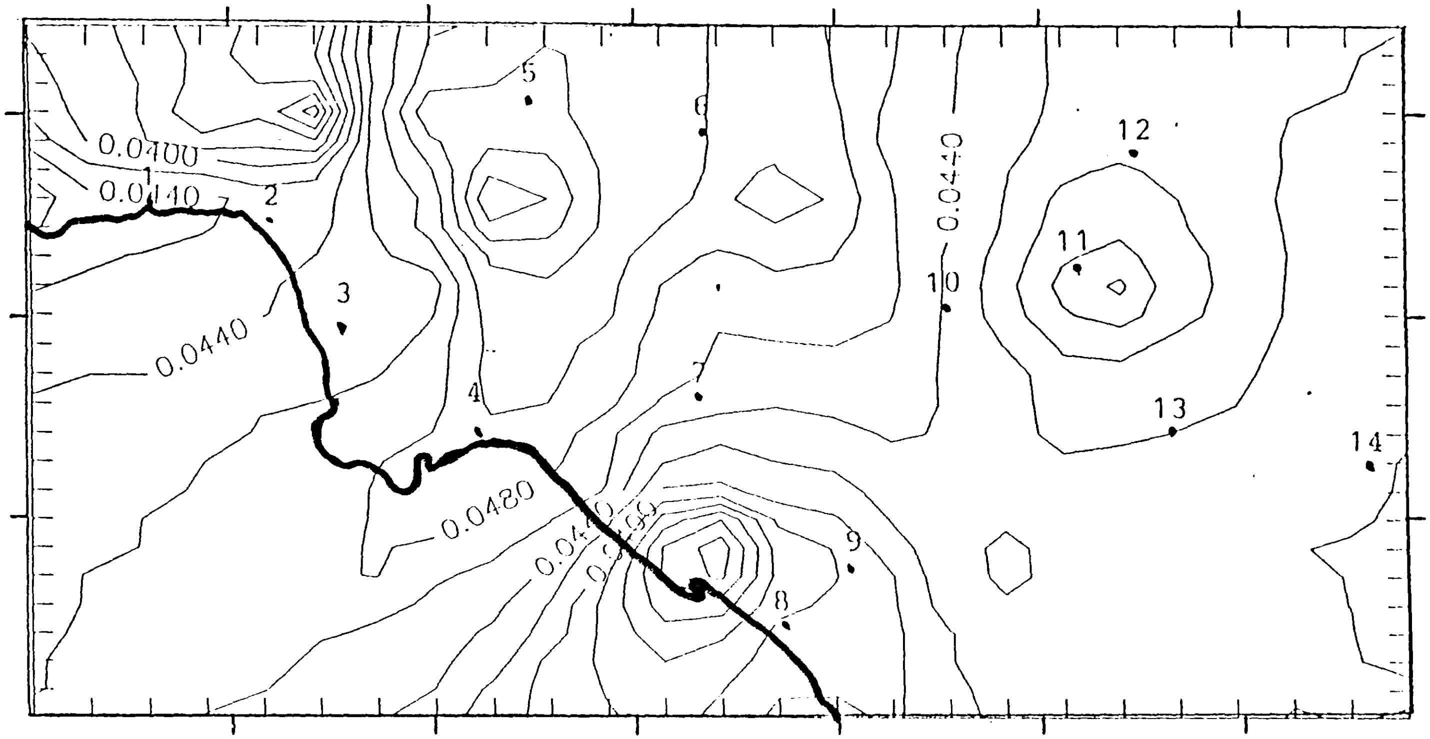


LEGEND:

1	Malibu	8	Laguna Beach
2	Santa Monica	9	El Toro
3	Los Angeles	10	Norco
4	Long Beach	11	Riverside
5	Pasadena	12	San Bernardino
6	Azusa	13	Perris
7	Anaheim	14	Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average NO_2 1986

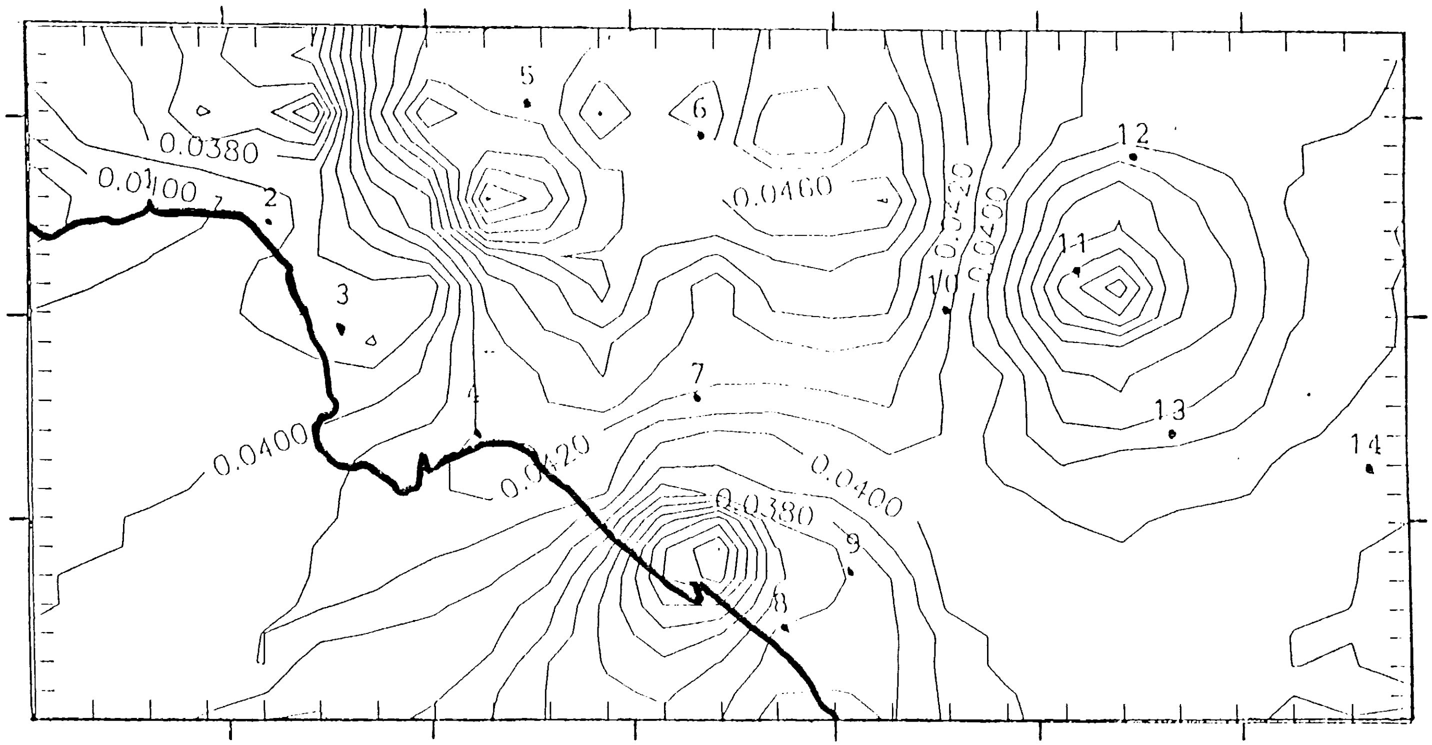


LEGEND:

1	Malibu	8	Laguna Beach
2	Santa Monica	9	El Toro
3	Los Angeles	10	Norco
4	Long Beach	11	Riverside
5	Pasadena	12	San Bernardino
6	Azusa	13	Perris
7	Anaheim	14	Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average NO_2 1987

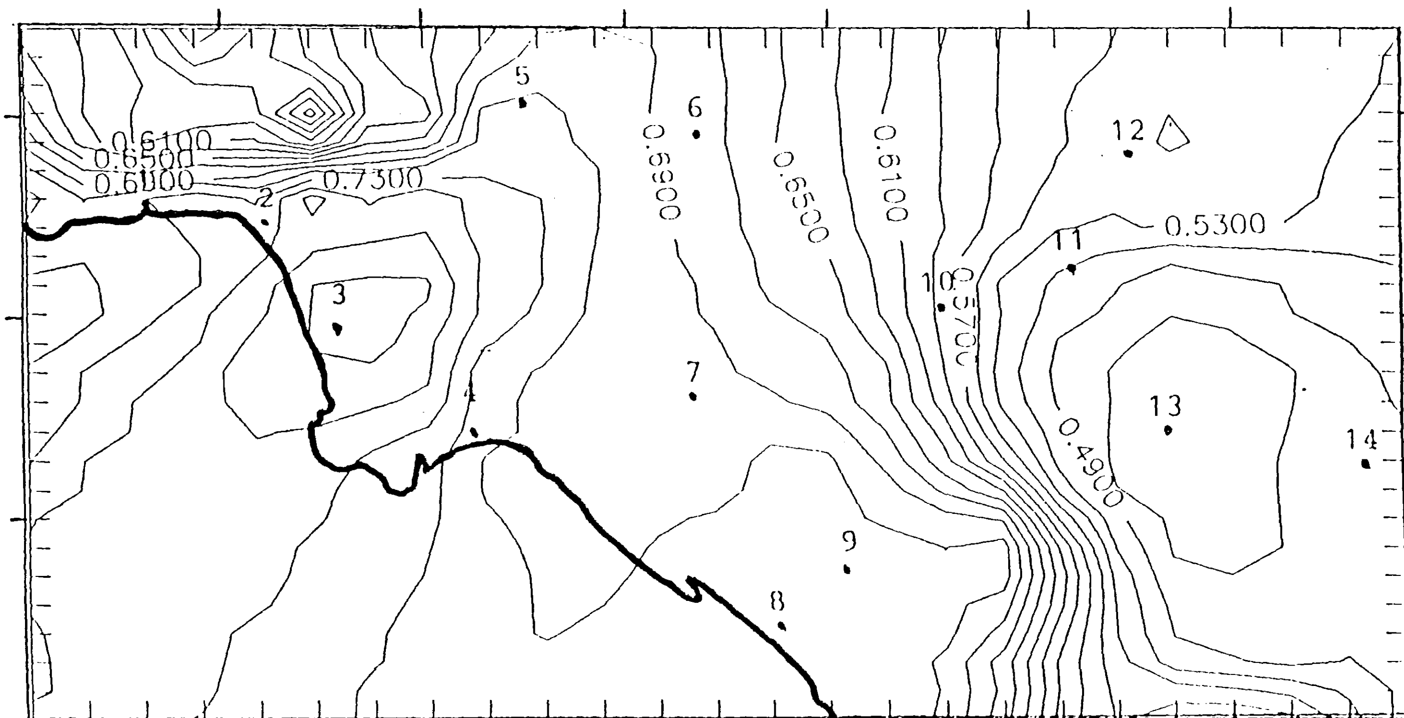


LEGEND:

1	Malibu	8	Laguna Beach
2	Santa Monica	9	El Toro
3	Los Angeles	10	Norco
4	Long Beach	11	Riverside
5	Pasadena	12	San Bernardino
6	Azusa	13	Perris
7	Anaheim	14	Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average Time of Wetness 1986

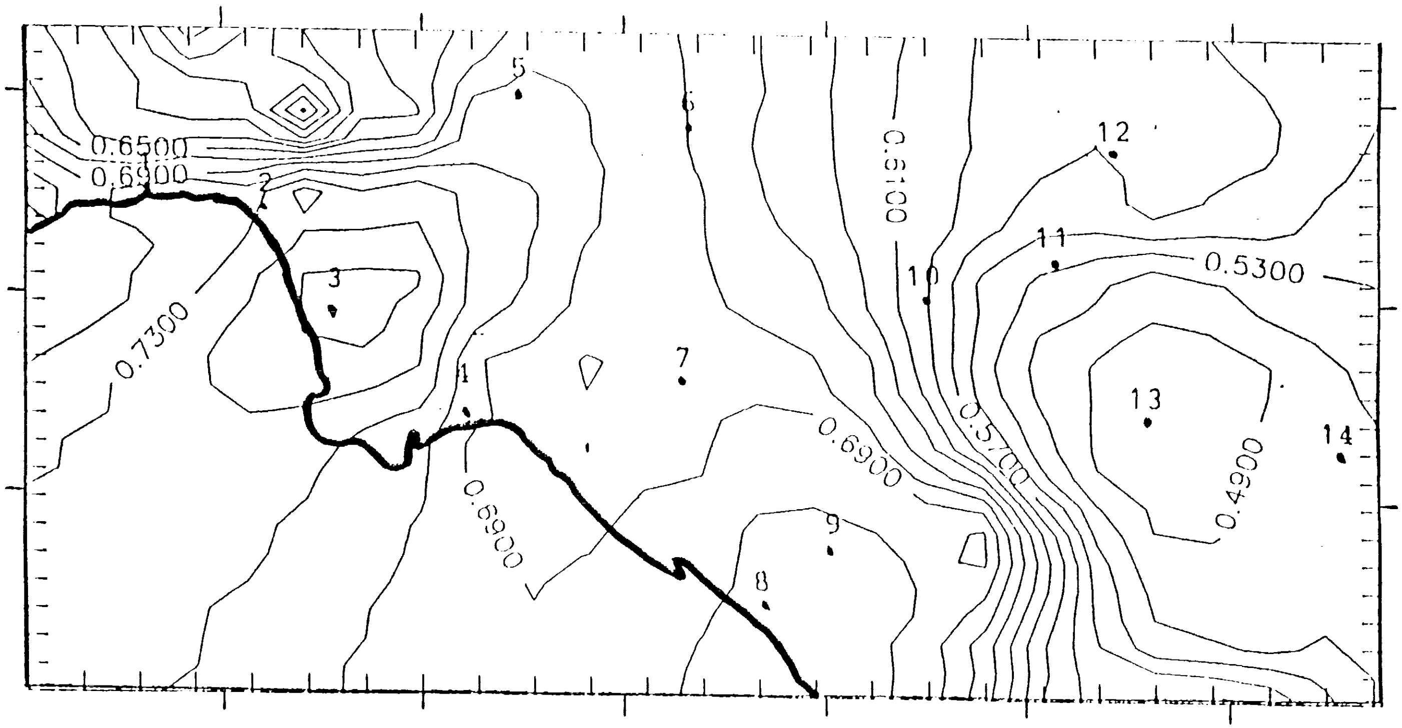


LEGEND:

1	Malibu	8	Laguna Beach
2	Santa Monica	9	El Toro
3	Los Angeles	10	Norco
4	Long Beach	11	Riverside
5	Pasadena	12	San Bernardino
6	Azusa	13	Perris
7	Anaheim	14	Hemet

Scale: 1":26.6 Km

SOUTH COAST AIR BASIN INTERPOLATION RESULTS
Annual Average Time of Wetness 1987



LEGEND:

1	Malibu	8	Laguna Beach
2	Santa Monica	9	El Toro
3	Los Angeles	10	Norco
4	Long Beach	11	Riverside
5	Pasadena	12	San Bernardino
6	Azusa	13	Perris
7	Anaheim	14	Hemet

Scale: 1":26.6 Km

SECTION 6

BEHAVIORAL SURVEY OF MAINTENANCE PRACTICES

6.1 INTRODUCTION

The purpose of the behavioral survey was to determine the economic effects of air pollution damage to the painted exteriors of single-family homes in the South Coast Air Basin. Survey questions were designed to elicit the following information from respondents:

- House construction: age, size, number of windows and entrances, and materials comprising the exterior wall surfaces
- Factors influencing frequency of painting and the main reasons the respondent decided to paint
- Kinds of locations on home of damage to exterior wall surfaces (e.g., Northern exposures)
- Amount of labor and dollar cost of painting, including use of loans to cover cost
- Painting of house: parts of house painted, methods of surface preparation, brands and gallons used, cost per gallon, number of coats applied, application methods, purchase of air pollution damage protection formula, and value added to home
- Consideration of replacement of home exterior surface with different materials
- Regular maintenance of house, besides painting
- Location of house according to ZIP code and nearest street intersection
- Demographic background of the respondent

One set of survey questions concerned the last time the respondent painted; a parallel set of survey questions concerned the respondent's future painting plans. A sample questionnaire is included as Appendix A of this section.

6.2 THE SAMPLE

A list of all telephone area codes and exchanges in the South Coast Air Basin was given to Opinion Research Corporation (ORC). The four area codes are: 213, 818, 805, and 714. ORC used it's Random Digit Dialing capability to generate a sample, for which the area codes and exchanges were in proportion to the universe of area codes and exchanges in the South Coast Air Basin.

The sample is designed to be a self-weighting stratified random sample of telephone households. The following procedure was followed to create the sample:

- A magnetic tape containing all active area codes and three-digit prefixes was obtained from AT&T. From this were extracted the area codes and prefixes specified for the survey.
- Using a variety of proprietary methods, ORC eliminated area code/prefixes that contained nonresidential numbers. (Typically, these exchanges are reserved for businesses or AT&T's exclusive use.)
- Four-digit random numbers were appended to each of the previously selected area code/prefix combinations. The resulting ten-digit numbers were checked to determine if they fell within a bank of working residential numbers. All numbers that might be residential were retained for use.
- Each telephone number was printed on a separate call record card. The card contained preprinted precoded call disposition categories for each call attempt.
- The cards containing the telephone number sample were arranged into replicates (i.e., subsamples). Each replicate is a probability sample in itself. The sample is released and controlled by replicate.

The procedure outlined above results in an efficient, projectable probability sample of telephone households in the area codes and prefixes surveyed. While it is desirable to maintain a random sample for purposes of credible extrapolation to the basin population, it is also important to obtain a sample that covers the range of air quality and economic conditions that exist.

Halfway through the collection of survey data, an assessment was made on the distribution of the sample obtained to that point. Two questions were asked:

- Is the distribution of respondents in line with the distribution of the population?
- Does the sample reflect exposure to the range of air quality conditions present in the basin?

With respect to the first question, it was determined that the 818 area code was underrepresented. It was not clear whether this was due to a disproportionate number of refusals or reflected a high percentage of ineligibles (e.g., more multi-family structures).

Therefore, a supplemental sample of the 818 area code was added to the original sample. The 818 area code completed interviews were then weighted to put them back into the proportion of the universe as follows:

$$\text{818 area code weight} = \frac{2348}{2348 + 900} = .722\%$$

where 2348 = the number of times area code 818 appeared in the original sample

900 = the supplemental number of sample pieces pulled in the 818 area code

Given that no additional sample was pulled in the other area codes, they were given a weight of 1.000.

With respect to the second question, isopleths of annual ozone and NO_2 concentrations in the basin were reviewed in order to classify areas of the basin into one of nine cells. The nine cells reflect possible combinations of "high," "medium," and "low" concentrations for ozone and NO_2. The specific classifications were based on the range of annual concentrations for 1983. For ozone, the annual average of daily maximums was used. The low category included areas with concentrations up to 0.07 ppm. The medium category included areas with concentrations up to 0.09 ppm. The high category included areas with concentrations above 0.09 ppm. This partitioned the basin into three areas, with the eastern part of the basin being classified as high and areas near the coast being classified as low.

The classifications for NO_2 used annual averages. The low category ranged up to 0.04 ppm; the moderate category included areas with concentrations up to 0.05 ppm; the high category included areas with concentrations above 0.05 ppm. The gradient for NO_2 concentrations is highest in Los Angeles county and decreases with distance on a Northwest-Southeast axis.

With these classifications, the distribution of the first 199 respondents was examined. Table 6-1 shows the distribution. With the exception of the low-low combination, the sample was being drawn for the range of concentrations. It was not unexpected that the low-low combination had few respondents in the sample since a crude mapping of the pollution cells revealed only a small geographic area in the basin with this combination. Consequently, no further adjustments were made in the sample design.

Table 6-1

DISTRIBUTION OF RESPONDENTS FOR PARTIAL SURVEY
BY LEVEL OF ENVIRONMENTAL QUALITY

		OZONE			
		Low	Moderate	High	Total
NO_2	Low	1	24	36	61
	Moderate	23	31	15	69
	High	20	40	9	69
	Total	44	95	60	199

There was some concern that the high-high combination was underrepresented in the partial sample. However, it was believed that subsequent over-sampling of the 818 area code would resolve the problem.

A total of 503 interviews were conducted. The number of completed interviews obtained in each area code are as follows:

Area Code	714	213	818	805
Number of Completed Interviews	202	157	137	7

The 503 completed interviews are not distributed in proportion to the populations associated with each area code. This occurs because of various screening criteria which affect the probability that a household that is contacted will be "eligible" to answer questions in the survey concerning maintenance practices. The 503 respondents all meet the screening criteria. These criteria are discussed further in Section 6.5.3.1.

Figure 6-1 shows the distribution of the final sample across the basin. The grid lines are designed to be representative of aggregate Thomas Brothers map grids. In general, each grid square contains four Thomas Brothers map grids. However, near the basin boundaries, only one to three map grids may be represented.

The number of observations shown in Figure 6-1 is 458. This is less than the 503 respondents for whom questionnaires were completed for several reasons. Specifically,

- Location information for some respondents was not complete.
- There was some inconsistency between ZIP codes and telephone numbers which made accurate location difficult.
- Some respondents were located outside the area for which air quality concentrations were predicted (e.g., mountainous areas to the north of the basin).

6.3 INTERVIEWING

All interviews were conducted from ORC's Central Telephone Interviewing Facility in Middlesex, New Jersey. The questionnaire was pre-tested on March 16, 1989 and the full-scale study was conducted from April 5 to 24, 1989; interviews lasted an average of 17 minutes. In order to obtain an interview with any one sample, three calls were placed in addition to the original call. Prior to interviewing, all interviewers were trained on how to conduct the interview.

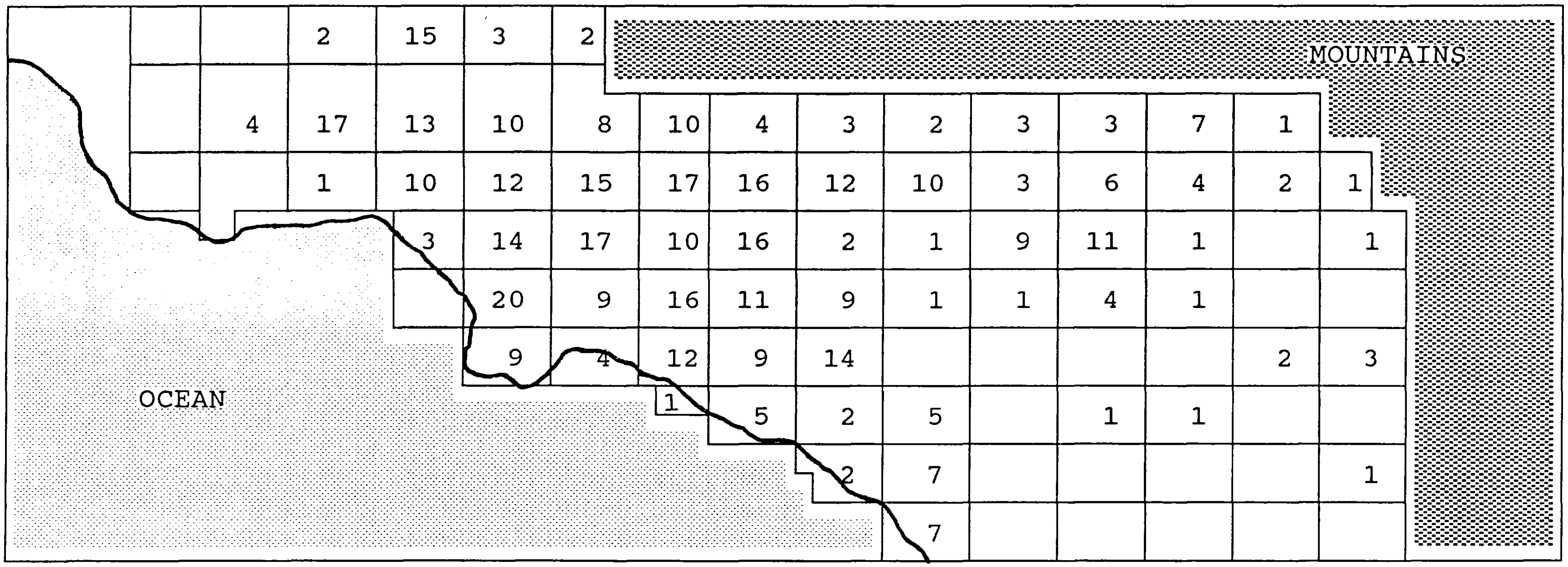


Figure 6-1. Distribution of Survey Respondents in the South Coast Air Basin

6.4 DATA PROCESSING

6.4.1 Editing

At ORC, every completed interview is examined by the editing staff at the Central Telephone Interviewing Facility. During the editing process, each questionnaire is reviewed to assure that it has been properly completed. The editors check that every respondent qualified for the interview, that the questionnaire skip patterns were followed properly, that all open-ended answers are written legibly, and that all questions have the right amount of responses required (some questions permit multiple responses, other permit only single responses). Since questionnaires vary in their design, they may require editors' attention to special details unique to the questionnaire. In addition to normal editing procedures, editors working on the Home Maintenance study were given the following instructions:

- For actual value questions, do not cross-off or round-off any answers in cents to dollars. Also, do not round-off any answers in months to years.

- The answers to Q.61 and D.10 are required in dollars. If a respondent gives a percent, instead of a dollar amount, then calculate the dollar amount and write it down. You can calculate the dollar amount by referring to the respondent's answers to other questions. These questions provide you with a total amount to multiply the percentage by in order to arrive at the proper answer. For Q.61, refer to Q.59; for Q.D10, refer to D9 (pick mid-point of answer range).

- Since the questionnaire has so many skip patterns, take extra care when editing any skips. Make sure that you understand what the skip patterns are.

6.4.2 **Serialization**

As completed questionnaires arrive in Princeton from the Central Telephone Interviewing Facility, each is stamped with a unique ballot number representing the order in which it is received. Often, more than one sequence (or serialization) of ballot numbers is used to classify the questionnaire according to the following criteria: skip patterns completed, or questionnaire form or sample used. Serialization acts as an aid in the data preparation process when each serialization has different data preparation requirements.

For the home maintenance study, four serializations were used to keep track of the skip patterns completed. This aided the coding process, because the serialization indicated to the coding department what questions on each questionnaire needed coding. A four digit ballot number was used, the first digit of which was the serialization number. Outlined below are the skip patterns found in each serialization.

Serialization	Q.s 11 - 42	Q.s 44 - 67
1	completed	completed
2	completed	skipped
3	skipped	completed
4	skipped	skipped

The serializations represent whether the retrospective part of the questionnaire was answered by the respondent (Serilizations 1 and 2) or whether the prospective questions were answered by the respondent (Serializations 1 and 3). Serilization 4 is the case where the respondent has never previously painted the house that the respondent currently occupies and has no plans to paint in the near future.

Table 6-2 shows the distribution of the original 503 respondents by area code and serialization. Approximately 75 percent of the eligible respondents completed the retrospective portion of the questionnaire. These responses are distributed fairly evenly across the three major telephone area codes in the basin. The prospective questions were answered by 25 percent of the respondents. A large number of this group falls in area code 714. There has been no attempt to try to explain this distribution in the present study.

Because of the larger number of respondents who answered questions of a retrospective nature and because of the greater confidence that can be placed in quantitative estimates of actual as opposed to planned behavior, this study focuses on the retrospective questions. Answers to the prospective questions are used only as plausibility checks on selected retrospective questions.

Table 6-2

DISTRIBUTION OF SAMPLE BY AREA CODE AND SERIALIZATION

	Area Code			
Serialization	714	213	818	805
1	59	60	45	0
2	74	71	60	4
3	34	10	16	0
4	35	16	16	3
Total	202	157	137	7

6.4.3 Coding

All questionnaires with "other specify" or open-ended questions are sent to ORC's Coding Department to categorize responses for quantification.

The standard ORC coding procedures are as follows:

> For each open-ended question (a question which the respondent answers in his own words), the coding analyst lists a random sample of responses. Those responses which appear with relative frequency are classified as codes.
>
> During the coding process, 10 percent of each coder's work is checked at intervals for mechanical error. If minimum error of 1 percent is found (usually no more than two inaccuracies), all work up to that point is reviewed and misinterpretations are clarified.

These procedures maintain the rate of coding error at below 1 percent.

The home maintenance questionnaire has two sets of questions which elicit similar responses. These are the question sets referring to the last time a respondent painted (retrospective) and the next time a respondent expects to paint (prospective). In order that coded answers to the sets could be compared, the following process was used:

> First, the series referring to the last time a respondent painted was coded. Then, using those codes, the series referring to the next time a respondent will paint was coded. For the second series, any responses which did not fit the existing codes were recorded. Responses which appeared with relative frequency were added to the list of codes.

6.4.4 Key-punch

Questionnaire data are key-punched by ORC's experienced data preparation staff. The rate of error is maintained at below 0.5 percent.

6.4.5 Sample Disposition

Table 6-3 shows the distribution of the 4,116 calls made in this study, in total and by area code. The top third of the table shows the distribution of calls for those who failed to meet one or more of the eligibility criteria. There are a series of questions asked at the start of the questionnaire that screen respondents according to the following criteria:

- Type of struture (single family homes only)
- Type of material (painted wood or stucco walls only)
- Responsible for maintenance decisions
- Adult head of household

The number of respondents who did not meet these criteria are shown in the table. Note, once a respondent has terminated, no further screening questions are asked.

The middle of the table shows the distribution of calls for those respondents who satisfied the eligibility criteria. Out of 613 respondents who were classified as eligible, over 80 percent completed the remainder of the questionnaire.

Table 6-3

SAMPLE DISTRIBUTION

	Total	714	213	818	805
INELIGIBLE					
Terminated at question:					
S1 (type of structure)*	957	259	443	245	10
S2 (type of material)	179	61	68	47	3
S6 (no decision maker)	116	28	51	37	0
S7 (under 18)	9	3	5	1	0
End of screener (siding only)	25	12	5	7	1
Total Ineligible	1,286	363	572	337	14
ELIGIBLE					
Completes	503	202	157	137	7
Eligible Refusals	80	35	26	17	2
Call Rule Completed**	21	7	9	5	0
Call Back Beyond Study Duration***	9	3	5	0	1
Total Eligible	613	247	197	159	10
ELIGIBILITY UNKNOWN					
Terminated at question:					
S3 (decision maker)	29	11	13	5	0
S4 (decision maker)	3	1	2	0	0
Refusals during screener	1,836	576	717	531	12
Language, hearing, etc. problems	349	58	192	99	0
Total Eligibility Unknown	2,217	646	924	635	12

* S1 refers to Question S1 in the screen portion of the questionnaire.

** The call rule was that the original call plus three additional calls were to be placed to any one respondent to attempt to complete an interview.

*** These respondents requested to be scheduled for callback to interview beyond the duration of the interviewing period.

The bottom third of Table 6-3 shows the distribution of responses for those individuals whose eligibility is unknown. This group includes those who refused to continue during the screening questions, those who had language or hearing problems, and those for whom it could not be determined whether or not maintenance decisions were made by a resident.

As mentioned previously, over 80 percent of those respondents who were identified as eligible completed the questionnaire. However, the fraction of eligible respondents to the total sample of eligibles and ineligibles is about 32 percent. In addition, nearly 54 percent of all calls made were terminated before eligibility could be determined. This raises the question as to whether a non-response bias is present in the sample.

There are several ways to address possible non-response bias. The most direct approach is to re-sample non-respondents with a shorter questionnaire. This follow-up survey would be designed to determine whether certain characteristics or attitudes of non-respondents were significantly different from responses to similar questions by eligible respondents.

Another way to assess non-response bias is to examine certain characteristics of the sample with known population estimates. In economic studies, income is often used to determine whether a sample is representative of the population.

A third way to consider non-response bias is to assess the potential for the subject matter of the questionnaire to evoke strong feelings, pro or con. Of interest is the extent to which a group of people with similar responses would be more likely to refuse to participate in the survey process.

In this study, no re-sampling of non-respondents was attempted. However, several demographic variables were examined to assess the sample representativeness. The most striking finding was that the income in the sample was in excess of $50,000. This is significantly greater than the average household income for individuals in the Western United States ($31,475 in 1985, Statistical Abstract (1988), Table 697). Even recognizing that the eligible sample is limited to those who make their own maintenance decisions, the national household income of homeowners was only $34,066 in 1985 (Statistical Abstract (1988), Table 697). These results are also buttressed by the observation that language problems resulted in the termination of some calls. The implication is that the sample reflects responses of a higher income group than would be expected with a random sample. It is expected that this non-response bias will lead to an upward bias in the measure of economic benefits. This is because individuals with higher incomes may be expected to perform maintenance activities more frequently than those with lower incomes.

6.4.6 Cleaning

During the cleaning process, the following were checked: acceptable ranges for actual value questions; skip patterns; logical relationships among questions; whether or not a question has the correct number of responses.

6.5 DATA ANALYSIS

The behavioral survey provides detailed information about the maintenance practices of individual homeowners. In order to use these data in the economic assessment, several tasks were required:

- Each respondent location needed to be matched with a Thomas Brothers map grid. This allows integration of the survey data with the inventory and aerometric data.

- A brief descriptive analysis of the data was conducted to identify potential problem areas.
- Probability estimates for performing specific, homogeneous maintenance tasks were calculated. These probabilities account for constraints included in the behavioral survey (i.e., screening questions for terminations) as well as the presence of specific materials. The probabilities are needed for the extrapolation analysis.
- Development of statistical relations using cost and maintenance interval responses.

The first three of these tasks are discussed below. The last task, which involves more detailed analysis of the data will be described in Sections 7 and 8.

6.5.1 Assignment of Respondent to Thomas Brothers Map Grid

Three pieces of data, collected as part of the behavioral survey, were instrumental in accurately identifying the location of the residence of each survey respondent. These data included:

- The telephone number of the respondent
- The ZIP code of the respondent
- The names of the nearest intersecting streets to the respondents' residence.

It was advantageous to obtain several types of location identifiers in order to avoid losing an observation because of missing location data. In addition, the availability of several location variables made it possible to check the consistency of responses.

The telephone number was always available. However, the area code and three-digit exchange were usually not defined for a sufficiently small area to permit assignment of the respondent to a unique Thomas Brothers map grid. Therefore, each responsent was also queried about their residence ZIP code and nearest intersecting streets. Both types of data were desirable since individuals may be reluctant to provide very specific location information (e.g., nearest intersection) over the telephone.

The procedure used to locate respondents in terms of Thomas Brothers Map grids involved the following:

- The area code and exchange were used to identify the city in which the respondent resides. The list of telephone exchanges by area code and city was provided by Valley Research and was the same list used to draw the sample.
- The Thomas Street Guides and Directories (1989) for Los Angeles, Orange, Riverside, and San Bernardino Counties[1] were used to match cities (determined from the telephone exchange) with ZIP codes and ZIP codes with a Thomas Brothers map grid. In those cases where the ZIP code area extended over more than one Thomas Brothers grid, the information on nearest street intersection was used to pinpoint the location.

This procedure worked well. Out of the 503 respondents, only 18 were not assigned to a Thomas Brothers map grid. These respondents either did not know or refused to answer the questions concerning ZIP code and nearest street intersection. No attempt was made to re-contact these respondents.

6.5.2 Descriptive Analysis

Following the data coding, answers to selected questions were reviewed to confirm the reasonableness of responses and to gain a better understanding on the best way to frame the economic analysis. Not all data items have been reviewed in detail.

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[1] The California Air Resources Board provided maps of ZIP codes for Riverside and San Bernardino Counties.

Instead, attention was given to those data that would most likely be important for the economic valuation.

As a result of this data review, the following observations can be made:

- Painting is the dominant maintenance practice for exterior walls. Only 14 percent of the respondents reported that they performed other maintenance such as washing down the walls.

- Substitution to materials that may be more resistant to air pollution seems to be a non-issue. Of those individuals who currently have aluminum or vinyl siding, only one respondent (out of 25) reported that it was a replacement material. Of those respondents who currently have painted wood or stucco walls, 87.3 percent said they had not considered replacing/covering their wood or stucco walls.

- Painting does not necessarily mean that everything gets painted. The survey indicates that 35 percent of most recent exterior paintings involved only a part of the house, with the trim most frequently mentioned.

- Forty-three percent of home painting is done by do-it-yourselfers. This has implications for the out-of-pocket costs incurred for maintenance.

- The distribution of maintenance interval responses is bi-modal, with peaks at 5 and 10 years. This result, and the previous two, indicate that it is appropriate to define very specific maintenance tasks for the quantitative analysis. This would lead to a more homogeneous set of observations.

- Visible deterioration is an important factor in the decision to paint for 84 percent of those who have painted. Peeling and cracking is the most frequently mentioned form of visible deterioration which prompts action.

- The incomes of the respondents averaged over $50,000. This relatively high value may be partially explained by the fact that the sample was primarily homeowners.

- A pre-test of an early form of the questionnaire used a series of pictures of damaged materials to attempt to determine critical damage levels for individual respondents. However, the picture set did not work well and was excluded from the final questionnaire.

- Twenty percent of respondents who have painted chose a paint formulation that was designed to protect against air pollution damage. On average, these paints cost $1.54 more per gallon. However, the hypothesis of no difference in the mean cost per gallon across paint types could not be rejected at standard levels of confidence. Consequently, quantitative estimates of damage designed to account for this form of prior mitigating behavior are not warranted based on the available data.[2]

These are a few of the observations drawn from the survey data. The distribution of responses to the questions addressed above are included as Appendix B of this section.

6.5.3 Probability of Painting

For a given Thomas Brothers map grid, data are available on the total number of single family homes present in the grid. However, not all houses have painted wood and not all houses are completely painted every time exterior painting is performed. Therefore, an aggregate measure of economic damage for the grid must consider the probability that a specific maintenance task will be undertaken. There are two features of the data that contribute to this probability. First, the behavioral survey is designed to screen out certain respondents. Second, there are different combinations of maintenance tasks that can be performed. These features are discussed below.

---

[2] At issue here is the idea that if a paint is available that is resistant to air pollution damage, then the maintenance interval length of individuals would not be affected by air pollution. However, economic damages would be realized if the unit cost of the pollution resistant paint is greater than the cost of non-pollution resistant paint, and the (more costly) pollution resistant paint would not otherwise have been selected.

6.5.3.1 Survey Screening Criteria -- The behavioral survey requires termination of the interview in the following circumstances:

- Respondent does not reside in a single family home.
- Respondent does not have some painted wood or painted stucco walls present.
- Respondent does not make his/her own maintenance decisions.
- Respondent is not over 18 years of age.

If a respondent survives these screening criteria, he/she is eligible to be asked the detailed questions about maintenance practices.

The probability that someone will be eligible can be calculated from the sample disposition data shown earlier in Table 6-3. First, note that it is not necessary to determine the probability that a respondent lives in a single family residence. This is because the total number of single family residences (by grid) is available from Valley Research (1989). As a result, extrapolation to the universe of single family homes can proceed directly without additional concern about the count of other building types.

For the other screening criteria, it is necessary to calculate the probability that a respondent will survive the criteria, conditional on surviving previous screening criteria. The probability relationship that is needed can be stated as:

$$Pr(X_1 \cap X_2) = Pr(X_2 | X_1) \cdot Pr(X_1) \qquad (6.1)$$

If, for example, X_1 is the event "lives in single family home" and X_2 is the event "has painted wood or stucco walls," then $Pr(X_1 \cap X_2)$

is the probability that a respondent lives in a single family home _and_ has painted wood or stucco walls. The term $Pr(X_2|X_1)$ on the right hand side of (6.1) is the conditional probability of having painted wood or stucco walls conditional on living in a single family home. This probability is calculated by adding up all respondents who answered Question S2 and dividing by the sum of the affirmative responses and the number who terminated at Question S2. Since Question S2 is asked only if Question S1 is answered properly (i.e., single family resident), the quotient is a probability that is conditional on being a single family resident. From Table 6-3, the number of respondents who answered Question S2 (i.e., type of wall material present) is (179+116+9+25+503+80+21+9+29+3). This sum equals 974. Note that two categories of eligibility unknown respondents have been included in the sum because they terminated at a question that was asked after Question S2. The number of respondents who terminate at S2 is 179+25. Therefore, 770 respondents answered Question S2 affirmatively for painted wood or stucco walls. Thus, 770/974 = 0.79 is the conditional probability. Since $Pr(X_1)$ is the probability of living in a single family home, and by design this probability is 1.0, the joint probability of a respondent living in a single family home and having painted wood or stucco walls is 0.79.

Similar calculations can be performed for the remaining screening criteria. The joint occurrence of all of the criteria is calculated as 0.651. This is the probability that a person living in a single family home satisfies all the remaining sreening criteria. This is the probability that the respondent is eligible.

6.5.3.2 Definition of Maintenance Tasks -- The behavioral survey obtained detailed data on the materials used on various parts of homes and the frequency with which these parts were painted. Six specific maintenance tasks were defined:[3]

- Painting wood trim only.
- Painting wood trim and wood eaves.
- Painting wood trim, eaves, and windowsills.
- Painting wood trim, eaves, windowsills and wood walls (when walls are all wood).
- Painting wood walls only (when walls are all wood).
- Painting the whole house, given that painted wood trim, eaves, windowsills, and walls are present.

The first column of Table 6-4 identifies each of the six paint maintenance tasks in terms of materials painted. The second column shows the number of eligible respondents who reported that their residence had the appropriate material (for the identified maintenance task in Column 1) present. For example, 450 (out of the 503 respondents who completed the survey) reported wood trim present. The third column shows the number of respondents who have previously painted (i.e., they answered the retrospective section of the questionnaire) and who have the materials present for completing the identified maintenance task. For example, 344 out of 450 respondents with wood trim present have previously painted some part of their house. The last column in Table 6-4 shows the number of respondents who have completed the specific maintenance task given that they have the material present and that they have previously painted. For example, 43 out of the 344 respondents who have previously painted and have wood trim present have painted wood trim only. It is important to realize that the maintenance task is "paint wood trim only." If a respondent painted other parts of the house, either wood or other material,

[3] Other combinations are possible. However, few respondents reported combinations other than these six.

Table 6-4

MAINTENANCE TASK DATA

Paint Maintenance Task	Have Materials Present	Have Painted	Completed Task
Wood Trim	450	344	43
Wood Trim + Eaves	375	288	12
Wood Trim + Eaves + Sills	267	220	8
Wood Trim + Eaves + Sills + Walls	33	16	2
Wood Walls	73	35	2
Whole House Painted (wood trim + eaves + sills + walls present)	45	24	24

they would not be counted in the entry shown in the first row and last column of Table 6-4. This is admittedly a narrow focus on a very specific maintenance task. However, this level of detail is appropriate if one is to avoid allocation difficulties with respect to damage rates and costs.

A total of 91 respondents completed one of the six specific maintenance tasks the last time they painted. Table 6-5 shows the distribution of these 91 responses in terms of location. This distribution can be compared with the distribution for the sample of 503 eligible respondents. Clearly, the Orange County area is underrepresented. This raises the question as to whether there is a pattern in the distribution of materials that needs

Table 6-5

DISTRIBUTION OF RESPONSES BY AREA

Area	Full Sample	Restricted Sample*
Los Angeles County	324	70
Orange County	83	2
Riverside/San Bernardino Counties	89	12
Other	7	7
	---	---
Total	503	91

* Sample of 91 observations that performed maintenance of painted wood components.

to be considered or whether other factors are at work. For example, if the distribution of materials in the basin shows that Orange County has much less painted wood present than Los Angeles County, this would explain why few respondents in Orange County have performed one of the six maintenance tasks. This becomes important in the extrapolation of per house damage estimates. The number of houses that complete a task in a grid area is equal to the total number of houses in the grid times the probability that maintenance task will be performed. If the materials distribution is sensitive to location, the probability needs to reflect this fact.

Linear regressions were estimated between the presence of various materials (e.g., painted wood trim) and dummy variables representing the respondent location. For example, for the sample of 503 respondents, the probability of having wood trim present given that the respondent lived in Los Angeles was estimated to be 0.895. If the respondent lived in Orange County, the predicted probability for wood trim being present was estimated to be 0.892, not significantly different from the probability predicted for Los Angeles. Similar results were obtained for the other materials. In all cases, we could not reject the hypothesis of no location impact on material distribution. Therefore, the materials distribution does not explain the low number of observations for Orange County in the sample of 91.

A second hypothesis was that people in Orange County had not previously painted, due perhaps to a shorter time lived in their homes. The null hypothesis that location has no effect on whether a respondent had painted was rejected. For example, define the following variables:

RETDUM = 1 if respondent answered retrospective questions; 0 otherwise

ORANGE = dummy variable = 1 if respondent lives in Orange County; 0 otherwise

RIVSB = dummy variable = 1 if respondent lives in Riverside or San Bernardino Counties; 0 otherwise

Then, a regression of RETDUM on ORANGE and RIVSB leads to the estimated equation:

$$\text{RETDUM} = 0.844 - \underset{(0.058)}{0.327} \cdot \text{ORANGE} - \underset{(0.05)}{0.201} \cdot \text{RIVSB}$$

This equation is estimated for the 450 respondents who have wood trim present. The equation indicates that the probability that a resident of Los Angeles County has wood trim present and has previously painted is 0.844 (this is the intercept). The probability that a resident of Orange County has wood trim present nad has previously painted is 0.517 (0.844-0.327). The coefficient for the Orange County location dummy variable is significantly different from zero. The coefficient for the RIVSB dummy variable is also significantly different from zero and the probability that a respondent in this location will have previously painted given that wood trim is present is 0.643 (0.844-0.201).

Based on this result, and similar results for other materials, the probabilities of painting are conditional on location. For the purposes of extrapolation, there is a greater probability that those individuals residing in Los Angeles County will have previously painted a particular part of their home.

The relationship between RETDUM and the location dummies does not help to explain why respondents in Orange County have not previously painted. To address this issue, the relationship between RETDUM and a series of variables available from the behavioral survey was examined. The strongest correlation was between RETDUM and the number of years lived in the house. For each year lived in the house, the probability of having previously painted increases by 0.02. Since much of Orange County is more recently built up, the number of years lived in the current residence is much lower in Orange County. This translates to a lower probability of having previously painted the current residence. The implication of this is that the overall probability for performing a maintenance task for Orange County residents will be lower than the corresponding probability for Los Angeles residents. Note, this difference in probabilities should narrow over time as the new development and growth in Orange County stabilizes.

Table 6-6 shows the final set of probabilities calculated for each maintenance task. These probabilities are conditional on the eligibility of the respondent, the presence of the material, the location of the respondent, and the maintenance task performed. An adjustment is also made to account for the proportion of individuals who reported that visible deterioration was a

Table 6-6

PROBABILITIES OF PAINTING FOR SPECIFIC MAINTENANCE TASKS

Task	Area*	Probability
Trim only	1	0.053
	2	0.040
	3	0.032
Trim + Eaves	1	0.013
	2	0.010
	3	0.009
Trim + Eaves + Sills	1	0.011
	2	0.008
	3	0.008
Trim + Eaves + Sills + Walls	1	0.004
	2	0.003
	3	0.002
Walls only (all wood present)	1	0.000
	2	0.000
	3	0.000
Whole House (wood only present)	1	0.014
	2	0.011
	3	0.009

* Area codes: 1 = Los Angeles, 2 = Riverside/San Bernardino, 3 = Orange.

very important or an important factor in their decision to paint. This is done to remove the effect of those people who have painted for reasons other than damage. It is assumed that the actions of these individuals would not be affected by changes in air pollution concentrations.

The probabilities shown in Table 6-6 can be multiplied by the total number of houses in a grid to yield the number of houses in the grid painted for each maintenance task. When this number is divided by the length of the maintenance interval, the quotient is an estimate of the probability of observing a specific maintenance task being performed in a single year. This probability is then multiplied by the cost of performing a specific maintenance task to get an estimate of maintenance expenditures.

The next two sections develop equations for the maintenance interval and the maintenance cost using data from the behavioral survey. These equations are then used in conjunction with the probabilities derived in this section to obtain aggregate (extrapolated) estimates of maintenance expenditures under different air pollution exposures.

REFERENCE

Thomas Brothers Street Guide and Directory (1989). Los Angeles, Orange, Riverside and San Bernardino Counties.

Valley Research Corporation (1989). Development of an Inventory of Materials Potentially Sensitive to Ambient Atmospheric Acidity in the South Coast Air Basin. Report prepared for the California Air Resources Board under Contract No. A6079-32, March.

APPENDIX 6-A

SCREENER AND QUESTIONNAIRE

OPINION RESEARCH CORPORATION
Princeton, New Jersey

54088
040589
REVISED

101-04 Ballot #
105-06 Card 01
107-16 Telephone #
117-24 Skip

HOME MAINTENANCE STUDY

SCREENER

DATE:______________________ TIME ENDED:______________

TELEPHONE NO.:______________________ TIME STARTED:______________

STATE:______________________ LENGTH:__________(MINUTES) *125-26*

INTERVIEWER:______________________ INTERVIEWER I.D.#:__________

Hello. My name is ______ from Opinion Research Corporation in Princeton, New Jersey. We are conducting a study on external home care for the California Air Resources Board, and would like to include your views. Your responses will be kept strictly confidential and will not be associated with your name in any way. No one will attempt to sell you anything as a result of this survey. The information you provide will help in studies of air pollution damage.

S1. First, do you live in a single-family home, a multiple-family home, an apartment, or a condominium? *127*

1 Single-family home
2 Multiple-family home
3 Apartment
4 Condominium
5 OTHER (Specify):__________
6 NO RESPONSE

(2–6) ----> THANK AND TERMINATE; CODE T1 *128*

S2. Would you tell me what material or materials the exterior walls of your home are made of? (CIRCLE ALL THAT APPLY. PROBE FOR PAINTED VS. UNPAINTED. IF MORE THAN ONE MATERIAL MENTIONED FOR ITEMS 1-4, ASK FOR EACH MATERIAL: What percent of the exterior walls are made of that material?) *129*

		% OF TOTAL	
1	PAINTED WOOD	______	*130-32*
2	PAINTED STUCCO	______	*133-35*
3	ALUMINUM	______	*136-38*
4	VINYL	______	*139-41*
5	UNPAINTED WOOD		
6	UNPAINTED STUCCO		
7	ASBESTOS SHINGLE		
8	BRICK		
9	STONE		
0	OTHER (Specify):		

(5–0) ----> THANK AND TERMINATE; CODE T2 *142*

S3. Are you the person primarily responsible for decisions regarding exterior painting and maintenance of your home? *143*

1 YES ----> SKIP TO Q. S7
2 NO
3 REFUSED ----> THANK AND TERMINATE; CODE T3

IF "2" ON Q. S3, ASK:

S4. Who is primarily responsible for exterior maintenance -- another family member, a landlord, or someone else? *144*

1 ANOTHER FAMILY MEMBER ----> ASK Q. S5
2 A LANDLORD
3 SOMEONE ELSE (Specify):__________

(2–3) ----> SKIP TO Q. S6

4 NOT SURE ----> THANK AND TERMINATE; CODE T4 *145*

Skip 146

IF "1" ON Q. S4, ASK:

S5. Is that person available to speak with me? (IF NOT AVAILABLE, DETERMINE BEST TIME TO RE-CONTACT.)

DATE:________ *CS*

TIME:________ *CS*

IF PERSON IS AVAILABLE, RETURN TO Q. S3.

IF "2" OR "3" ON Q. S4, ASK:

S6. Is that person available to speak with me or is that person at another location? *147*

1 LOCATED HERE, AVAILABLE NOW ----> ASK TO SPEAK WITH THAT PERSON AND RETURN TO Q. S3
2 LOCATED HERE, NOT AVAILABLE NOW ----> ARRANGE FOR A CALLBACK
3 LOCATED ELSEWHERE
4 DON'T KNOW ----> THANK AND TERMINATE; CODE T6

S7. Are you 18 years of age or older? *148*

1 YES
2 NO
3 REFUSED ----> THANK AND TERMINATE; CODE T7

IF "3" OR "4" ON Q. S2, ASK; OTHERWISE, SKIP TO Q. 1:

S8. Was the (aluminum/vinyl) a replacement for another material on the exterior walls of your house? *149*

1 YES
2 NO
3 NOT SURE ----> THANK AND TERMINATE; CODE T8

IF "1" ON Q. S8, ASK:

S9. What material did you replace on the exterior walls of your house? *150*

1 PAINTED STUCCO
2 PAINTED WOOD
3 UNPAINTED STUCCO
4 UNPAINTED WOOD
5 ASBESTOS SHINGLE
6 BRICK
7 STONE
8 OTHER (Specify): ----> THANK AND TERMINATE; CODE T9

151

IF "1" OR "2" ON Q. S9, ASK:

S10. Why did you replace the exterior painted surface of your house with this material? *152* *153*

Skip 154-55

S11. What was the cost of buying and installing the material? (PROBE: Your best estimate will be fine.)

$________ *156-159*

9999 DON'T KNOW/NO RESPONSE

S12. And, in what year did you install the material?

________YEAR *160-63*

9999 DON'T KNOW

IF "1" OR "2" ON Q. S2, CONTINUE WITH Q. 1 OF QUESTIONNAIRE; OTHERWISE, CONTINUE BELOW.

May I verify that I reached you by dialing ...

(________) ________________________

THANK THE RESPONDENT AND TERMINATE. MAKE ANY CORRECTIONS TO THE TELEPHONE NUMBER ON THE SAMPLE CARD; CODE TS ON SAMPLE CARD.

Skip 164

OPINION RESEARCH CORPORATION
Princeton, New Jersey

54088
040589
REVISED

HOME MAINTENANCE STUDY

QUESTIONNAIRE

1. Do you own your house, or do you rent it? *165*

1 OWN
2 RENT
3 NOT SURE

2. How long have you lived in your house? *166-67*

________YEARS

99 DON'T KNOW

3. In what year was your house built? Was it before 1946, between 1946 and 1964, or was it built after 1964? *168*

1 Before 1946
2 1946 - 1964
3 After 1964
4 NOT SURE

4. How many stories does your house have? *169*

1 ONE
2 TWO
3 THREE
4 OTHER (Specify):______________________________ ☐ *170*
5 NOT SURE

5. Approximately how many square feet of living area does your house have? Would you say ... (READ LIST) *171*

1 Less than 1,000 square feet,
2 1,000 but less than 1,500 square feet,
3 1,500 but less than 2,000 square feet,
4 2,000 but less than 3,000 square feet,
5 3,000 but less than 4,000 square feet, or
6 4,000 square feet or more?
7 NOT SURE

6. How many windows are there in your house? *172-73*

________WINDOWS

99 DON'T KNOW

Skip 174-80

201-04 Ballot #
205-06 Card 02

7. And how many exterior entrances of any material are there, including garage doors, patio doors, and other exterior entrances? *207-08*

________ENTRANCES

99 DON'T KNOW

Now I'd like to discuss some aspects of home maintenance, starting with painting.

8a. What type of material are your windowsills made of? (READ ANSWER CATEGORIES AND RECORD BELOW UNDER Q. 8a.)

	Q. 8a Windowsills *209-10*	Q. 8b Eaves *211-12*	Q. 8c Trim *213-14*
Painted wood	1	1	1
Unpainted wood	2	2	2
Something else? (Specify):	3	3	3
NOT SURE	4	4	4

8b. What type of material is used for the eaves? (READ ANSWER CATEGORIES AND RECORD ABOVE UNDER Q. 8b.)

8c. And what type of material is used for the trim? (READ ANSWER CATEGORIES. RECORD ABOVE UNDER Q. 8c.)

9. I'm going to read a list of factors that might influence how often your house needs painting. For each one, would you please tell me how much influence you think it has in the case of <u>your</u> house -- a lot, some, or none?

First, the age of your house. How much influence does the age of your house have on how often any part of it needs painting? (REPEAT FOR EACH ITEM.)

	A Lot	Some	None	NOT SURE	
a. The age of your house	1	2	3	4	*215*
b. The location of your house	1	2	3	4	*216*
c. The quality of the previous paint job	1	2	3	4	*217*
d. The cost of repainting	1	2	3	4	*218*
e. Moisture or humidity	1	2	3	4	*219*
f. Sunlight	1	2	3	4	*220*
g. Air pollution	1	2	3	4	*221*
h. Quality of the materials used on the exterior of the house	1	2	3	4	*222*

Skip 223

10. When was the last time you painted or had someone else paint any part of the exterior walls or trim of your house? (PROBE: How many years ago was that?)

224-25

________YEARS

97 NEVER PAINTED ----> SKIP TO Q. 43, PAGE 8

98 NOT SURE

IF EVER PAINTED OR "NOT SURE" IN Q. 10, ASK:

11. What part of the house did you paint the last time you painted? Was it ... (READ ANSWER CATEGORIES. CIRCLE ALL THAT APPLY.)

226

1 The trim,
2 The eaves,
3 The windowsills,
4 The exterior walls,
5 Something else? (Specify):____________

____, or
6 The whole house? *227*
7 NOT SURE/NO RESPONSE

12. How frequently would you estimate that you paint these parts of your house?

228-29

1 EVERY YEAR
2 EVERY TWO YEARS
3 EVERY THREE YEARS
4 EVERY FOUR YEARS
5 EVERY FIVE YEARS
6 EVERY SIX YEARS
7 EVERY SEVEN YEARS
8 EVERY EIGHT YEARS
9 EVERY NINE YEARS
10 EVERY TEN YEARS
11 OTHER (Specify):____________________
12 NOT SURE *230*

13. The last time you painted, what were the main reasons you decided to paint?

231

232

Skip 233

14. I am going to read a list of factors that often influence people to paint their houses. For each of these factors, would you tell me how important it was the last time you decided to paint -- very important, somewhat important, or not important?

	Very Important	Somewhat Important	Not Important	NOT SURE	
a. Visible deterioration	1	2	3	4	234
b. You wanted a new color	1	2	3	4	235
c. There was a sale on paint	1	2	3	4	236
d. To sell the house	1	2	3	4	237
e. To keep up the appearance of the neighborhood	1	2	3	4	238
f. Something else (Specify):__________	1	2	3	4	239

Skip 240-44

IF "1" OR "2" ON Q. 14a, ASK; OTHERWISE, SKIP TO Q. 20, PAGE 5:

15. What type of deterioration were you thinking of? Was it ... (READ LIST) (CIRCLE ALL THAT APPLY.)

245

1 Blistering,
2 Dullness or fading,
3 Cracking or peeling,
4 Flaking or chipping,
5 Mildew,
6 Wood rot, or
7 Something else? (Specify):__________
8 NOT SURE *246*

16. The last time you painted, where was the damage occuring? Was it ... (READ LIST)

	YES	NO	DON'T RECALL	
a. On the window sills	1	2	3	247
b. On the trim	1	2	3	248
c. Under the eaves	1	2	3	249
d. On the exterior walls	1	2	3	250

IF "1" ON Q. 16d, ASK; OTHERWISE, SKIP TO Q. 20:

17. Were all of the exterior walls affected, or were just some of them affected?

251

1 ALL OF THEM ----> SKIP TO Q. 19
2 SOME
3 DON'T REMEMBER ----> SKIP TO Q. 19

Skip 252

IF "2" ON Q. 17, ASK:

18. Which walls were affected, the ones on the north, south, east, or west side of your house? (ACCEPT MULTIPLE RESPONSES.)

253

1 NORTH
2 SOUTH
3 EAST
4 WEST
5 DON'T RECALL

19. What percent of the outside walls did you actually paint?

254-56

________PERCENT

999 DON'T KNOW

20. The last time you painted the exterior of your house, did you or your family do the work yourselves, or did you hire someone to do it? (ACCEPT MULTIPLE RESPONSES.)

257

1 RESPONDENT OR FAMILY
2 HIRED SOMEONE ----> SKIP TO Q. 24
3 OTHER (Specify):__________ ----> SKIP TO Q. 35, PAGE 7
4 NOT SURE/DON'T RECALL ----> SKIP TO Q. 35, PAGE 7

IF "1" ON Q. 20, ASK:

21. How many days did you personally spend painting? (PROBE: Your best estimate is fine.)

258-59

________DAYS

99 DON'T RECALL

22. How many days did other family members spend painting? (PROBE: Your best estimate is fine.)

260-61

________DAYS

99 DON'T RECALL

23. And what was spent for paint and materials? (PROBE: Your best estimate is fine.)

262-66

$________

99999 DON'T RECALL

IF "2" ON Q. 20, ASK; OTHERWISE, SKIP TO Q. 34, PAGE 7:

24. About how many people were hired to complete the job? (PROBE: Your best estimate is fine.)

267-68

________PEOPLE

99 DON'T RECALL

Skip 269

25. How many hours, in total, did all of the people you hired work? (PROBE: Your best estimate is fine.) *270-73*

_________HOURS

9999 DON'T RECALL

26. Did you take out a long-term loan to pay for some or all of your most recent exterior painting? *274*

1 YES
2 NO ----> SKIP TO Q. 34
3 NOT SURE ----> SKIP TO Q. 34

IF "1" ON Q. 26, ASK:

27. Was the loan a home-equity loan? *275*

1 YES
2 NO
3 NOT SURE

28. What were the monthly payments on the loan? (PROBE: Your best estimate is fine.) *276-78*

$_________

999 DON'T RECALL

29. What was the term of the loan? *279-80*

_________MONTHS

99 DON'T RECALL

301-04 Ballot #
305-06 Card 03

30. And what was the annual interest rate on the loan? *307-09*

_________%

999 DON'T RECALL

31. Was the loan used entirely for your most recent exterior painting, or did you use it for something else as well? *310*

1 ENTIRELY FOR PAINTING ----> SKIP TO Q. 33
2 SOMETHING ELSE
3 NOT SURE ----> SKIP TO Q. 33

IF "2" ON Q. 31, ASK:

32. What part of the loan was used for the most recent exterior painting? (PROBE: How many dollars was that?) *311-15*

$_________

99999 DON'T RECALL

33. For your most recent exterior painting, what amount, if any, did you spend in addition to the loan?

316-19

$________

9999 DON'T RECALL

34. What was the total cost of the work the most recent time you painted the exterior of your house? (PROBE: Your best estimate is fine.)

320-23

$________

9999 DON'T RECALL

35. The last time you or someone else painted the exterior of your house, how was the surface prepared? Was it ... (READ LIST) (CIRCLE ALL THAT APPLY.)

324

1 Sanded,
2 Scraped,
3 Primed, or
4 High-pressure washed?
5 OTHER (Specify):________ *325*
6 NOT SURE

36. In total, how many coats of primer and coats of paint were applied?

326

1 ONE
2 TWO
3 THREE
4 OTHER (Specify):________ *327*
5 NOT SURE

37. What method was used to apply the paint? (READ ANSWER CATEGORIES. CIRCLE ALL THAT APPLY.)

328

1 Brush?
2 Roller?
3 Spray?
4 OTHER (Specify):________ *329*
5 NOT SURE

38. How many gallons of paint were used? (PROBE: Your best estimate is fine.)

330-32

________GALLONS

999 DON'T KNOW

39. And what was the cost per gallon? (PROBE: Your best estimate is fine.)

333-36

$________PER GALLON

9999 DON'T KNOW *Skip 337*

40. And what brand of paint was used?

338-39

1 BENJAMIN MOORE
2 CON-LUX
3 COOK & DUNN
4 DUTCH BOY
5 DUNN & EDWARD
6 GLIDDEN
7 MURALO
8 PITTSBURGH
9 SHERWIN-WILLIAMS
10 SINCLAIR
11 OTHER (Specify):______________________ 340
12 NOT SURE

41. Did you choose a paint that was specially formulated to protect your house against air pollution damage?

341

1 YES
2 NO
3 DON'T KNOW

42. If you had sold your house after you last painted it, what, if anything, do you think painting it would have added to the value? (PROBE: Your best estimate is fine.)

342-45

$________

9999 NOT SURE

0000 NOTHING

Skip 346-80

401-04 Ballot #
405-06 Card 04
407-20 Skip

ASK EVERYONE

43. Do you have any plans to paint any part of the exterior of your home in the future?

421

1 YES
2 NO ----> SKIP TO Q. 68, PAGE 12
3 NOT SURE

IF "1" OR "3" ON Q. 43, ASK:

44. In what year are you planning to paint?

422-25

YEAR:________

9999 DON'T KNOW

45. What part of the house are you planning to paint? Are you planning to paint ... (READ LIST. CIRCLE ALL THAT APPLY.)

426

1 The trim,
2 The eaves,
3 The windowsills,
4 The exterior walls,
5 Something else (Specify):________________

____, or

6 The whole house? 427
7 NOT SURE/NO RESPONSE

46. How frequently would you estimate that you paint these parts of your house?

428-29

1 EVERY YEAR
2 EVERY TWO YEARS
3 EVERY THREE YEARS
4 EVERY FOUR YEARS
5 EVERY FIVE YEARS
6 EVERY SIX YEARS
7 EVERY SEVEN YEARS
8 EVERY EIGHT YEARS
9 EVERY NINE YEARS
10 EVERY TEN YEARS
11 OTHER (Specify):______________
12 NOT SURE

430

47. What are the main reasons you are planning to paint this next time?

431

432

Skip 433

48. I am going to read a list of factors that often influence people to paint their houses. For each of these factors, would you tell me how important it is in your decision to paint the next time -- very important, somewhat important, or not important?

	Very Important	Somewhat Important	Not Important	NOT SURE	
a. Visible deterioration	1	2	3	4	434
b. Wanting a new color	1	2	3	4	435
c. A sale on paint	1	2	3	4	436
d. To sell the house	1	2	3	4	437
e. To keep up the appearance of the neighborhood	1	2	3	4	438
f. Something else (Specify):__________	1	2	3	4	439

Skip 440-44

IF "1" OR "2" ON Q. 48a, ASK; OTHERWISE, SKIP TO Q. 54, PAGE 10:

49. What type of deterioration were you thinking of? Would that be ... (READ LIST) (CIRCLE ALL THAT APPLY.)

445

1 Blistering,
2 Dullness or fading,
3 Cracking or peeling,
4 Flaking or chipping,
5 Mildew,
6 Wood rot, or
7 Something else? (Specify):__________
8 NOT SURE

446

50. Where is the damage occuring? Is it ... (READ LIST)

	YES	NO	DON'T RECALL	
a. On the window sills	1	2	3	447
b. On the trim	1	2	3	448
c. Under the eaves	1	2	3	449
d. On the exterior walls	1	2	3	450

IF "1" ON Q. 50d, ASK; OTHERWISE, SKIP TO Q. 54:

51. Are all of the exterior walls affected, or are just some of them affected?

451

1 ALL OF THEM ----> SKIP TO Q. 53
2 SOME
3 DON'T REMEMBER ----> SKIP TO Q. 53

Skip 452

IF "2" ON Q. 51, ASK:

52. Which walls are affected, the ones on the north, south, east, or west side of your house? (ACCEPT MULTIPLE RESPONSES.)

453

1 North
2 South
3 East
4 West
5 DON'T KNOW

53. What percent of the outside walls will you actually paint?

454-56

________PERCENT

999 DON'T KNOW

54. Do you plan to have the work done by your or your family, or will you hire someone to do it? (ACCEPT MULTIPLE RESPONSES.)

457

1 RESPONDENT OR FAMILY
2 HIRE SOMEONE ----> SKIP TO Q. 58, PAGE 11
3 OTHER (Specify):________ ---> SKIP TO Q.64 PAGE 12
4 NOT SURE/DON'T RECALL

IF "1" ON Q. 54, ASK:

55. How many days do you personally expect to spend painting? (PROBE: Your best estimate is fine.)

458-59

________DAYS

99 DON'T KNOW

56. How many days do you expect other family members to spend painting? (PROBE: Your best estimate is fine.)

460-61

________DAYS

99 DON'T KNOW

57. And what do you expect to spend for paint and materials? (PROBE: Your best estimate is fine.)

462-66

$________

99999 DON'T KNOW

Skip 467-73

IF "2" ON Q. 54, ASK; OTHERWISE, SKIP TO Q. 64, PAGE 12:

58. Do you plan to take out a long-term loan to pay for some or all of the painting?

474

1 YES
2 NO
3 NOT SURE ----> SKIP TO Q. 63

IF "1" ON Q. 58, ASK:

59. What do you expect the amount of the loan will be? (PROBE: Your best estimate is fine.)

475-78

$________

9999 NOT SURE

Skip 479-80
501-04 Ballot #
505-06 Card 05
507-09 Skip

60. Will you use the loan entirely for your exterior painting or will it be used for something else as well?

510

1 ENTIRELY FOR PAINTING ----> SKIP TO Q. 62
2 SOMETHING ELSE
3 NOT SURE ----> SKIP TO Q. 62

IF "2" ON Q. 60, ASK:

61. What part of the loan will be used for exterior painting? (PROBE: Your best estimate is fine.) (PROBE: How many dollars is that?)

$________ *511-15*

99999 NOT SURE

62. What amount, if any, do you think you will spend in addition to the loan for your exterior painting? (PROBE: Your best estimate is fine.)

$________ *516-19*

9999 DON'T KNOW

63. What do you expect to pay to have the exterior of your house painted? (PROBE: Your best estimate is fine.)

$\$$________ 520-23

9999 DON'T KNOW

Skip 524-29

64. About how many gallons of paint do you expect to use? (PROBE: Your best estimate is fine.)

530-32

________GALLONS

999 DON'T KNOW

65. What do you expect to pay for each gallon? (PROBE: Your best estimate is fine.)

533-36

$\$$________PER GALLON

9999 DON'T KNOW

66. How much more per gallon would you be willing to pay for a paint that protects against air pollution damage?

537-40

$\$$________

9999 NOT SURE

0000 NOTHING

Skip 541

67. What, if anything, do you think painting adds to the value of your house? (PROBE: Your best estimate is fine.)

$\$$________ *542-45*

9999 NOT SURE

0000 NOTHING

ASK EVERYONE

68. Have you ever considered covering or replacing the exterior painted surfaces of your house with some other material?

546

1 YES
2 NO
3 NOT SURE ----> SKIP TO Q. 73, PAGE 14

IF "1" ON Q. 68, ASK:

69. What material were you considering? (CIRCLE ALL THAT APPLY.)

547

1 ALUMINUM SIDING
2 VINYL SIDING
3 OTHER (Specify):____________________
4 NOT SURE *548*

Skip 549

70. Why were you considering covering or replacing the exterior painted surfaces of your house with this material?

550

551

71. What would it cost to buy and install the replacement material? (PROBE: Your best estimate is fine.)

552-56

$________

99998 DON'T RECALL

72a. Did you decide to install the replacement material or not to install it?

557

1 YES, WILL INSTALL ----> SKIP TO Q. 73
2 NO, WILL NOT INSTALL
3 DON'T KNOW ----> SKIP TO Q. 73
4 NO RESPONSE

IF "2" ON Q. 72a, ASK:

72b. Why did you decide not to install the replacement material?

558

559

Skip 560

Qs. 73-78 *561-80* *607-47* *601-04 Ballot #* *605-06 Card 06*

ASK EVERYONE

73. Aside from painting, do you do any other maintenance of the exterior walls of your house on a regular basis?

1 YES
2 NO
3 NOT SURE ---> SKIP TO Q. D1, PAGE 15

IF "1" ON Q. 73, ASK:

74. What types of maintenance, aside from painting, do you do? (RECORD BELOW UNDER COLUMN Q. 74.)

	Q. 74	Q. 75			Q. 76			Q. 77	Q. 78	Q. 79
		YES	NO	NO ANS.	Self	Hire	NOT SURE	COST	# DAYS	FREQUENCY
a.	_____	1	2	3	1	2	3	$_____	____DAYS	____MO(S)
	_____				9	DON'T KNOW		9999 DON'T KNOW	99 DON'T KNOW	____YR(S)
	_____									
b.	_____	1	2	3	1	2	3	$_____	____DAYS	____MO(S)
	_____				9	DON'T KNOW		9999 DON'T KNOW	99 DON'T KNOW	____YR(S)
	_____									
c.	_____	1	2	3	1	2	3	$_____	____DAYS	____MO(S)
	_____				9	DON'T KNOW		9999 DON'T KNOW	99 DON'T KNOW	____YR(S)
	_____									
d.	_____	1	2	3	1	2	3	$_____	____DAYS	____MO(S)
	_____				9	DON'T KNOW		9999 DON'T KNOW	99 DON'T KNOW	____YR(S)
	_____									

FOR EACH TYPE OF MAINTENANCE LISTED, ASK:

75. Is physical damage a major reason you do this maintenance? (RECORD ABOVE UNDER Q. 75.)

76. Do you do the work yourself or do you hire someone to do it? (RECORD ABOVE UNDER Q. 76.)

77. Approximately how much does it cost to do the work? (PROBE: Your best estimate is fine.) (RECORD ABOVE UNDER Q. 77.)

78. And, about how many days does the work take? (PROBE: Your best estimate is fine.) (RECORD ABOVE UNDER Q. 78.)

79. And, about how often do you do the work -- every few months, every year, every two years, or what? (PROBE: Your best estimate is fine.) (RECORD ABOVE UNDER Q. 79.)

These last few questions are for background purposes, to help us analyze the study results.

D1. What is your age, please?

648-49

________YEARS OLD

99 DON'T KNOW/NO RESPONSE

D2. What is the last grade of school you completed? (READ CATEGORIES ONLY IF NECESSARY.)

650

1 SOME HIGH SCHOOL OR LESS
2 HIGH SCHOOL GRADUATE
3 SOME COLLEGE
4 COLLEGE GRADUATE
5 POST-GRADUATE WORK
6 TECHNICAL OR BUSINESS SCHOOL
7 DON'T KNOW/NO RESPONSE

D3. What is your occupation?

651

1 EXECUTIVE/ADMINISTRATIVE/MANAGERIAL
2 PROFESSIONAL (I.E., LAWYER, DOCTOR)
3 SALES
4 CLERICAL/ADMINISTRATIVE SUPPORT
5 BLUE COLLAR - LABOR/SERVICE WORKER/FARMER
6 STUDENT
7 HOMEMAKER
8 RETIRED
9 UNEMPLOYED
0 OTHER (Specify):________________ 652
X DON'T KNOW/NO RESPONSE

D4. Including yourself, how many adults, that is, persons age 18 or over, live in your household?

653-54

________ADULTS

99 DON'T KNOW/NO RESPONSE

D5. Are there any children, that is, persons under the age of 18, living in your household?

655

1 YES
2 NO
3 DON'T KNOW/NO RESPONSE ----> SKIP TO Q. D8, PAGE 16

IF "1" ON Q. D5, ASK:

D6. How many children under the age of 13 live in your household?

656-57

________CHILDREN

00 NONE

99 DON'T KNOW/NO RESPONSE

Skip 658

D7. How many children age 13 to 17 live in your household? 659-60

________CHILDREN

00 NONE

99 DON'T KNOW/NO RESPONSE

D8. What would you estimate to be the current market value of your house? Would it be less than $100,000 or $100,000 or more? 661

1 Less than $100,000 ----> Would it be ... (READ LIST)

1 Under $50,000, or 662
2 $50,000 but less than $100,000?
3 DON'T KNOW/NO RESPONSE

2 $100,000 or more ----> Would it be ... (READ LIST)

4 $100,000 but less than $150,000,
5 $150,000 but less than $200,000, or
6 $200,000 or more?
7 DON'T KNOW/NO RESPONSE

3 DON'T KNOW/NO RESPONSE

D9. Was your total household income before taxes in 1988 less than $40,000 or $40,000 or more? 663

1 Less than $40,000 ----> Was that ... (READ LIST)

1 Under $10,000, 664
2 $10,000 but less than $20,000,
3 $20,000 but less than $30,000, or
4 $30,000 but less than $40,000?
5 DON'T KNOW/NO RESPONSE

2 $40,000 or more ----> Was that ... (READ LIST)

6 $40,000 but less than $50,000,
7 $50,000 but less than $60,000,
8 $60,000 but less than $70,000, or
9 $70,000 or more?
0 DON'T KNOW/NO RESPONSE

3 DON'T KNOW/NO RESPONSE

D10. How much of your 1988 household income came from wages, salary, or other compensation associated with work? 665-70

$________

999999 DON'T KNOW/NO RESPONSE

Skip 671

Before we close, I would like to get the approximate geographic location of your house. The California Air Resources Board needs this for data anlysis only.

D11. Would you please give me your zip code? 672-76

ZIP CODE:__________

99999 DON'T KNOW/NO RESPONSE

D12. And what are the names of the two streets that intersect nearest to your house? 677-78

______________________________STREET

______________________________STREET

9 DON'T KNOW/NO RESPONSE

D13. INTERVIEWER: RECORD SEX. 679

1 MALE
2 FEMALE

May I verify that I reached you by dialing ...

(________)________________________

THANK RESPONDENT AND TERMINATE.

MAKE ANY CORRECTIONS TO THE TELEPHONE NUMBER ON THE SAMPLE CARD.

Skip 680

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APPENDIX 6-B

DESCRIPTIVE STATISTICS FOR
SELECTED QUESTIONS OF THE BEHAVIORAL SURVEY

Question 1. Do you own your own house, or do you rent it?

1 OWN
2 RENT
3 NOT SURE
4 NO RESPONSE

	CHOICE			
	1	2	3	4
NUMBER	475	28	0	0
PERCENT*	94.4	5.6	0.0	0.0

* Percentages based on 503 respondents.

Question 3. In what year was your house built? Was it before 1946, between 1946 and 1964, or was it built after 1964?

1 BEFORE 1946
2 1946-1964
3 AFTER 1964
4 NOT SURE
5 NO RESPONSE

	CHOICE				
	1	2	3	4	5
NUMBER	87	196	199	21	0
PERCENT*	17.3	39.0	39.6	4.2	0.0

* Percentages based on 503 respondents.

Question 11. What part of the house did you paint the last time you painted? Was it...

1 THE TRIM
2 THE EAVES
3 THE WINDOWSILLS
4 THE EXTERIOR WALLS
5 THE GARAGE
6 THE PATIO
7 DOORS/GARAGE DOORS
8 FACEBOARD
9 THE WHOLE HOUSE
10 SOMETHING ELSE
11 NO RESPONSE/NOT SURE

CHOICE	NUMBER	PERCENT*
1	96	25.7
2	44	11.8
3	37	9.9
4	39	10.5
5	3	0.8
6	0	0.0
7	3	0.8
8	0	0.0
9	242	64.9
10	14	3.8
11	4	1.1

* Percentages are based on 373 respondents. Respondents may make more than one choice.

Question 12. How frequently would you estimate that you paint these parts of your house?

1 EVERY YEAR
2 EVERY TWO YEARS
3 EVERY THREE YEARS
4 EVERY FOUR YEARS
5 EVERY FIVE YEARS
6 EVERY SIX YEARS
7 EVERY SEVEN YEARS
8 EVERY EIGHT YEARS
9 EVERY NINE YEARS
10 EVERY TEN YEARS
11 EVERY TWELVE YEARS
12 EVERY FIFTEEN YEARS
13 OTHER (SPECIFY)
14 NOT SURE
15 NO RESPONSE

	CHOICE							
	1	2	3	4	5	6	7	8
NUMBER	11	15	25	26	99	22	24	22
PERCENT*	2.9	4.0	6.7	7.0	26.5	5.9	6.4	5.9

	CHOICE						
	9	10	11	12	13	14	15
NUMBER	8	72	5	11	9	23	1
PERCENT*	2.1	19.3	1.3	2.9	2.4	6.2	0.3

* Percentages based on 373 respondents.

Question 14. I am going to read a list of factors that often influence people to paint their houses. For each of these factors, would you tell me how important it was the last time you decided to paint -- very important, somewhat important, or not important?

1 VISIBLE DETERIORATION
2 YOU WANTED A NEW COLOR
3 THERE WAS A SALE ON PAINT
4 TO SELL THE HOUSE
5 TO KEEP UP THE APPEARANCE OF THE NEIGHBORHOOD

		INFLUENCE OF FACTOR*				
FACTOR		ALOT	SOME	NONE	NOT SURE	NO RESPONSE
1	Number	242	70	60	1	0
	Percent	65.9	18.8	16.1	0.3	0.0
2	Number	94	94	182	3	0
	Percent	25.2	25.2	48.8	0.8	0.0
3	Number	18	39	313	3	0
	Percent	4.8	10.5	83.9	0.8	0.0
4	Number	62	36	269	5	1
	Percent	16.6	9.7	72.1	1.3	0.3
5	Number	193	120	57	2	1
	Percent	51.7	32.2	15.3	0.5	0.3

* Percentages based on 373 respondents.

Question 15. If visible deterioration was important in deciding to paint your house, what type(s) of deterioration were you thinking of?

1 BLISTERING,
2 DULLNESS OR FADING,
3 CRACKING OR PEELING,
4 FLAKING OR CHIPPING,
5 MILDEW,
6 WOOD ROT, OR
7 SOMETHING ELSE? (SPECIFY)
8 NOT SURE
9 NO RESPONSE

	CHOICE								
	1	2	3	4	5	6	7	8	9
NUMBER	88	141	206	143	24	47	18	3	1
PERCENT*	28.2	45.2	66.0	45.8	7.7	15.1	5.8	1.0	0.3

* Percentages based on 312 respondents. Respondents may make more than one choice.

Question 20. The last time you painted the exterior of your house, did you or your family do the work yourselves, or did you hire someone to do it?

1 RESPONDENT OR FAMILY
2 HIRED SOMEONE
3 OTHER (SPECIFY)
4 NOT SURE/DON'T RECALL
5 NO RESPONSE

	CHOICE				
	1	2	3	4	5
NUMBER	159	212	3	7	0
PERCENT*	42.6	56.8	0.8	1.9	0.0

* Percentages based on 373 respondents.
Respondents may make more than one choice.

Question 41. Did you choose a paint that was specially formulated to protect your house against air pollution damage?

1 YES
2 NO
3 DON'T KNOW
4 NO RESPONSE

	CHOICE			
	1	2	3	4
NUMBER	72	228	73	0
PERCENT*	19.3	61.1	19.6	0.0

* Percentages based on 373 respondents.

Question 68. Have you ever considered covering or replacing the exterior painted surfaces of your house with some other material?

1 YES
2 NO
3 NOT SURE

	CHOICE		
	1	2	3
NUMBER	63	439	1
PERCENT*	12.5	87.3	0.2

* Percentages based on 503 respondents.

Question 73. Aside from painting, do you do any other maintenance of the exterior walls of your house on a regular basis?

1 YES
2 NO
3 NOT SURE
4 NO RESPONSE

	CHOICE			
	1	2	3	4
NUMBER	65	433	5	0
PERCENT*	12.9	86.1	1.0	0.0

* Percentages based on 503 respondents.

Question D1. What is your age, please?

AGE (YEARS)	NUMBER	PERCENT*
< 20	4	0.8
20 - 29	45	8.9
30 - 39	152	30.2
40 - 49	114	22.7
50 - 59	71	14.1
60 - 69	58	11.5
70+	42	8.4
NR	17	3.4

* Percentages are based on 503 respondents.

Question D8. What would you estimate to be the current market value of your house? Would it be less than $100,000 or $100,000 or more?

1 LESS THAN $100,000 -----> WOULD IT BE....

 1 UNDER $50,000, OR
 2 MORE THAN $50,000 BUT LESS THAN $100,000?
 3 DON'T KNOW/NO RESPONSE

2 $100,000 OR MORE -----> WOULD IT BE....

 4 MORE THAN $100,000 BUT LESS THAN $150,000,
 5 MORE THAN $150,000 BUT LESS THAN $200,000, OR
 6 $200,000 OR MORE?
 7 DON'T KNOW/NO RESPONSE

3 DON'T KNOW/NO RESPONSE

	LESS THAN $100,000	MORE THAN $100,000	DON'T KNOW/ NO RESPONSE	TOTAL
NUMBER	28	462	13	503
PERCENT	5.6	91.8	2.6	100.0

	LESS THAN $100,000			
	LESS THAN $50,000	$50,000- $100,000	MORE THAN $100,000	TOTAL
NUMBER	3	24	1	28
PERCENT	10.7	85.7	3.6	100.0

	MORE THAN $100,000				
	$100,000- $150,000	$150,000- $200,000	MORE THAN $200,000	DON'T KNOW	TOTAL
NUMBER	80	108	266	8	462
PERCENT	17.3	23.4	57.6	1.7	100.0

Question D9. Was your total household income before taxes in 1988 less than $40,000 or $40,000 or more?

1 LESS THAN $40,000 -----> WAS THAT....

   1 UNDER $10,000, OR
   2 MORE THAN $10,000 BUT LESS THAN $20,000,
   3 MORE THAN $20,000 BUT LESS THAN $30,000, OR
   4 MORE THAN $30,000 BUT LESS THAN $40,000?
   5 DON'T KNOW/NO RESPONSE

2 $40,000 OR MORE -----> WAS THAT....

   6 MORE THAN $40,000 BUT LESS THAN $50,000,
   7 MORE THAN $50,000 BUT LESS THAN $60,000,
   8 MORE THAN $60,000 BUT LESS THAN $70,000, OR
   9 $70,000 OR MORE?
   0 DON'T KNOW/NO RESPONSE

3 DON'T KNOW/NO RESPONSE

	LESS THAN $40,000	MORE THAN $40,000	DON'T KNOW/ NO RESPONSE	TOTAL
NUMBER	139	313	51	503
PERCENT	27.6	62.2	10.2	100.0

	LESS THAN $40,000					
	LESS THAN $10,000	$10,000- $20,000	$20,000- $30,000	$30,000- $40,000	DON'T KNOW	TOTAL
NUMBER	19	26	31	48	15	139
PERCENT	13.7	18.7	22.3	34.5	10.8	100.0

	MORE THAN $40,000					
	$40,000- $50,000	$50,000- $60,000	$60,000- $70,000	MORE THAN $70,000	DON'T KNOW	TOTAL
NUMBER	88	53	33	124	15	313
PERCENT	28.1	16.9	10.5	39.6	4.8	100.0

SECTION 7
COST OF PAINTING

7.1 INTRODUCTION

The basic information needed to develop estimates of the cost of painting all or a portion of a single family residence can be obtained from the behavioral survey. The survey is designed to obtain the following types of information for the most recent painting experience:

- Who did the painting?
- How long did it take?
- How much out-of-pocket expense was incurred?
- Was a long-term loan used to pay for the painting costs?
- What methods were used to paint your house (e.g., surface preparation, number of coats, paint implements)?
- What brand, how many gallons, and what was the unit price of the paint?

The equation that determines the costs incurred by do-it-yourselfers (DIY) is:

$$\mathbf{COST(DIY)} = \mathbf{X} + (TIME_{HH} \cdot OC_{HH}) + (TIME_{OTH} \cdot OC_{OTH}) \qquad (7.1)$$

where COST(DIY) is the total cost incurred by DIY for painting; X is the out-of-pocket expense incurred by DIY (e.g., paint, brushes, ladders, etc.); $TIME_{HH}$ is the time spent by the head of household in painting, OC_{HH} is the **opportunity cost** of time spent painting. $TIME_{OTH}$ and OC_{OTH} are the time and opportunity cost measures for others in the household who spend time painting.

The equation that expresses the total costs incurred by the respondent when the painting was performed by hired labor is:

$$\textbf{COST(HIRE)} = PV\ (HL + HM) \tag{7.2}$$

where COST(HIRE) is the total cost of painting when the job is done by hired labor; HL is the labor cost (including any overhead charges); HM is the cost of materials used by the hired labor; and PV is a factor which converts a stream of costs into a present value.

This section describes the methods used to determine COST(DIY) and COST(HIRE) from the variables shown in the right-hand side of Equations 7.1 and 7.2. The data used to represent the right-hand side variables come from Questions 20 to 37 of the behavioral survey. Note that separate estimates for HL and HM in Equation 7.2 are not available.

There are several issues that should be discussed in developing estimates for COST(DIY) and COST(HIRE).

- All dollar values should be reported in the same year's dollars.
- If costs are incurred over time, present values should be computed.
- A procedure is required for estimating the opportunity cost of time for the head of household and others who help with painting.

These three topics are discussed below. Following the discussion of these issues, a cost function is estimated which can be used to obtain extrapolated estimates of maintenance costs. A final section examines the plausibility of the estimated cost function.

7.2 CONSTANT DOLLAR VALUES

The responses to the questions involving costs of the previous exterior painting episode may refer to any previous year. Because of price inflation, the out-of-pocket cost, in current year dollars (i.e., dollars in the year the activity took place), will be less for the same paint job the further back in time the painting occurred. For the estimates of costs to be comparable across respondents, it is necessary to adjust all dollar values to a common, base year. The year 1988 is chosen in this report as the base year for expressing dollar values.

The 1988 Statistical Abstract (Table 740, p. 451) was used to obtain Consumer Price Indexes for Maintenance and Repairs from 1970 to 1986.[1] Recent issues of the Survey of Current Business were used to obtain an estimate of the Materials and Repair price index for 1987 and 1988. These indexes were then used to form a multiplier that would convert past year expenditures to the equivalent value in 1988 dollars. Table 7-1 shows the pattern of the multiplier as a function of the time since last maintenance. The table also shows the distribution of survey respondents with respect to time since last maintenance. The total number of respondents, 359, is equal to the number of individuals who answered the retrospective section of the behavioral survey.[2]

7.3 PRESENT VALUES OF COSTS

For those who choose to hire professional painters, the out-of-pocket costs incurred can be significant. In some cases, it

---

[1] This index is a national index. If the Los Angeles area index differs from the national index, this could introduce a bias.

[2] This count is reduced from 361 because two individuals reported that their last maintenance was performed more than 20 years ago.

Table 7-1

MULTIPLICATIVE FACTORS USED IN THE CONVERSION OF COSTS TO CONSTANT 1988 DOLLARS

Years Since Last Maintenance	Conversion Factor	Respondent Count
0	0.990	1
1	1.000	131
2	1.030	64
3	1.060	44
4	1.073	32
5	1.102	37
6	1.144	13
7	1.185	3
8	1.260	13
9	1.390	3
10	1.544	11
11	1.700	1
12	1.830	2
13	1.964	0
14	2.110	0
15	2.290	3
16	2.490	0
17	2.710	1
18	2.940	0
19	3.190	0

		359

may be necessary for those who HIRE to take out a loan to pay the painters in full at the completion of the job. When this occurs, the lender of the money will require repayment over time at some rate of interest. The total cost of painting includes both the payment to the painters as well as the finance charges paid over time to the lending institution.

In the behavioral survey, respondents who had previously painted some or all of their house and had hired professional painters were asked if they had taken out a long-term loan to pay for their most recent painting. Seventeen of 212 eligible respondents (8 percent) answered "yes." Thus, the issue of additional costs borne over time may be important.

To illustrate the issues, consider the responses of one individual. This individual reported that a loan was taken for a period of 120 months beginning in 1986 with payments of $240/month and an annual rate of interest of 21 percent. With these data, it is possible to compute that the total discounted present value of the loan was $11,675.[3] The respondent also reported that about one-half of the loan ($6,000) was used to pay for painting. The total payment over the 10 year life of the loan is $28,800, so that $14,400 represents the portion of the loan attributable to painting.

Since the monthly payments occur over time, the value of a dollar ten years from now is less than a dollar held presently. The discounted present value of a stream of constant costs ($1,440/year) over a ten year horizon, using a real discount rate of 10 percent is $8,848. This number exceeds the money actually paid to the painters by almost $2,850 or 47 percent. Given the assumption about the discount rate, $8,848 would be a more appropriate estimate of the painting costs incurred by this individual.

For those individuals who performed one of the specific maintenance tasks described in Section 6 and who hired professional painters, the respondent estimate of cost was adjusted to include any loan charges. Also, a dummy variable was defined for

---

[3] This value is computed on the basis of annual payments.

possible use in an extrapolation equation. This variable was set equal to 1 if a loan was taken, and 0 otherwise.

7.4 OPPORTUNITY COST

The out-of-pocket expenses incurred by DIY do not represent the full economic cost of the DIY choice. The time spent painting has an opportunity cost since those who paint will forego other leisure time activities.

In the economics literature, the opportunity cost of leisure time is generally regarded to be represented by the reservation wage. The reservation wage is the lowest or minimum wage that will induce an individual to tradeoff work for leisure. The reservation wage is a good proxy for the opportunity cost of leisure time under the assumption that the individual is free to make marginal work-leisure choices. That is, it must be assumed that there are no institutional constraints on the number of hours the individual chooses to work.

The opportunity cost concept that is relevant here is between leisure and non-paid work (i.e., painting) conditional on the paid work-leisure choice having been made. This is much more difficult to relate to specific economic values such as wage rates. It must be recognized that some individuals may get great satisfaction out of painting. For these individuals, this may be their highest-valued allocation of leisure time, and their opportunity costs would be low. Others may prefer using their leisure time in different pursuits. For these individuals the prospect of spending time painting would likely have a high opportunity cost. Indeed, it is people in this latter group who we would not expect to be DIY. Instead, they would be willing to pay for professional painters, though this means greater out-of-pocket expenditures.

Ideally, one could analyze the monies paid to professional painters and costs incurred by DIY, to get an estimate of opportunity cost (conditional on the personal attributes of the individuals making the choices). A rigorous analysis was beyond the scope of the present study. However, some approximate methods may be tried which provide estimates of opportunity costs.

The approach that is adopted relies on the two cost equations reported earlier. In particular, for those who choose DIY it must be the case that:

$$\mathrm{COST(DIY)} \leq \mathrm{COST(HIRE)} \tag{7.3}$$

otherwise the individual would have chosen to hire. Since COST(DIY) depends on the opportunity cost, the above inequality can be written as:

$$(\mathrm{TIME}_{HH} \cdot \mathrm{OC}_{HH}) + (\mathrm{TIME}_{OTH} \cdot \mathrm{OC}_{OTH}) + X \leq \mathrm{COST(HIRE)} \tag{7.4}$$

If it is assumed that the head of household can "acquire" TIME_{OTH} at no additional cost then the decision by the Head of Household is based on total time available by head of household and others. The equation then becomes:

$$(\mathrm{TIME}_{ALL} \cdot \mathrm{OC}_{HH}) + X \leq \mathrm{COST(HIRE)} \tag{7.5}$$

Solving for OC_{HH},

$$\mathrm{OC}_{HH} \leq \frac{\mathrm{COST(HIRE)} - X}{\mathrm{TIME}_{ALL}} \tag{7.6}$$

A value of OC_{HH} that solves equation (7.6) as an equality represents the maximum opportunity cost that the individual may have and still remain a DIY.

The behavioral survey obtains information on the variables X and $TIME_{ALL}$ for the DIY. However, the survey did not ask DIY respondents whether or not they had obtained an estimate of cost from professional painters and the value of any cost estimate (COST(HIRE)).

This problem can be overcome if it is possible to predict COST(HIRE) using data available for both DIY and HIRE respondents. The approach involves a regression analysis of COST(HIRE) from the sample of HIRE respondents on variables that describe important elements of a painting job.

The plausible set of explanatory variables includes: size of house (area to be painted); whether the whole house is to be painted; the number of stories; the number of coats of paint; the age of the house; and the method of painting.

The chosen specification was:

$$\underset{R^2 = 0.372}{\mathrm{LNCOST(HIRE)}} = 5.6104 + \underset{(0.269)}{0.46} \cdot \mathrm{YRBLT} + \underset{(0.275)}{0.636} \cdot \mathrm{WHOLE} + \underset{(0.00016)}{0.0006} \cdot \mathrm{SIZE} \qquad \mathrm{NOBS} = 33 \tag{7.7}$$

where LNCOST(HIRE) is the natural logarithm of COST(HIRE) data for the HIRE households (Question 34 of survey, adjusted to 1988 dollars); YRBLT is a dummy variable which equals 1 if the house was built prior to 1964 and 0 otherwise (Question 3); WHOLE is a dummy variable which equals 1 if the whole house was painted and 0 otherwise (Question 11); SIZE is the reported living space of the home which is used as a proxy for exterior area (Question 5).

The coefficients of the explanatory variables are significant at standard levels of confidence and are of the expected signs. For SIZE = 2,000, WHOLE = 1 and YRBLT = 0, COST(HIRE) is predicted to be $1,713.

Equation 7.7 can be used to predict COST(HIRE) for the sample of DIY respondents. This predicted value can then be substituted into equation 7.6 to get an estimate of OC_{HH} since X and T_{ALL} are available from the survey. OC_{HH} represents the upper-bound of the opportunity cost associated with DIY. In fact, an individual respondent could have a lower opportunity cost. Unfortunately, there is not sufficient information available to better define the opportunity cost for individual respondents. The maximum estimate derived from Equation 7.6 will be used. It should be recognized that this is likely to bias COST(DIY) in an upward direction.

The values of OC_{HH} which are derived from equation 7.6 pertain to the DIY observations. In order to predict opportunity cost for a larger set of observations, it is useful to attempt to explain variations in opportunity cost as a function of demographic variables that are generally available from the behavioral survey. Plausible explanatory factors include the income of the respondent, the age of the respondent and whether other family members are available to help with the painting. The following equation was estimated

$$\mathbf{LN(OPPCST)} = 0.655 + \underset{(0.000013)}{0.000037} \cdot \mathbf{INC} + \underset{(0.0217)}{0.0518} \cdot \mathbf{AGE} \qquad (7.8)$$

$$R^2 = 0.371 \qquad NOBS = 19$$

where LN(OPPCST) is the natural logarithm of the opportunity cost estimate derived from equation 7.6; INC is the annual income of the respondent (Question D9); AGE is the age of the respondent (Question D1). As expected, as income and age increase, opportunity cost increases. The coefficients of both variables are statistically different from zero.

The predicted value of opportunity cost from equation 7.8 is multiplied by $TIME_{ALL}$. This product is then summed with X (out-of-pocket expenditures for DIY) to get an estimate of COST(DIY).

7.5 TOTAL COSTS OF A MAINTENANCE ACTION

The total cost of a maintenance action is defined as:

$$TCOST = COST(DIY) + COST(HIRE) \tag{7.9}$$

Given the results of Sections 7.2 through 7.4, it is possible to predict TCOST for the sample of respondents who have painted wood components. This provides a sample of observations from which a more general cost equation can be estimated.

The simplest form of a cost function involves a relationship between cost and output. If the output of the maintenance action is square feet painted, then a measure of area would help to explain cost variations. Other plausible explanatory factors include: input prices of maintenance materials; variables describing what was painted and who did the painting; whether a loan was required; and the age of the house.

There are at least three ways to define an area variable for the sample of respondents:

- Use estimates of measured living space which are readily available from the survey.
- Compute the area painted based on survey information on the number of gallons used and the number of coats applied.

- Predict areas using regression equations developed by Valley Research Corporation (see Section 3).

The first approach was used for this study to define an area variable for the cost equation. The second option was tried but did not yield plausible results. The third approach was not used because the building components used by Valley Research did not coincide with the maintenance tasks that have been defined here. Also, the predicted areas in the Valley Research study are for a representative house, not a house with painted wood.

With respect to the other plausible explanatory factors, several points are worth mentioning. First, it is reasonable to assume that input prices for paint materials are constant across respondents. Second, variables for who paints and what is painted are decision variables. They are not exogenous. Therefore, it is more appropriate to estimate the cost equation as part of a system of equations. However, this is beyond the scope of the present study.

The estimated equation for the cost of maintenance is shown in Table 7-2. The coefficient of the area variable is positive and significantly different from zero. The dummy variable for what was painted is set equal to one if the whole house is painted and is zero otherwise.[4] The coefficient for this variable is also statistically significant. The positive coefficient for **DLOAN** is as expected. The positive coefficient on the YRBLT dummy indicates that homes built prior to 1964 cost more to paint after controlling for the other explanatory factors. A dummy variable for DIY versus HIRE was included in some specifications

[4] A specification with multiple dummy variables for each maintenance task was specified. However, it was not possible to reject the hypothesis of no difference among the partial painting tasks.

Table 7-2

ESTIMATED EQUATION FOR COSTS OF MAINTENANCE ACTIONS
(Dependent Variable: LN(TOTCOST))

Independent Variable	Coefficient
Constant	5.576945
Area	0.000548 (0.00018)*
WHOLE	0.7542 (0.306)
DLOAN	0.8466 (0.601)
YRBLT	0.4805 (0.259)
R^2 = 0.344 NOBS = 47	

* Numbers in parentheses are standard errors.

but was not statistically significant. This is likely a reflection of the consideration of opportunity cost in the estimate of DIY costs.

7.6 PLAUSIBILITY OF THE PAINTING COST ESTIMATES

The plausibility of the TOTCOST equation can be judged in several ways. Qualitatively, an evaluation of the cost equation can be performed. Set Area = 2,000, WHOLE = 1, DLOAN = 0, and YRBLT = 0. With these values, TOTCOST equals $1,681. If WHOLE is set to 0, with the other explanatory factors as previously defined, the value of TOTCOST is $791. This latter figure is the predicted cost when only part of the house is painted.

A second way to assess plausibility is to use the materials inventory results of Valley Research in order to develop a cost estimate in terms of dollars per square feet. This cost estimate can then be compared to the cost per square foot estimates developed in TRC (1985) and Horst et al. (1986).

Valley Research (1989) used simple regression techniques to predict the total material area by building component. The independent variable was reported liveable space. For single family homes in Los Angeles, Valley Research estimated an equation for the basic wall component with intercept of 796.76 and slope of 0.8. The mean of the dependent variable (basic wall area) was 2,045.4. These values can be substituted in the regression equation to solve for the average value of reported living space. This value is 1,561. If the mean living space is substituted into the TOTCOST equation shown in Table 7-1 (with WHOLE=DLOAN=YRBLT=0) then TOTCOST is predicted to be $622.

The detailed inventory can also be used to determine that painted wood accounts for 17.29 percent of basic wall area. Thus, the average single family home has about 354 (2,045.4 • 0.1729) square feet of painted wood. This is likely to be an underestimate of the area of painted wood on homes that have only painted wood trim, eaves, sills, and walls present.

The ratio of cost to square feet is (622/354) = $1.76. This represents a likely upper bound on unit cost since the denominator is biased downwards. This estimate is not too far out of line with previous studies. In TRC (1985), an estimate of $0.067/square feet was used as an annual cost. If this number is multiplied by 7 to account for the average maintenance interval and then by 1.54 to convert to 1988 dollars, the TRC estimate is \$0.72. In Horst et al. (1986) the cost of painting ranged from \$0.77 to \$1.54 per square foot depending on what was being painted. Converting these to 1988 dollars, the range is \$0.85 to \$1.70.

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SECTION 8

CALCULATION OF ECONOMIC DAMAGES

8.1 INTRODUCTION

The data described in Sections 3 through 7 can be combined with maintenance interval data available from the behavioral survey to determine the annual cost of maintenance actions at current levels of air pollution for any one individual. Applying the physical damage function and assuming a fixed critical damage level, a new maintenance interval length can be predicted for a change in air pollution concentrations. Annual maintenance costs are then recomputed. The difference in annual maintenance costs is a measure of the cost-savings associated with the air pollution change.

The only additional data development that is required to estimate aggregate economic impacts is the specification of an extrapolation algorithm for the maintenance interval variable. This topic is addressed below and leads to an economic estimate for what is termed the physical damage function approach. In addition, a second approach is presented which relies on a different set of assumptions for estimating cost-savings. The principal feature of the second analysis is that an explicit physical damage function is not necessary. This implies that estimates of cost-savings may be possible for a greater range of materials than can be accomplished with currently available physical damage functions. This second approach is called the economic damage function approach. Finally, an appendix to the section extends the economic damage function approach to more complex models which incorporate statistical and economic features.

8.2 PHYSICAL DAMAGE FUNCTION APPROACH

A major advantage of the behavioral survey is that it permits one to match maintenance interval lengths of individual respondents to the specific maintenance tasks that they have performed. As noted earlier, the distribution of maintenance interval lengths for respondents who have previously painted is bi-modal. Generally, people who paint only a portion of their homes do so more frequently than those who paint their whole house. This information should be used.

8.2.1 Prediction of Maintenance Intervals

There are three options available for defining the maintenance interval lengths for use in the analysis.

- Calculate a single average value from the maintenance interval distribution.
- Calculate average values for maintenance interval length conditional on what was painted.
- Estimate maintenance interval lengths as a function of what was painted and other relevant explanatory factors.

The first option was not chosen because too much information is discarded. The second option is appealing but it would not allow us to use some of the detailed information provided by Valley Research concerning the spatial distribution of single family residences. Therefore, the third option was selected.

There are a variety of plausible factors that may help to explain variations in the length of a maintenance interval. Some factors are economic and are instrumental in estimating the demand for maintenance.[1] Other factors are more subjective. Question 9 of the behavioral survey queried respondents about the factors that influenced their decision about when to paint. The factors that were mentioned most frequently were the quality of the previous paint job, the quality of materials used on the exterior of the home, and sunlight. Approximately 50 percent of the respondents reported that these factors were important. The cost of painting, the location of the home, and the age of the house were cited as important by 30 percent of the respondents. Exposure to air pollution and moisture were important for 20 percent of the respondents.

An attempt was made to define variables that would be representative of these factors. These variables included the paint quality, the respondent income, location and age of the house, and the value of maintenance action. Environmental variables were not considered since these factors are embedded in the physical damage functions.

The final maintenance interval specification included variables for what was painted and the age of the house as explanatory factors:

$$L = 4.598 + \underset{(0.725)}{1.91} \cdot \text{WHOLE} + \underset{(0.670)}{0.724} \cdot \text{YRBLT} \tag{8.1}$$

$$R^2 = 0.126 \qquad \text{NOBS} = 74$$

Where L is the length of the maintenance interval and WHOLE and YRBLT are as defined previously.

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[1] See the Appendix to Section 2 for a discussion of demand for maintenance and its relationship to the measurement of economic benefits. A demand curve for maintenance is not estimated in this study. Such estimation would require expenditure data for all actions that contribute to the production of building services.

The explanatory power of the equation is poor. Consequently, it is not likely that a good prediction of L could be made for any one individual. However, on an aggregate basis, the equation is useful for identifying the variations in L associated with the included explanatory factors.

The coefficient for WHOLE is of the expected sign and is statistically significant. The equation indicates that those who paint their whole house wait nearly an additional two years to paint relative to those who do partial painting. The dummy variable for YRBLT is set to 1 if the home was built prior to 1964. The positive coefficient indicates that older homes are painted less frequently, after controlling for what was painted.

It was somewhat surprising that income was not a significant explanatory factor. A regression specification with income included resulted in a negative coefficient (those with higher incomes paint more frequently). However, the standard error was large relative to the coefficient value.

One source of possible error in the specification of the maintenance interval equation is measurement error in the dependent variable. Kmenta (1971) shows that where the measurement error is not systematic, a regression of the mismeasured dependent variable on the independent variables will be formally equivalent to the classical (without measurement error) regression model. Despite the above observation, it is of interest to determine the extent to which the responses to the maintenance interval length question are plausible. The consistency of the responses can be checked by comparing the responses of individuals who reported on the same maintenance task in the prospective and retrospective section of the questionnaire. Three separate questions are asked concerning the typical maintenance interval length.

- When did you last paint the exterior of your house?
- What is the typical maintenance interval for the part of the house you last painted?
- When do you next plan to paint the part of the house you last painted?

The correlations among the responses to these questions were about 0.80. These correlations were computed for the sample of respondents who painted their whole house the last time they painted and also plan to paint their whole house the next time they paint.

8.2.2 Results of Physical Damage Function Analysis

For each grid area, the following data are available:

- N_g, the number of single family homes in the grid g (from Valley Research)
- P_t, the proportion of homes that perform maintenance task t (from Table 6-6)
- A_g, the percentage of homes in grid g built after 1964 (from Valley Research, RESTAT file)
- S_g, the weighted average size (measured liveable space) of houses in grid g (from Valley Reserch, RESTAT file)
- C_{tg}, the cost of performing maintenance task t. This variable depends on S_g and A_g (from Table 7-2)
- L_{0tg}, the length of the maintenance interval under current environmental conditions for maintenance task t. This variable depends on A_g (from Equation 8.1).
- NO_{2g}, the concentration of NO_2 in grid g (Section 5)

At current levels of NO_2, the expenditures on maintenance task t in grid g equals:

$$N_g \cdot P_t \cdot C_{tg}/L_{0tg} \tag{8.2}$$

This is the calculation shown previously in Box 10 of Figure 2-2, where $N_g \cdot P_t \cdot C_{tg}$ represents expenditure E. If NO_2 concentrations fall, then L_{tg} increases. The amount of increase depends on the relationship between physical damage and NO_2. At the new maintenance interval length, say L_{1tg}, the expenditures on maintenance task t in grid g is:

$$N_g \cdot P_t \cdot C_{tg}/L_{1tg} \tag{8.3}$$

The difference between equations 8.2 and 8.3 is the measure of cost-savings associated with the reduction in NO_2. This difference was shown earlier in Box 11 of Figure 2-2. Summation across t and g leads to aggregate cost-savings across maintenance tasks for the basin.

Table 8-1 shows the annual cost-savings computed for a 10 percent reduction in the annual average of NO_2. The table entries are reported in 1988 dollars. Separate estimates are provided for each aggregate grid. The location of the grids is shown in Figure 8-1. Much of the variation in the computed cost-savings across grids is due to differences in the density of population. However, calculation of per household estimates for each grid results in a range of \$0.32 to \$0.82. The high per household value occurs in grid 20 which encompasses the city of Burbank. The low value is in grid 98 which occurs around Costa Mesa. The range in values for the per household estimates is the result of the relationship between location and the probability that a maintenance task will be performed.

The overall annual cost-savings for a 10 percent reduction in NO_2 is estimated to be \$1.39 million (1988 dollars). This number reflects the economic damage that would result if the painted wood surfaces considered in this study were covered with

Table 8-1

ANNUAL COST-SAVINGS FOR A 10 PERCENT REDUCTION IN NO_2:
PHYSICAL DAMAGE FUNCTION ANALYSIS
(1988 dollars)

Grid	Cost-Savings	Grid	Cost-Savings	Grid	Cost-Savings
1	$ 0	47	$ 0	92	$ 0
2	0	48	0	93	0
3	9,200	49	10,513	94	0
4	43,384	50	50,290	95	0
5	15,290	51	44,238	96	0
6	7,524	52	45,146	97	0
7	0	53	31,101	98	224
8	0	54	9,390	99	15,502
9	0	55	5,004	100	6,433
10	0	56	8,030	101	13,389
11	0	57	19,967	102	275
13	0	58	6,839	103	2,503
14	0	59	1,877	104	3,010
15	0	60	2,240	105	1,822
16	0	61	0	106	132
17	3,522	62	0	107	0
18	30,571	63	0	108	0
19	43,159	64	0	109	0
20	48,444	65	44,377	110	0
21	38,393	66	43,928	111	0
22	37,311	67	57,771	112	0
23	11,141	68	45,648	113	0
24	5,145	69	25,583	114	3,092
25	7,345	70	366	115	7,687
26	361	71	12,454	116	0
27	3,785	72	4,467	117	0
28	23,038	73	5,141	118	597
29	588	74	351	119	373
30	0	75	15	120	72
31	1,293	76	0	121	0
32	520	77	0	122	0
33	2,310	78	0	123	0
34	30,953	79	0	124	0
35	58,340	80	33,339	125	0
36	44,264	81	12,033	126	0
37	54,234	82	38,429	127	0
38	46,340	83	46,257	128	0
39	25,932	84	26,468	129	0
40	30,651	85	56	130	4,486
41	11,721	86	118	131	0
42	23,841	87	193	132	0
43	18,968	88	2,345	133	0
44	10,197	89	734	134	967
45	469	90	7,075	135	55
46	0	91	0		

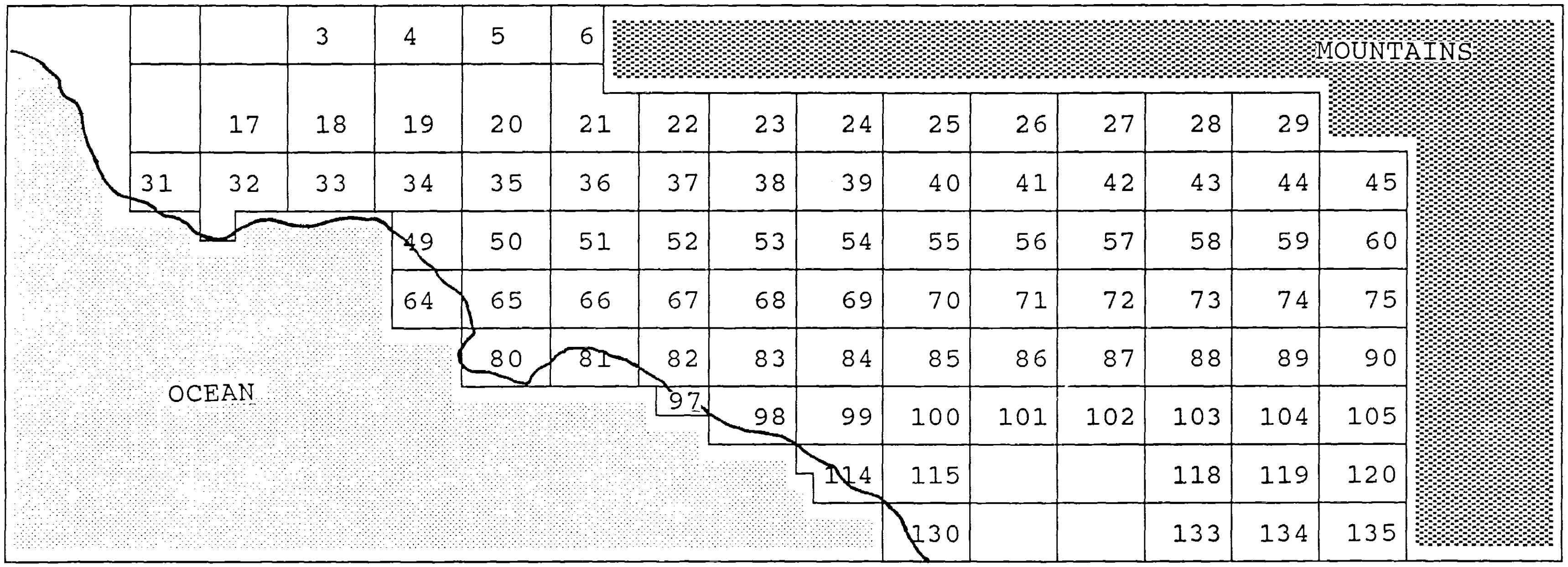

Figure 8-1. Location of Receptor Grid in South Coast Air Basin

the type of paint for which the physical damage function was estimated. However, the physical damage research found a meaningful statistical association only for a paint formulation with relatively high calcium carbonate extender. It was estimated that paints of this formulation accounted for about 50 percent of the sales of exterior paint in the region. Therefore, it is appropriate to adjust downward the economic value reported above by a factor of 2. This implies that the best estimate of annual cost savings is about $0.7 million (1988 dollars).

It is very important to realize that this is not a comprehensive estimate of materials damage in the basin. The scope of the present analysis is limited in the following ways:

- The estimate is for single family residences only.
- The estimate is for a selection of maintenance tasks which involve only painted wood.
- The estimates do not account for all wood painting. Wood painted in conjunction with other materials as part of a single maintenance task is not considered.
- The estimates reflect a 10 percent reduction in NO_2. Since the cost savings algorithm is linear, a 20 percent reduction in NO_2 doubles the measure of cost-savings.

In TRC (1985), it was estimated that air pollution in the South Coast Air Basin was responsible for $42 million per year in damages, in 1979 dollars. The major differences between the studies include:

- TRC computes total damages. Thus, the comparison of air pollution levels was between current and clean. This is a larger change than is assumed in this study.
- TRC estimates include all building types. Although, since the residential sector dominates for most materials (including painted wood), the coverage of materials in this study may not be bad.

- TRC measures different types of damage (e.g., soiling) and uses different damage functions and pollutants. The focus of this analysis is acidic deposition. NO_2 is used as a proxy for acidic deposition.

- TRC includes estimates of damage for paint on stucco. The present analysis is limited to paint on wood.

- TRC reports estimates in 1979 dollars.

Qualitatively, it is estimated that these differences explain about 80 percent of the differences in the results of the two studies. While the present study is more limited in focus, this appears to be warranted because of the restrictions associated with application of the estimated physical damage functions.

8.2.3 Uncertainty in the Physical Damage Function Analysis

Each of the inputs used to estimate cost-savings is subject to uncertainty. Some information is fairly precise since the data come from nearly complete censuses. These data include N_g and A_g, the number of single family homes and the percent of new homes in grid g, respectively. Other data may be less accurate.

Among the variables that may contribute to uncertainty in the cost-savings estimate are the cost, the current maintenance interval length, and the probability that a specific maintenance task will be performed. A rigorous assessment of uncertainty for each of these items has not been attempted. Qualitatively, it is not expected that the cost or maintenance interval length estimates are subject to significant uncertainty. The predicted values appear plausible when judged against exogenous information.

With respect to the probabilities, it is possible to calculate the standard error of the probability of observing a given maintenance task. For example, out of the sample of individuals who were contacted and live in single family homes, 0.053 were determined to have painted wood trim only the last time they painted. The standard error of the probability is:

$$\sigma_{\hat{p}} = (\pi\ (1-\pi)/n)^{1/2} \tag{8.4}$$

where π is the probability of observing someone painting wood trim and n is the number of people in the sample who live in single family residences. For the sample of respondents contacted in the behavioral survey, the standard error of the painted wood trim probability is 0.0078. With a large sample size, a normal approximation implies that a 95 percent confidence interval for the probability could affect cost-savings by ± 30 percent of the mean value. Other maintenance tasks have larger confidence intervals and smaller probabilities of occurrence.

Another source of uncertainty is the coefficient of the NO_2 variable in the physical damage function. This coefficient is 0.03324 with a standard error of 0.01681. If the cost-savings calculations are performed with the coefficient of NO_2 varied by plus and minus two standard deviations, the range of cost-savings estimates is $0 - $1.02 million. This range adjusts for those surfaces that are painted with relatively high amounts of calcium carbonate extender.

8.3 ECONOMIC DAMAGE FUNCTION APPROACH

The analysis described in the previous section uses the physical damage function to drive the calculations. For a given level of air quality, the length of the maintenance interval can be inferred from the ratio of the critical damage level and the rate of physical damage predicted from the damage function. Implicitly, the length of the maintenance interval is a function of the air pollution level.

An alternative formulation of the maintenance problem makes the relationship between air pollution and the maintenance interval explicit. This is accomplished by including environmental variables on the right-hand side of the maintenance interval prediction equation.

For the sample of respondents who painted wood, the estimated specification is:

$$L = 9.547 + \underset{(0.691)}{1.117} \cdot YRBLT + \underset{(0.756)}{2.444} \cdot WHOLE - \underset{(56.284)}{115.816} \cdot NO_2 \quad (8.5)$$

$$R^2 = 0.192 \qquad NOBS = 69$$

where L is the maintenance interval length, NO_2 is annual average concentrations of NO_2, YRBLT and WHOLE are as defined previously. The coefficient for NO_2 (ppm) is negative and significantly different from zero. This implies that greater concentrations of NO_2 lead to shorter maintenance intervals. Variables for ozone and time of wetness were included in the specification, but they did not add significantly to the explanatory power of the equation.

Equation (8.5) can be used to predict L for current and reduced levels of NO_2 concentrations. As a result, a physical damage function is not required. Changes in maintenance expenditures are then calculated the same way as in the physical damage function approach.

Table 8-2 reports the results of the econommic damage function analysis. As before, the estimates of annual cost-savings are reported by grid. The annual cost-savings for a 10 percent reduction in NO_2 concentrations are estimated at $3.6 million (1988 dollars). Unlike the physical damage function analysis, it is not necessary to reduce this estimate by the proportion of surfaces painted with other than high calcium carbonate paint. The larger value of cost-savings with this approach relative to the physical damage function analysis is due to a difference in the elasticity of the maintenance interval length with respect to NO_2.

Three issues concerning this approach deserve mention:

- Equation (8.5) is arbitrary in form. More confidence would be generated if an economic rationale for the relationship could be developed.
- The economic damage function analysis was carried out for painted wood only. This was done to permit a comparison of the results of the physical damage function analysis and the economic damage function analysis. However, it is also possible with the economic damage function framework to analyze other materials and maintenance tasks. Painted stucco walls are examined below.
- The economic damage function framework leads to non-proportional changes in cost-savings for a doubling of the hypothetical pollution reduction.

8.3.1 Development of the Maintenance Interval Equation

Equation (8.5) is based only on the definitional relationship among the maintenance interval length, the physical damage function, and the critical damage level. A better way to develop a specification for this relationship is to build an economic/statistical model. A first attempt in this direction is provided in an Appendix to this section.

8.3.2 Cost-Savings for Painted Stucco

As a further application of the economic damage function analysis approach, respondents in the behavioral survey who had 100 percent painted stucco walls and who had painted their walls at their last maintenance were identified. A specification between the length of the maintenance interval for this task and various explanatory variables was formed. The estimated equation was:

Table 8-2

ANNUAL COST-SAVINGS FOR A 10 PERCENT REDUCTION IN NO_2:
ECONOMIC DAMAGE FUNCTION ANALYSIS
(1988 dollars)

Grid	Cost-Savings	Grid	Cost-Savings	Grid	Cost-Savings
1	$ 0	47	$ 0	92	$ 0
2	0	48	0	93	0
3	11,349	49	26,110	94	0
4	62,415	50	118,520	95	0
5	41,631	51	147,290	96	0
6	21,731	52	134,649	97	0
7	0	53	73,447	98	279
8	0	54	26,008	99	18,857
9	0	55	13,588	100	12,113
10	0	56	14,767	101	35,413
11	0	57	25,283	102	719
13	0	58	10,958	103	5,095
14	0	59	3,566	104	6,129
15	0	60	4,661	105	3,707
16	0	61	0	106	275
17	5,965	62	0	107	0
18	36,404	63	0	108	0
19	43,533	64	0	109	0
20	164,379	65	119,570	110	0
21	132,980	66	139,591	111	0
22	112,915	67	164,117	112	0
23	31,957	68	104,370	113	0
24	14,802	69	68,652	114	6,335
25	15,214	70	963	115	15,822
26	755	71	25,758	116	0
27	7,513	72	7,606	117	0
28	44,939	73	8,839	118	1,134
29	1,183	74	671	119	772
30	0	75	32	120	160
31	3,664	76	0	121	0
32	1,524	77	0	122	0
33	6,191	78	0	123	0
34	69,388	79	0	124	0
35	164,017	80	96,336	125	0
36	241,183	81	34,543	126	0
37	172,716	82	92,634	127	0
38	132,839	83	106,158	128	0
39	87,212	84	63,725	129	0
40	80,351	85	135	130	10,316
41	23,747	86	199	131	0
42	38,373	87	366	132	0
43	34,275	88	4,486	133	0
44	20,499	89	1,459	134	1,907
45	978	90	14,783	135	100
46	0	91	0		

$$L = 12.834 + \underset{(1.38)}{0.462} \cdot YRBLT - \underset{(90.81)}{141.427} \cdot NO_2 \qquad (8.6)$$

$$R^2 = 0.152 \qquad NOBS = 22$$

where L is the maintenance interval length for painted stucco walls and YRBLT, NO_2 are as defined previously.

The coefficient for NO_2 is of the expected sign. However, the coefficient is not statistically significant at standard levels of confidence. In the absence of other confirmatory information, like that available from physical damage function research, it is not appropriate to interpret equation 8.6 as showing a causal link between the length of the maintenance interval (when the maintenance task is painting stucco walls) and NO_2. However, this work is preliminary and further analysis could lead to statistically significant results.

8.3.3 Alternative NO_2 Scenarios

The two analyses are conducted for a hypothetical uniform reduction in NO_2 concentrations of 10 percent. It may also be of interest to consider the relationship between a change in NO_2 and the impact on cost-savings.

In the physical damage function analysis, the change in cost-savings is proportional to the change in the percent reduction of NO_2. Therefore, if the hypothetical NO_2 percent reduction doubles (e.g., from 10 percent to 20 percent), the effect will be a doubling of cost-savings.

The relationship between the percent reduction in NO_2 concentrations and cost-savings in the economic damage function analysis is more complex. The methodology used for that analysis implies that a change in the percent reduction of NO_2 leads to a change in cost-savings that is proportional to the difference in the inverse of the predicted maintenance interval lengths. For reductions in air pollution, cost-savings increase at a rate that is less than the rate of change in air pollution. Conversely, if air quality gets worse, the economic damages increase at a rate that is greater than the cost-savings of an equivalent improvement in air pollution levels.

Table 8-3 displays the estimated levels of cost-savings, for different percent reductions in NO_2, under the assumptions of the two analyses. The values in the table are consistent with the previous discussion.

These values can also be presented in graphical form. Figure 8-2 shows the benefits functions for the two analyses in terms of percent changes in air pollution. The horizontal axis is percent change in NO_2 (i.e., the right-hand side of the figure is worse air quality). The vertical axis represents annual cost-savings (benefits). At the origin there is no change from the current air quality situation. Therefore, no cost-savings are realized.

Table 8-3

ESTIMATES OF COST-SAVINGS FOR ALTERNATIVE NO_2 SCENARIOS
(millions of 1988 dollars)

	Model	
Percent Reduction in NO_2	Physical Damage Function Analysis	Economic Damage Function Analysis
10	$ 0.695	$ 3.60
20	1.391	6.55
-10	-0.695	-4.52

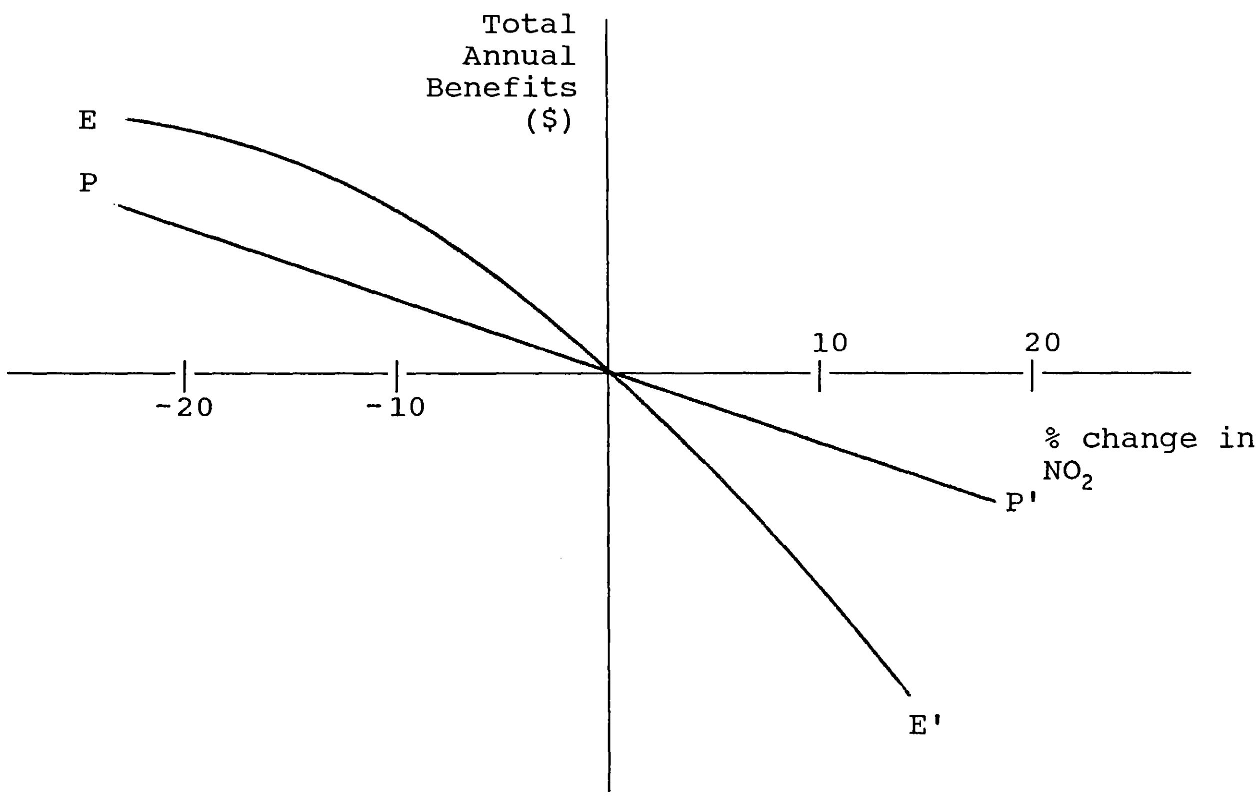

Figure 8-2. Benefits Functions for Alternative Analysis Frameworks

As air quality changes, the physical damage function analysis predicts that cost savings will increase linearly along line PP'. However, the benefits function for the economic damage function analysis is non-linear. This is shown as line EE'. For improvements in air quality (percent change in NO_2 is negative), the increment to cost-savings decreases as the percent reduction in NO_2 increases. For decrements in air quality, the increment to (negative) cost-savings (i.e., damages) increases as the percent increase in NO_2 concentrations increases. This type of relationship is more consistent with economic theory than the linear relationship of the physical damage function approach.

An implication of Figure 8-2 is that studies which rely on the physical damage function framework (i.e., some variation of CA/PA) will likely understate damages if large decrements in air quality are evaluated. This is exactly the type of scenario analyzed in TRC (1985) and Horst et al. (1986).

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APPENDIX 8-A

ANALYSIS OF MAINTENANCE INTERVALS DATA USING STATISTICAL/ECONOMIC MODELS

8.A.1 INTRODUCTION

The availability of individual responses to questions concerning maintenance practices made it possible to estimate L, the length of a maintenance interval, as a function of NO_2, while controlling for factors such as the age of the house and what was painted. In Section 8, a simple linear equation was specified. This functional form was selected more for convenience than any theoretical reason. In fact, given the assumptions of the CA/PA models, a non-linear specification would be more appropriate. By definition, L equals Z/D(AQ) where Z is the critical damage level and D(AQ) is the physical damage function. Consequently, a log-log function or other non-linear estimating form appears more appropriate.

In this Appendix, two distinct ways of defining an appropriate specification for predicting the maintenance interval variable are developed. The first approach is based on statistical considerations. The second approach relies on a specific economic model and a decision rule that substitutes a dollar-valued measure of critical damage for the more usual physical damage units of critical damage. The economic approach also incorporates information generated from the statistical data analysis.

8.A.2 STATISTICAL ANALYSIS OF DURATION DATA

Statistical analysis of duration data has a long history. Models of time-to-failure, durations of events, product durability, etc. have been developed for practical application.

Kiefer (1988) describes how the techniques of duration analysis might be applied to economic problems. His discussion examines both descriptive analyses as well as formal modeling.

The basic concept of the statistical methods is that an analysis of duration data need not be limited by asking simple unconditional questions like: What is the probability that I will paint by year T? Instead, it is more informative to examine the conditional transition probabilities: What is the probability I will paint at time T, given that I haven't painted in N years? A gain is achieved because different statistical distributions have discernible patterns in alternative descriptions of the underlying duration data.

For example, associated with every density function which describes the frequency distribution of duration data, is the hazard function. The hazard function is defined:

$$h(t) = f(t)/S(t) \tag{8.A.1}$$

where $f(t)$ is the density function and $S(t)$ is the survivor function (the probability of observing a non-painter after t years duration). Basically, $h(t)$ is the rate at which a maintenance action will be performed at period t, given that maintenance has not yet occurred (since time of last maintenance). It represents a transition probability.

A nice feature of the hazard function is that it indicates whether a particular set of data exhibits duration dependence. Positive duration dependence indicates that the probability that a maintenance action will be undertaken in the near term increases as the length of time since last maintenance increases. This type of time dependence seems appropriate for the present problem. A distribution that permits positive duration dependence is the Weibull distribution.

The Weibull distribution hazard function has the form:

$$h(t) = \sigma \alpha t^{\alpha-1} \tag{8.A.2}$$

where σ, α are parameters greater than 0. The corresponding survivor function is:

$$s(t) = \exp(-\sigma t^{\alpha}) \tag{8.A.3}$$

where exp is the exponential function. Positive duration dependence occurs if $\alpha > 1$. The parameter σ can depend on explanatory factors such as air pollution.

Using the LIMDEP econometric software package, a restricted specification was estimated to test the hypothesis of positive time dependence. Two subsamples of the data were examined. The first subsample consisted of people who painted only a portion of their home (e.g., trim, eaves, sill). The second subsample examined the responses of individuals who painted their entire house. The results of the maximum likelihood estimation are shown in Table 8-A-1. For both samples, the parameter α is greater than 1, indicating positive duration dependence, as expected. Although, the individual parameters are statistically significant, the overall explanatory power of both equations is poor. This corresponds to what was observed with the simple linear specification.

The next step involved defining the parameter σ as a function of the age of house (dummy variable equal to 1 if house built after 1964 and 0 otherwise) and the NO_2 concentration. Table 8-A-2 shows the unrestricted results (i.e., coefficients for explanatory variables not restricted to zero) when σ is specified as a linear function. The results indicate that NO_2 is a significant explanatory variable only in the subsample of

Table 8-A-1

MAXIMUM LIKELIHOOD ESTIMATES FOR
MAINTENANCE INTERVAL DURATION ANALYSIS

(Weibull distribution; restricted)

	CASE	
	Partial Painting	Whole House
Parameters		
α	2.135 (.255)*	2.4016 (0.553)
σ_0	-1.727 (.0698)	-2.099 (0.105)
Median	4.73	7.00
Log-Likelihood	-40.562	-12.566
NOBS	50	19

* Numbers in parentheses are standard errors.

Table 8-A-2

MAXIMUM LIKELIHOOD ESTIMATES FOR
MAINTENANCE INTERVAL DURATION ANALYSIS

(Weibull distribution; unrestricted)

	CASE	
	Partial Painting	Whole House
Parameters		
α	2.383 (0.254)*	2.408 (0.566)
σ_0	-2.547 (0.445)	-1.911 (1.92)
σ_1 (NO_2)	22.158 (10.414)	-3.665 (41.99)
σ_2 (DYRBLT)	-0.276 (0.136)	-0.111 (0.318)
Median	4.73	7.01
Log-Likelihood	-36.084	-12.552
NOBS	50	19

* Numbers in parentheses are standard errors.

partial painters. The overall explanatory power of the equation remains low.[1]

The results in Table 8-A-2 are suggestive of a hypothesis. Is it the case that the length of the maintenance interval will be sensitive to air quality improvements only for those people who paint minor parts of their house on a relatively frequent basis? Subjectively, one might guess that people who wait longer to paint do not perceive material degradation as an adverse impact on their welfare. In this case, a marginal change in air pollution may not affect their behavior. This could have important consequences for welfare calculations. However, additional analysis is required before objective conclusions can be made.

The final item examined for the Weibull specification is the implied elasticity between the duration and air pollution at the median of the distribution. For the Weibull distribution,

$$t = [(-\ln(.5))^{1/\alpha}]/\sigma(NO_2, DYRBLT) \qquad (8.A.4)$$

so that

$$\partial t/\partial NO_2 = -1\ [(-\ln(.5))^{1/\alpha}]\ \sigma(NO_2, DYRBLT)^{-2}\ \partial\sigma/\partial NO_2 \qquad (8.A.5)$$

From Table 8-A-2, $\alpha = 2.383$; $\sigma_0 = -2.547$; $\sigma_1 = 22.158$; $\sigma_2 = -0.276$. Also $\overline{NO_2} = 0.0448$, $\tilde{t} = 4.73$, $\overline{DYRBLT} = 0.56$. The elasticity is equal to -0.06162. Therefore, a 10 percent reduction in NO_2 will lead to a 0.62 percent increase in the maintenance interval. This can be compared to the elasticity implied by the linear specification computed at the mean of the sample for those individuals who engage in partial painting. This elasticity is

[1] See Gallant (1975).

-0.0698. Consequently, near the sample means the cost-savings computed from the linear specification are expected to be only slightly greater than those estimates that would be derived using the non-linear model with a Weibull distribution. Greater divergences are likely at points further from the mean.

8.A.3 AN ECONOMIC MODEL OF MAINTENANCE TIMING

A problem with both the simple linear specification and the non-linear Weibull model is that they have no economic content. In this section, a simple model is presented which views maintenance decisions as being part of a deterioration process that begins immediately after a maintenance action is performed and continues until the next maintenance action. The statistical analysis of the previous section is used to help select a mathematical representation for the deterioration process.

One reason for undertaking maintenance is to add to the market value of the home by increasing the level of building services provided. (See the discussion in Appendix 2.A). Maintenance actions can be viewed as an investment in one's home which increase equity value. These investments provide an increment to the discounted present value of the property. The stream of benefits resulting from a specific maintenance action can be written as

$$\sum_{i=0}^{L} B_i(T)/(1+r)^i$$

where L is a length of time till next maintenance; $B_i(T)$ is the benefits generated at period i; T is the time since last maintenance; and r is a discount factor representing the time rate of preference. In continuous terms, this expression can be written

$$\int_0^L B_\ell(T)\, e^{-r\ell} d\ell .$$

The performance of the maintenance action will also have costs. Ordinarily, these costs will be incurred in period 0. However, an equivalent present value of a stream of costs can be computed when payments are made over time (see discussion in Section 7 on loans). Note, the costs may be a function of time since last maintenance due to increases in surface preparation costs. In this case, the longer one waits before performing maintenance, the greater the total cost. In economics, the optimal time to perform an action is when net benefits are maximized; that is, where marginal benefits equal marginal costs.

A discussion of maintenance decision rules will be provided below. First, it is instructive to examine how air pollution may effect the level of B_i as the length of time since last maintenance increases.

One way to model the damage caused by air pollution is to use a physical damage function and the basic CA/PA model. This model imposes some restrictive assumptions about behavior; that is, critical damage levels are fixed for different levels of air pollution. An implication of this is that the elasticity between economic damage and physical damage will be constant and equal to 1.

The model developed in this section bypasses physical damage functions and incorporates air pollution effects within a depreciation framework.[2] Based on the results of the statistical duration analysis, an exponential process of some type seems appropriate.

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[2] Grossman (1972) and Cropper (1981) use a similar approach to model the welfare effects of health changes.

Let B_i equal the benefits at time i given that a maintenance action takes place at i=0. Describe the flow of benefits by:

$$B_{i+1} - B_i = Q(i) - \delta(i)\, B_i \qquad (8.A.6)$$

where Q(i) represents investment and $\delta(i)$ is a depreciation rate that may be a function of time i. Assume that Q(i) = 0 for all i > 0.[2] At i = 0, B_0 represents the benefits generated by the most recent maintenance action. The solution of this equation in continuous terms is:

$$B_t = B_0 \exp[-\int \delta(i)di] \qquad (8.A.7)$$

Given this relationship, it is possible to substitute back into the stream of benefits to obtain an expression for the discounted present value of a maintenance action as a function of B_0, $\delta(i)$, and L, the time at which next maintenance will be performed. In particular,

$$X = \int_0^L B_0 \exp[\int \delta(i)di]\ e^{-r\ell} dl \qquad (8.A.8)$$

where X is a measure of the total benefits associated with the maintenance action taken at time t = 0.

In order to evaluate this equation, information is required on B_0, the form of $\delta(i)$, the discount rate r, and the interval L. An appropriate estimate for B_0 can be obtained from the behavioral survey. In Question 42, respondents were asked: "If you had sold your house after you last painted it, what, if

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[2] Q(i) > 0 for i > 0 implies intermittent investment. Relaxation of Q(i) = 0 would allow consideration of other mitigating activities such as hosing down walls. In this case, the mathematics become more complex.

anything, do you think painting it would have added to the value?" Although it was felt _a priori_ that this question would be very difficult to answer, a large number of respondents provided an estimate. Note, even if the estimate is wrong, it is the perception of the respondent that counts. If the response is perceived as correct that is what matters in an analysis of owner maintenance decisions.

The choice of functional form for $\delta(i)$ can be guided to some extent by the prior statistical analysis that showed positive time dependence. The maximum likelihood estimation indicated that the exponent of t was approximately of second order. This would imply that $\delta(i)$ would be linear in t (i.e., the integral of $\delta(i)$ would be second-order in t). This makes sense because the time path of air pollution may vary and materials may be sensitive to peaks. However, to ease the complexity of the problem, it is assumed that air quality is constant across time at levels found in 1986, a representative year. This implies that the integral of $\delta(i)$ is linear in time. It will be assumed that other explanatory factors used to define δ are also constant across time.

The choice of discount rate is not straightforward. There is no accepted theory that permits selection of a unique social discount rate. Oftentimes, analysts conduct sensitivity analyses at different discount rates to assess the impact of different assumptions on the output of the model. In the present case, a real discount rate of 0.05 will be assumed. No sensitivity analysis is conducted. However, given the form of the model, a higher discount rate will lead to a shorter maintenance interval, ceteris paribus.

The final type of data needed to evaluate equation 8.A.8 is the length of the maintenance interval L. This variable cannot be determined unless a specific decision rule is specified so that the choice of L comes from a constrained opportunity set. To date, two decision rules have been examined in a preliminary fashion. The first decision rule is that L must be chosen so that the discounted present value of marginal benefits equals the discounted present value of marginal costs. The second decision rule is based on the premise that individuals will undertake maintenance when the expected gain in benefits from the maintenance is equal to the benefits obtained at the last maintenance action. This decision rule implies that the critical damage level in dollar terms is fixed. Thus, it is similar to the CA/PA framework but the constraint is in economic terms and not physical damage units.

8.A.3.1 Marginal Benefits Equal Marginal Costs

The marginal benefits of a maintenance action, as a function of L, can be determined from equation 8.A.8. In particular,

$$MB = B_0 \exp[-(k_0NO_2+r)]L = MC \qquad (8.A.9)$$

where MB is marginal benefits and MC is marginal costs. The estimate of marginal cost is set equal to the total cost of performing a unit maintenance action on a home, as developed in Section 7.

Solving for L:

$$L = \frac{\ln(B_0/MC)}{(k_0NO_2+r)} \qquad (8.A.10)$$

Maximum likelihood estimation of equation (8.A.10) was not successful. Generally, the problem was with the ratio (B_0/MC). The responses to Question 42 of the behavioral survey resulted in estimates of B_0 that were very large as well as very small. In fact, some individuals answered that they did not believe that painting added any value to their property. Since painting does incur costs, this implies that other types of benefits are being generated. For example, a respondent may decide to paint to keep up the aesthetic appearance of the neighborhood even though the maintenance action is not expected to affect property values.[3] However, given the data available for B_0, estimation of (8.A.10) did not result in convergence for the maximum likelihood estimations. Additional data collection involving perhaps contingent valuation, may lead to better estimates of B_0.

8.A.3.2 Constant Critical Economic Value

The second decision rule that was examined assumes that individuals perform maintenance when a critical economic value is reached. If costs are assumed constant over time, then this decision rule becomes:

$$B_t = B_0 \exp[-(k_0+k_1NO_2+r)]L \doteq 0.99\ B_0 \qquad (8.A.11)$$

Solving for L:

$$L = \frac{-\ln(.01)}{(k_0+k_1NO_2+r)} \qquad (8.A.12)$$

Table 8-A-3 shows the results of the non-linear estimation for the cases in which the respondent painted a portion of his home or painted the whole house.

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[3] There is a large literature on the capitalization of environmental quality into property values (Anderson and Crocker, 1971). The discussion here relates to the effect of air pollution on maintenance decisions.

Table 8-A-3

NON-LINEAR LEAST SQUARES

(Decision Rule: Constant Critical Economic Damage)

	CASE	
	Partial Painting	Whole House
Parameters		
k_0	0.177 (0.350)	0.541 (0.740)
k_1	24.089 (8.582)	0.9776 (15.121)
R^2	0.106	0.0002
S(Y)	0.538	0.715
NOBS	50	19

The results in Table 8-A-3 are similar to those found in Table 8-A-2 in that NO_2 is not a significant explanatory variable in the subsample of whole house painters. The elasticity of L with respect to NO_2 at the means of the data for partial painters is -0.0442. This implies that a 10 percent reduction in NO_2 will lead to a 0.44 percent increase in the length of the maintenance interval. This is lower than the elasticities computed for the linear model and Weibull specification. However, the set of included variables is slightly different.

8.A.4 SUMMARY

This Appendix has described some alternative statistical/economic models that may be applied to evaluate the relationship between maintenance intervals and NO_2. The results of the more complex modeling do not differ significantly from those obtained with a simple linear specification. In all cases, the elasticity between maintenance interval L and NO_2 is about -0.05. Although NO_2 is a statistically significant factor in the L equation for partial paintings, the overall explanatory power of the equation is low.

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GLOSSARY OF TERMS

ACRM: An acronym for Atmospheric Corrosion Rate Monitor. Used to assess the rate of damage for exposed materials at field sites.

AGE: The age of the respondent.

Consumers' surplus: An estimate of the welfare gain experienced by consumers associated with the purchase of all units of a good or service at a fixed price.

Cost of Ameliorative/Preventative Action (CA/PA): An approach for estimating the economic value of materials damage based on maintenance activities.

COST(DIY): The maintenance costs incurred by those who paint themselves (do-it-yourselfers).

COST(HIRE): The maintenance costs incurred by those who hire labor.

Critical Damage Levels: The level of cumulative damage at which maintenance or replacement action is required.

DLOAN: A dummy variable which is equal to 1 if a loan was taken to pay for the maintenance; 0 otherwise.

Economic Damage Function Approach: A methodology for estimating economic damages as a direct function of air pollution. Individuial maintenance practice data are used, but physical damage functions are not needed.

INC: The annual household income.

L_{0tg}: The maintenance interval length under current environmental conditions for maintenance task t and grid g.

L_{1tg}: The predicted maintenance interval length with improved environmental conditions for maintenance task t and grid g.

Opportunity Cost: A measure of the value of the foregone altern-tive. Used to assess the value of time spent performing maintenance for do-it-yourselfers.

ORANGE: A dummy variable that is equal to 1 if a respondent lives in Orange County; 0 otherwise.

Physical Damage Function: A statistical equation that relates measures of physical damage rates to air pollution and other variables.

Physical Damage Function Approach: A methodology for estimating economic damages which utilizes physical damage functions and individual maintenance practice data.

Prevailing Practice: The usual behavioral response to perceived materials damage.

Producers' Surplus: An estimate of the welfare gain experienced by producers associated with the sale of all units of a good or service at a fixed price.

RESTAT: A computer file which contains detailed information on building counts, age, and average size by map-book area.

RETDUM: A dummy variable that is equal to 1 if the respondent has previously painted his/her current residence; 0 otherwise.

RIVSB: A dummy variable that is equal to 1 if the respondent lives in Riverside or San Bernardino Counties; 0 otherwise.

SIZE: The reported living space of the home.

Thomas Brothers map grid: An area that is approximately 10 km. square and used by the Thomas Brothers map company to identify locations in the South Coast Air Basin. Each of the major components of this study are defined at this level of spatial detail.

$TIME_{ALL}$: Time spent by do-it-yourselfers (respondent and helpers) in maintenance task.

Value of Lost Material (VLM): An approach for estimating the economic value of materials damage based on replacement costs.

WHOLE: A dummy variable which is set equal to 1 if the whole house is painted; 0 if partial painting.

Willingness to pay: A measure of the economic benefits derived from an action that increases economic welfare.

X: The out-of-pocket expenses incurred by do-it-yourselfers.

YRBLT: A dummy variable which equals 1 if the house was built prior to 1964; 0 otherwise.