REPORT FOR CONSULTATION ON THE WASHINGTON, D.C. NATIONAL CAPITAL INTERSTATE AIR QUALITY CONTROL REGION

U.S. Department of Health, Education, and Welfare
Public Health Service

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PREFACE

The Secretary, Department of Health, Education, and Welfare, is directed by the Air Quality Act of 1967 to designate "air quality control regions" * to provide a basis for the establishment and implementation of air quality standards. In addition to listing the major factors to be considered in the development of region boundaries, the Act stipulates that the designation of a region shall be preceded by a consultation with appropriate State and local authorities.

The National Air Pollution Control Administration, DHEW, has conducted a study of the Washington urban area, the results of which are presented in this report. The region boundaries proposed herein reflect consideration of all available data, but the boundary is subject to revision prior to formal designation within the discretion of the Secretary, HEW, on the basis of the consultation. This report is intended to serve as the background document for that consultation.

The National Air Pollution Control Administration (NAPCA) is appreciative of assistance received either directly during the course of this study or indirectly during NAPCA's previous activities in the National Capital Area from the official air pollution agencies of the District of Columbia and the States of Maryland and Virginia, the Washington Council of Governments, the Northern Virginia Regional Planning Commission, and the Metropolitan Washington Board of Trade.

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* The word "region" (uncapitalized) means air quality control region unless specifically noted otherwise. When capitalized, the word "Region" refers to the specific air quality control region under discussion.

INTRODUCTION

> "For the purpose of establishing ambient air quality standards pursuant to section 108, and for administrative and other purposes, the Secretary, after consultation with appropriate State and local authorities shall, to the extent feasible, within 18 months after the date of enactment of the Air Quality Act of 1967 designate air quality control regions based on jurisdictional boundaries, urban-industrial concentrations, and other factors including atmospheric areas necessary to provide adequate implementation of air quality standards. The Secretary may from time to time thereafter, as he determines necessary to protect the public health and welfare and after consultation with appropriate State and local authorities, revise the designation of such regions and designate additional air quality control regions. The Secretary shall immediately notify the Governor or Governors of the affected State or States of such designation."
>
> Section 107(a)(2), Air Quality Act of 1967

THE AIR QUALITY ACT

Air pollution in most of the Nation's urban areas is a regional problem. Consistent with the problem, the solution demands coordinated regional planning and regional effort. Yet, with few exceptions, such corrdinated efforts are notable by their absence in the Nation's urban complexes.

Beginning with the Section quoted above, in which the Secretary is required to designate air quality control regions, the Air Quality Act presents an approach to air pollution control involving closely coordinated efforts by Federal, State, and local governments, as shown in Figure 1. After the Secretary has (1) designated regions, (2) published air quality criteria, and (3) published corresponding documents on

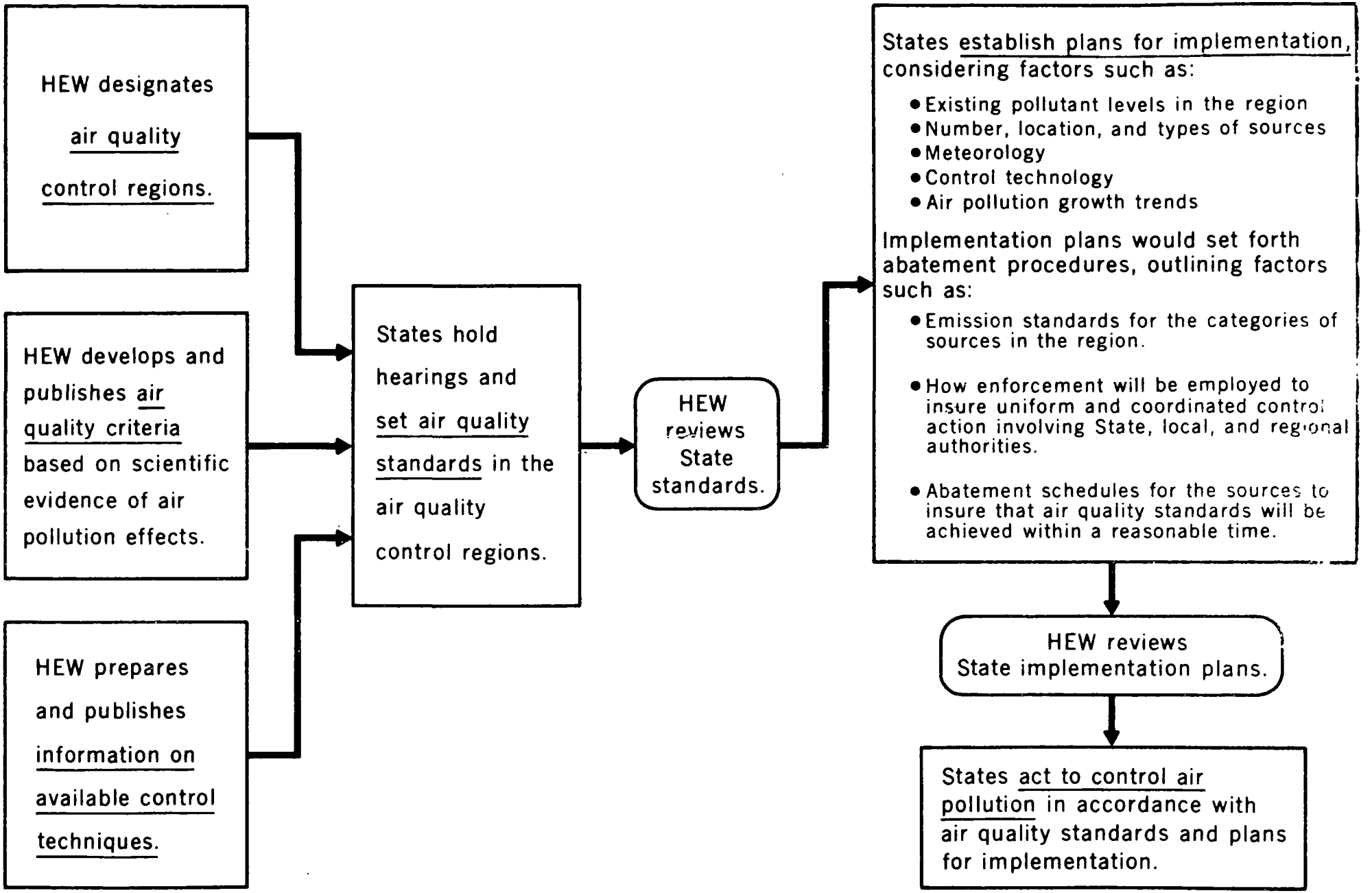


Figure 1. Flow diagram for State action to control air pollution on a regional basis.

control technology and associated costs, the Governor(s) of the State(s) must file with the Secretary within 90 days a letter of intent, indicating that the State(s) will adopt within 180 days ambient air quality standards for the pollutants covered by the published criteria and control technology documents and adopt within an additional 180 days plans for the implementation, maintenance, and enforcement of those standards in the designated air quality control regions.

The new Federal legislation provides for a regional attack on the problem and, at the same time, provides latitude in the form which regional efforts can take. While the Secretary has approval authority, the State(s) involved in a designated region assumes the responsibility for developing an administrative procedure as part of their implementation plan. It is conceivable that informal cooperative arrangements with proper safeguards will be adequate in some regions, whereas in others, more formal arrangements, such as interstate compacts may be selected. The objective in each instance will be to provide effective mechanisms for control on a regional basis.

PROCEDURE IN DESIGNATION OF REGIONS

Figure 2 illustrates the procedure used by the NAPCA in the designation of an air quality control region. A preliminary delineation of the region is developed by bringing together two essentially separate studies - the "Engineering Evaluation" and the "Urban Factors." To be successful, a region must include jurisdictions capable of administering a coordinated control effort, and the com-

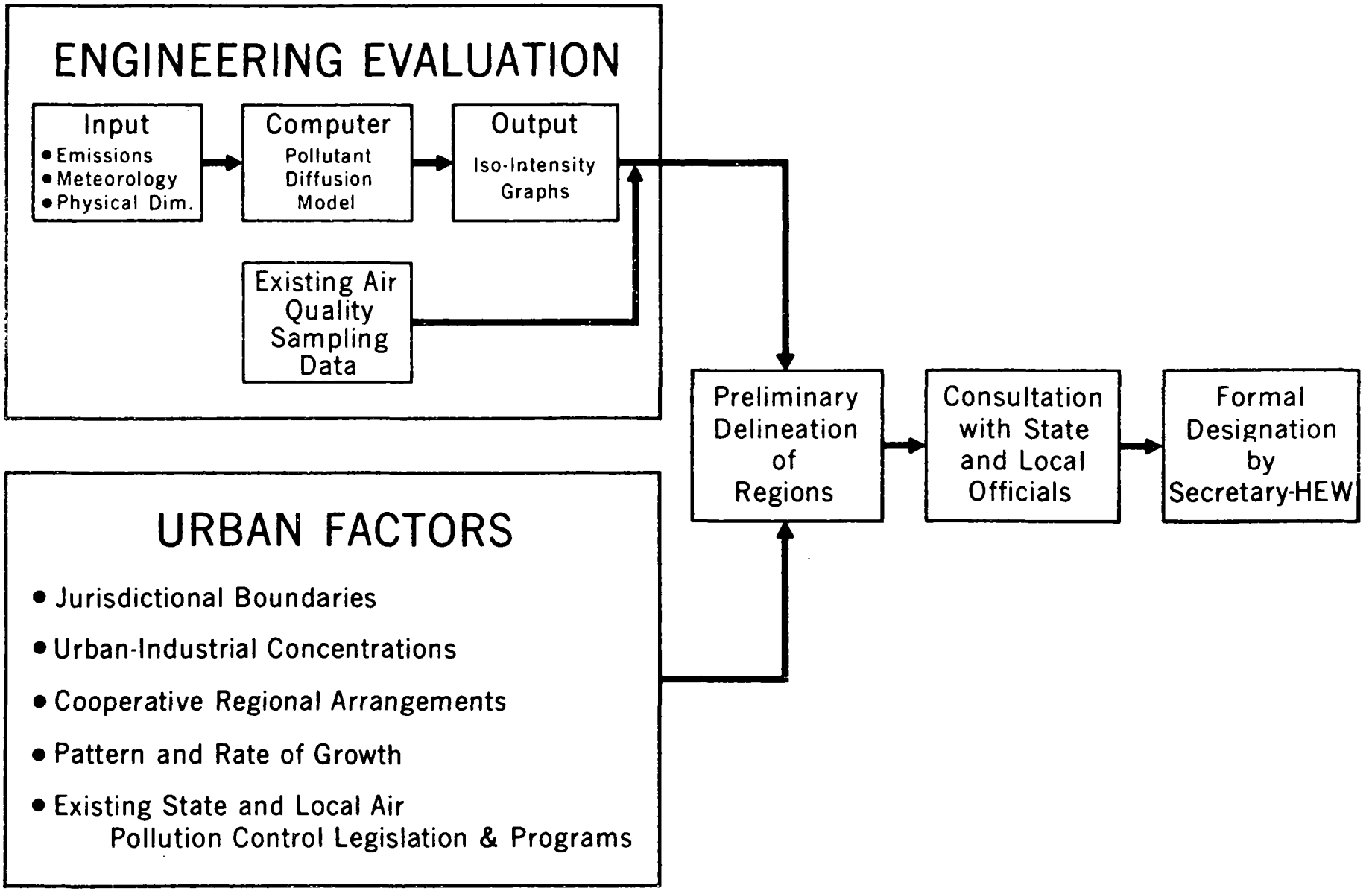


Figure 2. Flow diagram for the designation of air quality control regions.

bination must include an area large enough to attack the air pollution problem as a whole. The study of urban factors provides insight as to the nature of the jurisdictions and the engineering evaluation provides an indication of the geographical extent of the problem.

For air pollution control that is truly regional in scope, air quality control regions must be defined to include the majority of the pollution emissions contributing to the problem in an urban area and must be extensive enough to encompass the majority of the population and property affected by pollution emanating from sources within the area. This requirement could be generally satisfied by individual evaluation of the major factors - the location, nature, and quantity of pollutant emissions; the pattern of urban development; existing air quality levels; and prevailing air pollution meteorology. While separate consideration of these individual factors provides useful insight on the nature of an urban area, it does not provide any direct or dynamic indication of the extent of influence of sources in an urban complex.

In the absence of adequate air quality data (which is the case in most urban areas), the only recourse is to estimate air quality levels by a constantly-evolving technique referred to as diffusion modeling. Diffusion modeling is a semi-dynamic process in which the air quality levels at selected locations are estimated by calculating and adding together the weighted contribution from each of the sources, or groups of sources, within the area under consideration. As with most mathematical simulation approaches, the calculations are repetitive and time-consuming, and so they are routinely carried out with the aid of a computer.

These steps are outlined under "Engineering Evaluation" in Figure 2, and the box labeled "Input" describes the information required to apply the diffusion model. This information consists of data on the nature and quantity of the pollutants being released and the physical location of the sources, the average depth of air available for mixing and dilution, frequency of various wind velocities (direction and speed), and physical dimensions and topography of the urban area under study. The necessary calculations are made with this information in the next step, labeled "Computer." The result or "Output" of the diffusion model approach is the estimated pattern of ground-level pollutant concentrations caused by the sources of each pollutant within the area. Based on this information, "iso-intensity" lines (which will usually be closed, irregularly-shaped contours of equal concentrations) can be developed and presented in graphic or map form. Validation of the iso-intensity graphs with available ambient air quality data completes the engineering evaluation process. These graphs help delineate geographical limits for the extent of influence of pollution sources in a given area and, thus, serve as a guide to the boundaries of the air quality control region.

The term "Urban Factors" encompasses all considerations of a non-engineering or non-quantitative nature. Several examples are listed in Figure 2, but many other factors are considered. The existence and extent of Standard Metropolitan Statistical Areas and Planning Areas of the Department of Housing and Urban Development are examples of some of the additional factors that can influence the final delineation of boundaries in a given region.

Based on the concept that, with some possible exceptions, it is inadvisable to consider the inclusion of only part of a county in a region, the study of urban factors results in a preliminary region made up of the most reasonable combination of counties consistent with the engineering evaluation.

The recommendation for the air quality control region for the Washington, D.C. National Capital area and the necessary documentation make up the body of this report. The report itself is meant to serve as the background document for the formal consultation with the appropriate State and local authorities, and based on the consultation, the Region boundaries suggested herein are subject to revision within the discretion of the Secretary, HEW. Following the consultation, the Secretary will publish the final determination of the region in the Federal Register and notify Governors of Maryland and Virginia and the Mayor of the District of Columbia of his official designation.

SUMMARY OF PRELIMINARY FINDINGS

Subject to the scheduled consultation, the Secretary, Department of Health, Education, and Welfare, proposes to designate an air quality control region for the Washington, D.C. Interstate National Capital area, consisting of the following jurisdictions:

District of Columbia

In the State of Maryland:

Montgomery County

Prince Georges County

In the State of Virginia:

Arlington County

Fairfax County

Loudoun County

Prince William County

As so proposed, the Washington, D.C. Interstate National Capital Air Quality Control Region would consist of the territorial area encompassed by the outermost boundaries of the above counties, including the independent cities of Alexandria, Falls Church, and Fairfax; and the territorial area of all other municipalities as defined in Section 302 (f) of the Clean Air Act, 42 U.S.C. 1857h (f). The proposed region is illustrated in Figure 3.

The consideration of jurisdictional, social, and economic factors and available demographic data influenced the selection of the proposed

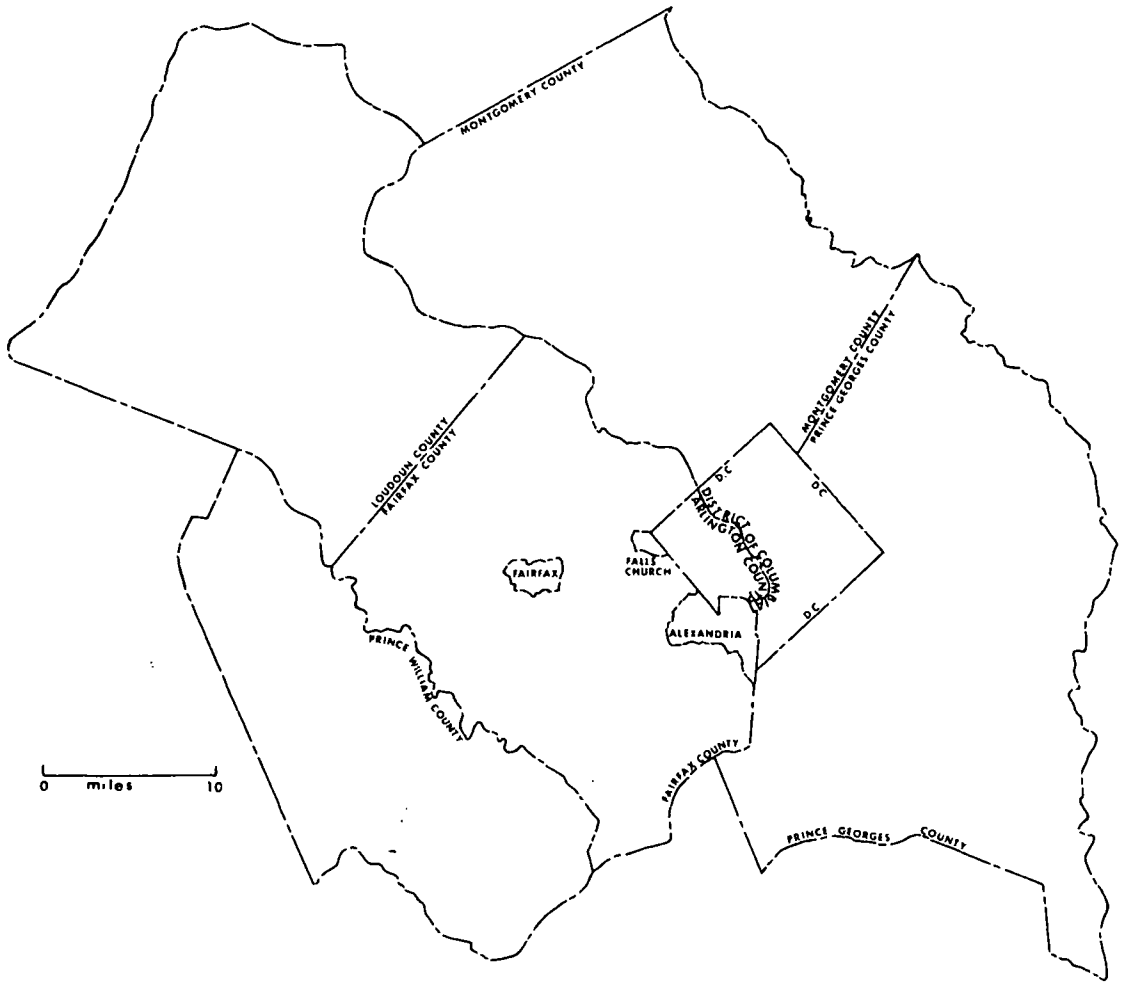


Figure 3. Area proposed for inclusion in the Washington, D.C. National Capital Air Quality Control Region.

boundaries for the Washington, D.C. Air Quality Control Region. The geographical area suggested here is considered the most cohesive and suitable base for the establishment of regional air pollution control in the Washington, D.C. National Capital area.

One of the more important considerations which influenced the choice was the existence of other governmental groupings with boundaries coextensive with those recommended here. It is felt that existing boundaries, agencies, and programs should be utilized wherever possible to aid in the ease of administering newly-established regional programs. NAPCA's proposed Region is coextensive with the Standard Metropolitan Statistical Area of the Department of Commerce and its Bureau of the Census. The Department of Housing and Urban Development has designated the same group of jurisdictions as a Planning Area for that Department's regional purposes. Finally, the Washington Council of Governments, whose limits coincide with the boundaries of the proposed Region, has been designated the official HUD Planning Agency in the Washington urban area and has in the past worked with local elected and appointed officials on plans to control air pollution.

The Secretary of Health, Education, and Welfare initiated an Abatement Activity in early 1967 for the Washington interstate area to which all jurisdictions proposed here for regional inclusion were a party. The work conducted during the course of the Abatement Activity provided most of the technical data upon which this recommendation for designation of a region is based. The engineering evaluation suggests that two of the Virginia counties, Prince William and Loudoun, are not

overly involved in the pollution problem in the National Capital area at the present time. The fact that these two counties are primarily agricultural and rural would also mitigate in favor of their exclusion from the Washington Air Quality Control Region. These findings were over-ruled on the basis of their potential for economic growth and their growing involvement in existing regional arrangements and the economic and social life of the metropolitan Washington, D.C. urban complex. As members of the Washington Council of Governments, the two counties have participated in that organization's efforts to control pollution in the Washington area and have developed working relationships with the other jurisdictions involved.

Region boundaries, to be adequate, must provide for urban growth and thus remain stable over a longer period of time. As shown in Table 1, Loudoun and Prince William counties have by far the highest projected growth rates of any jurisdictions in the Washington area. Statistics on the start of the new housing (Table C-7 , Appendix C) substantiate the expected population trends within the area. There was a 600-fold increase in the number of housing starts in Prince William County in the 5-year period 1962 through 1966 over the 1950 through 1954 period. The similar statistic for Loudoun County is 392 per cent, over twice the next highest rate of increase (Prince Georges County).

Comparison of 1965 population distribution (Figure 4) and employment distribution (Figure 5) illustrates the dependence of suburbanites on urban employment. There is also an obvious outward trend in population distribution predicted for the 1965-2000 period (Figure 6), whereas there

Table 1. Percentage Growth Rates by Jurisdiction, 1940-2000.

County or City	Past and Projected Growth Rates, per cent					
	1940-1950	1950-60	1960-70	1970-80	1960-80	1970-2000
District of Columbia	21.0	-5.0	9.0	6.5	16	16
Montgomery Co.	95.9	107.6	49.0	34.0	100	95
Prince Georges Co.	116.2	84.2	74.8	32.8	132	91
Alexandria City	84.5	42.5	61.5	23.7	100	52
Arlington Co.	137.0	20.6	20.8	9.2	32	28
Fairfax Co.	141.0	152.5	70.0	44.0	147	139
Fairfax City	99.0	600.0	81.0	47.0	165	84
Falls Church	192	22	17	8.3	28	25
Loudoun Co.	4.2	16	75	86	226	306
Prince William Co.	27	122	120	81	300	261

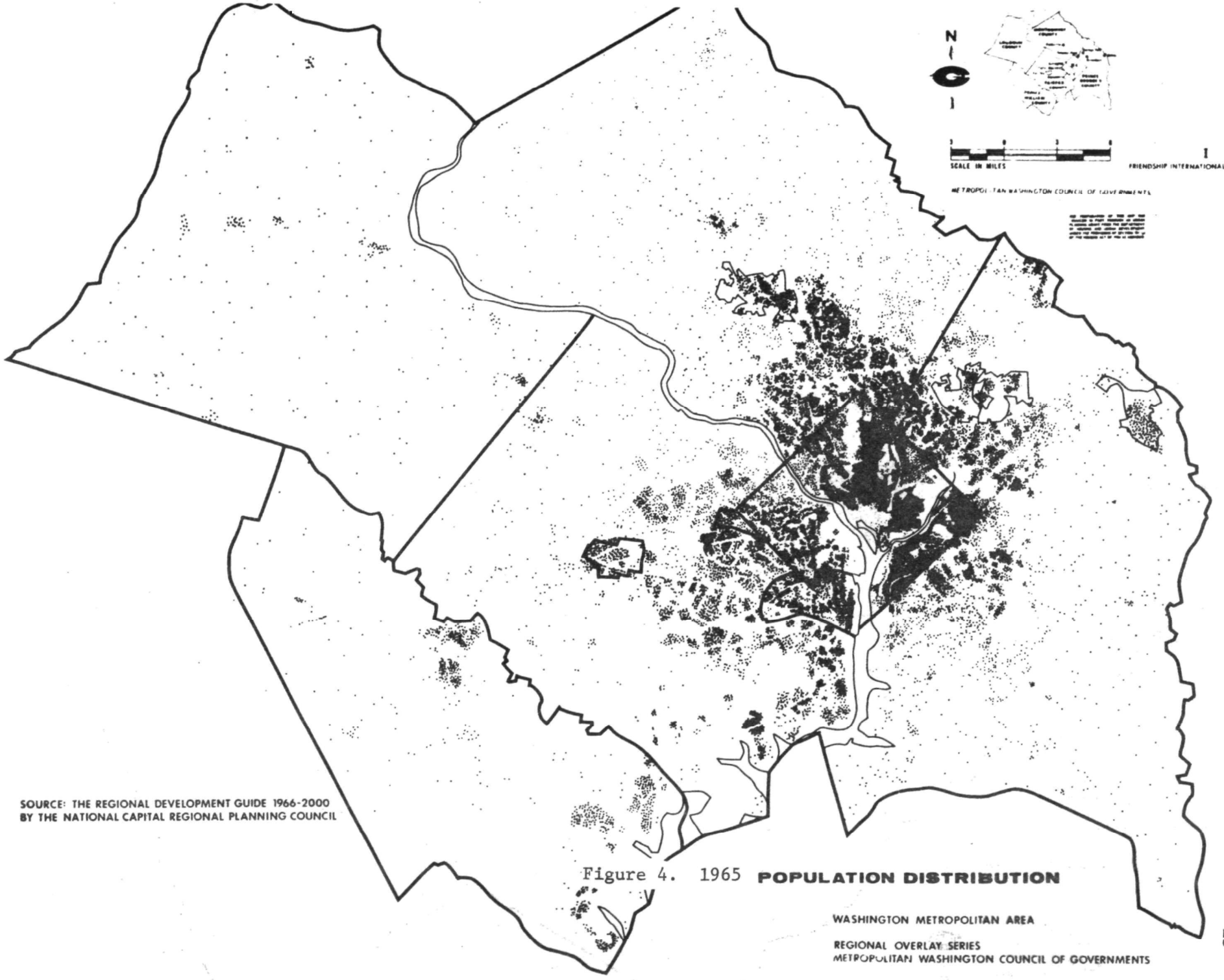


Figure 4. 1965

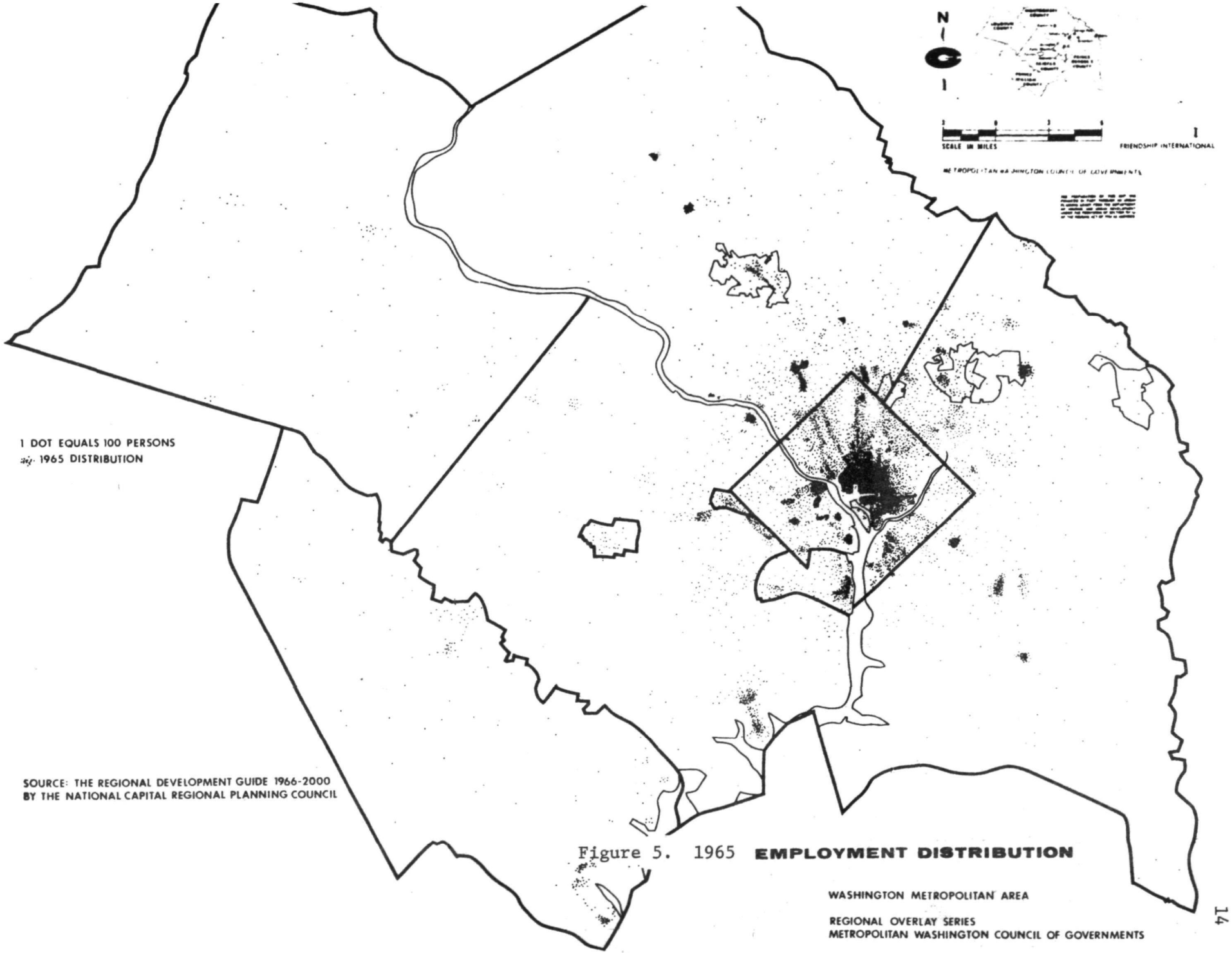


Figure 5. 1965 **EMPLOYMENT DISTRIBUTION**

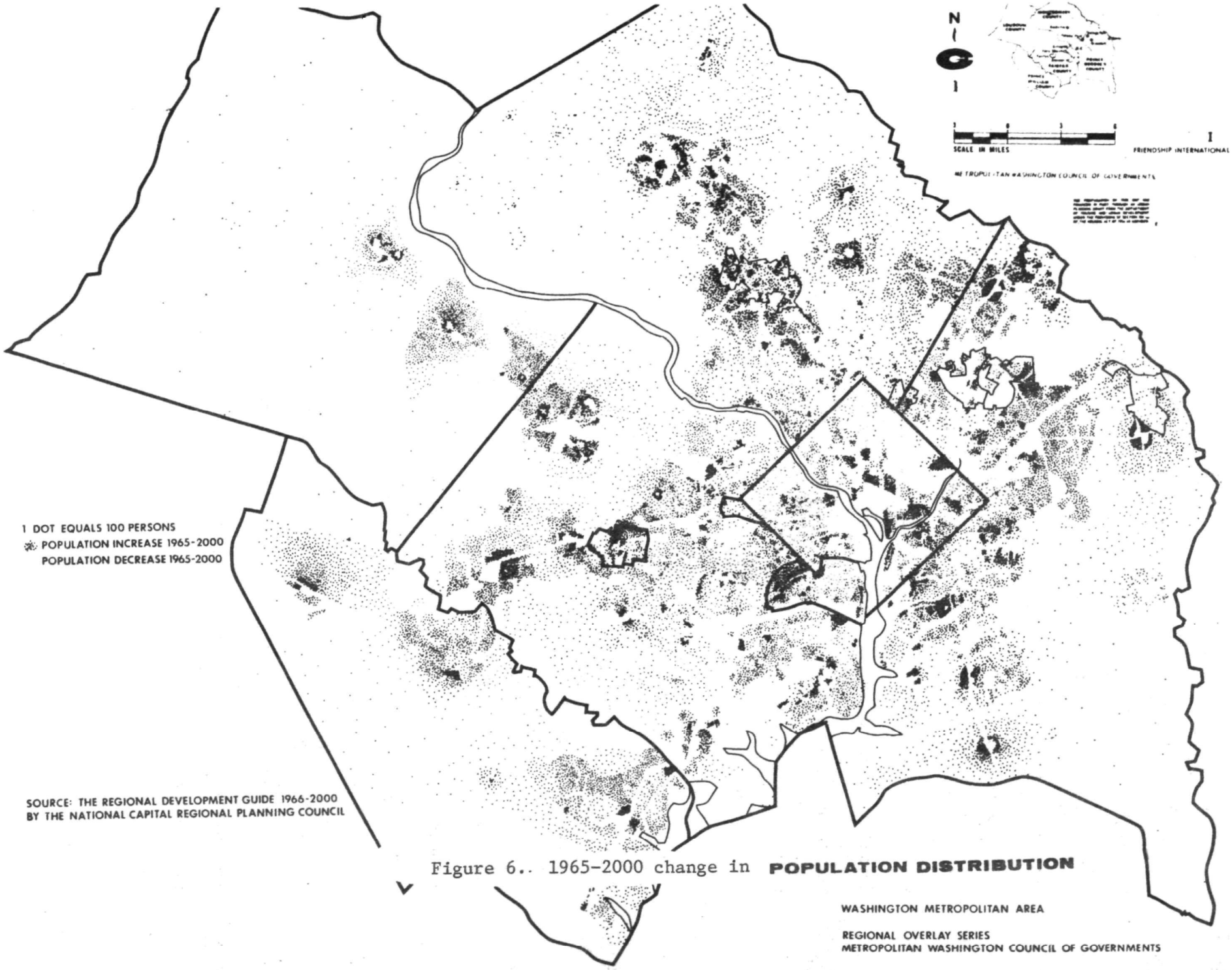


Figure 6.. 1965-2000 change in **POPULATION DISTRIBUTION**

appears to be no such trend in employment distribution during that period (Figure 7). This suggests that the dependence of people in the suburbs on the central city will increase, leading to a more cohesive region in the future.

Figure 8 illustrates the existing major transportation system for the region, and again, Loudoun and Prince William counties appear as satellites to the urban area. All future plans for transportation facilities include provisions for the expected growth of these two counties. The location of Dulles International Airport in Loudoun County is expected to lead to increased expansion in that area, both residential and industrial.

The Northern Virginia Regional Planning and Economic Development Commission has developed a regional plan for the four Virginia counties and associated independent cities. The Commission plans for the year 2000 (Figure 9) envision land-use and associated transportation systems. The expected role of Loudoun and Prince William counties as sites for residential, commercial, and indistrial development, all of which will be closely associated with the more centralized portion of the Washington, D. C. urban area, are illustrated in this plan.

In short, the factors mentioned above all point out the cohesive nature of the region proposed here as to its social and economic make up. The next section illustrates the geographical nature of the area's air pollution and demonstrates that the region boundaries suggested here are sufficiently encompassing to provide for a truly regional attack on the problem.

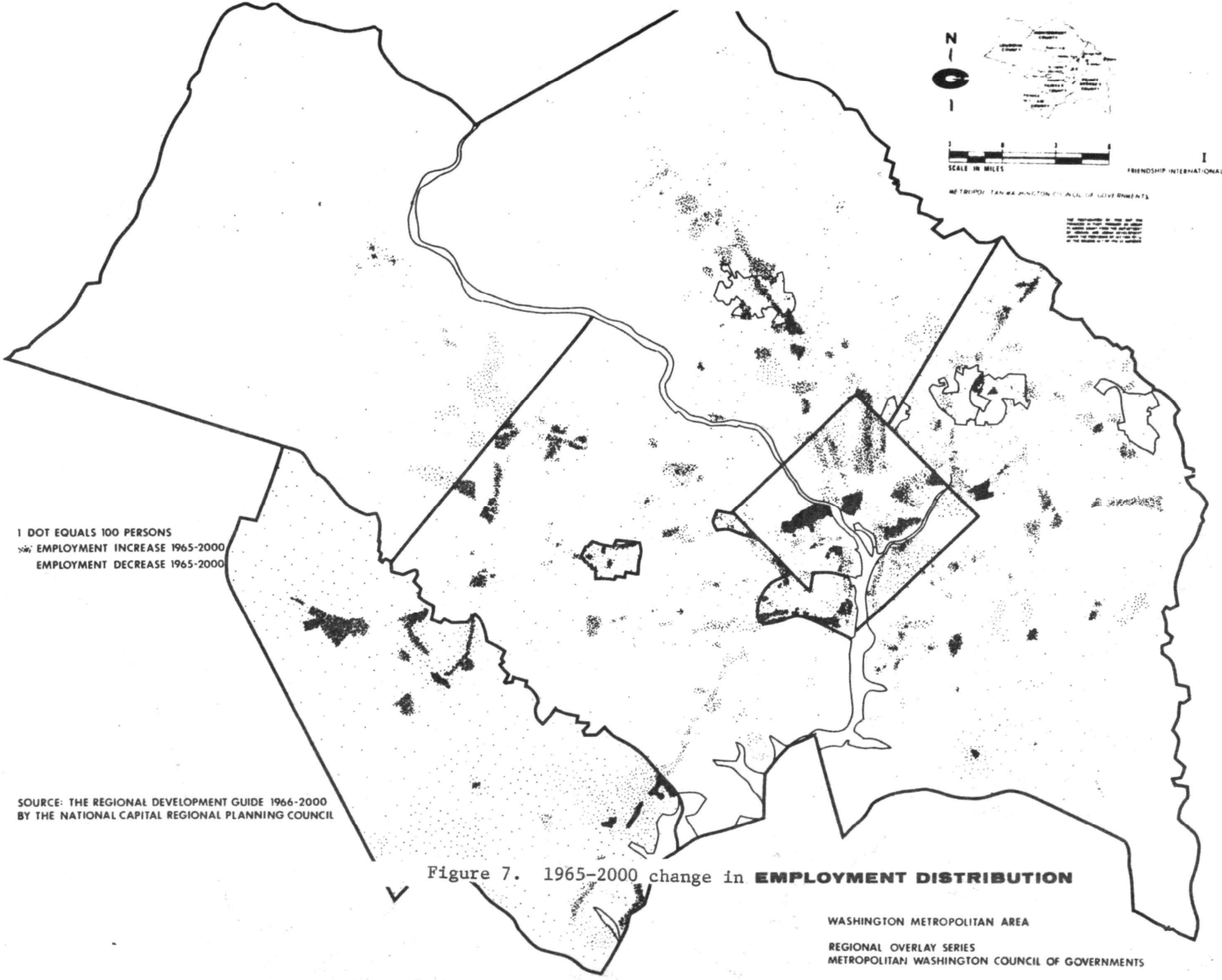


Figure 7. 1965-2000 change in **EMPLOYMENT DISTRIBUTION**

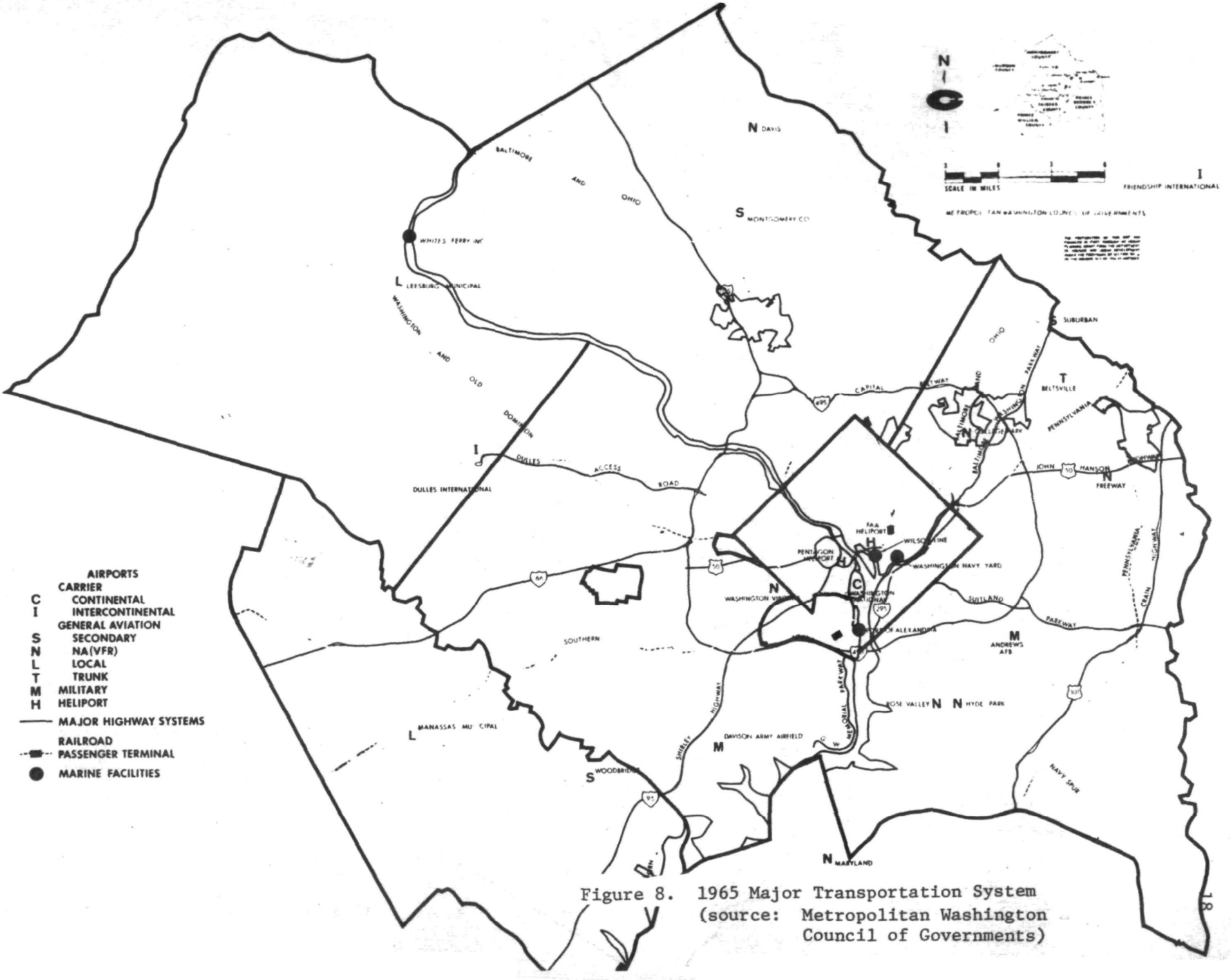


Figure 8. 1965 Major Transportation System (source: Metropolitan Washington Council of Governments)

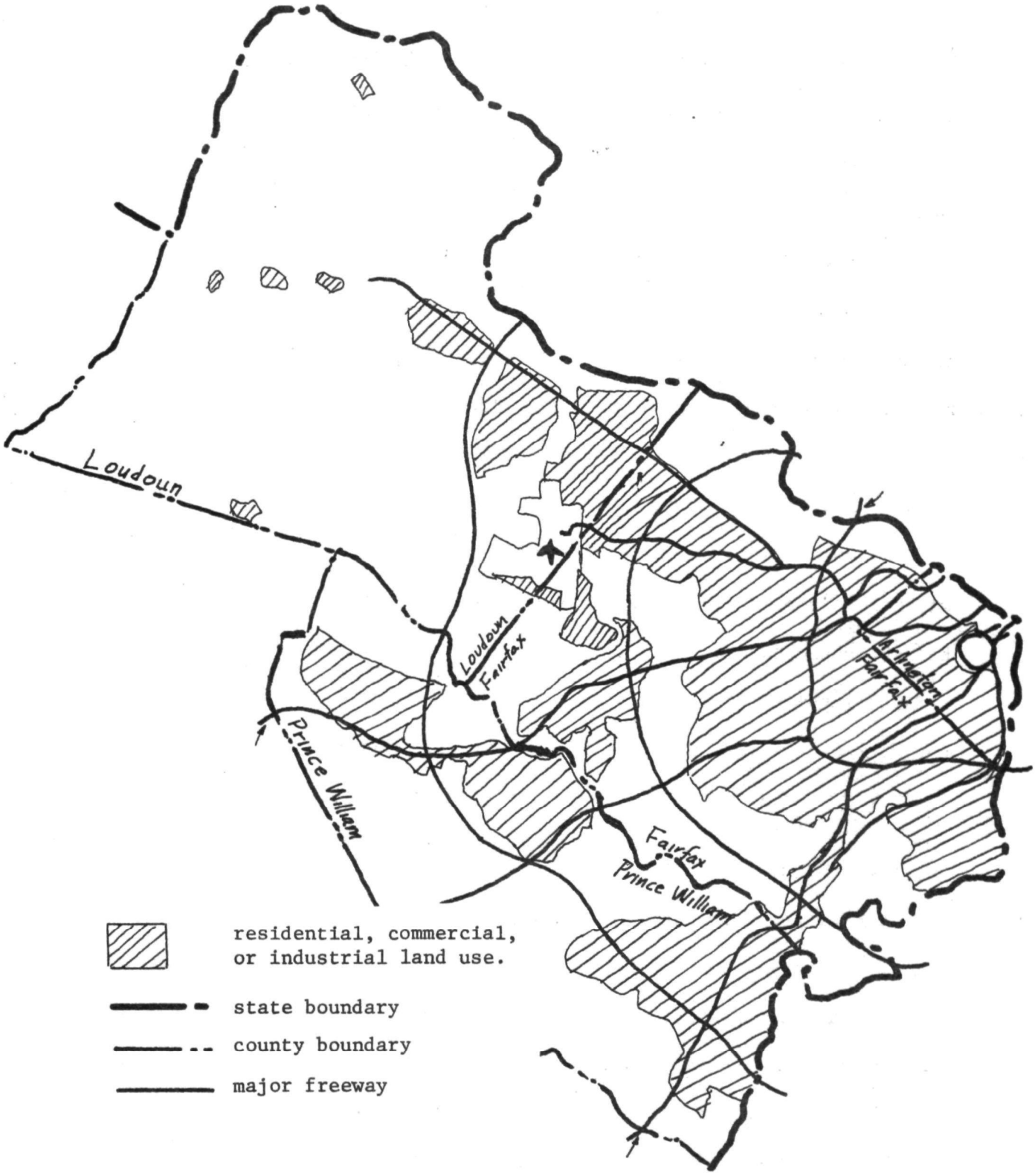


Figure 9. Northern Virginia Regional Planning Commission Year 2000 Plan.

ENGINEERING EVALUATION

The engineering evaluation is based on a study of pollutant emissions, meteorology, available ambient air quality data, and air quality levels as estimated on the basis of diffusion model calculations. The Technical Report[3] previously conducted for the Washington, D.C. Abatement Action served as a major reference during this study.

Evaluation of all data available for the Washington area including the diffusion model results, indicates that the region should include at least Montgomery and Prince Georges counties in Maryland; the District of Columbia; Fairfax and Arlington counties in Virginia; and the independent Virginia cities of Fairfax, Falls Church, and Alexandria. As was indicated in the summary section of this report, the above conclusion prevailed with the exception that Loudoun and Prince William counties in Virginia have been proposed for inclusion in the region, not because of their present involvement in the area's air pollution problem, but because of their growth pattern and what it portends for the future. The factors leading to the above conclusion are discussed below.

EMISSION INVENTORY RESULTS

The emission inventory conducted for the Abatement Action[4] included estimates for emission of five major pollutants - particulates, sulfur oxides, carbon monoxide, nitrogen oxides, and total hydrocarbons. Table 2 summarizes the results from the more in-depth discussions of the emission inventory technique and results, presented in Appendix A of this report.

Emissions are listed in Table 2 for sulfur oxides, carbon monoxide, and particulates, with totals shown for each of the major jurisdictions

Table 2. Mean Day Emissions for Various Averaging Times
(Tons)

County or City	Sulfur Dioxide			Carbon Monoxide			Particulates		
	Annual	Winter	Summer	Annual	Winter	Summer	Annual	Winter	Summer
District of Columbia	175	281	90	978	861	1,046	30	43	25
Montgomery Co.	189	208	177	602	530	644	18	20	17
Prince Georges Co.	179	202	198	698	614	747	21	24	22
Maryland Subtotal	368	410	375	1,300	1,144	1,391	39	44	39
Arlington Co.	22	49	4	282	248	302	5	8	4
Fairfax Co.	17	38	3	521	458	557	7	12	6
Loudoun Co.	2	3	-	57	50	61	1	1	1
Prince William Co.	43	43	43	122	107	131	7	7	7
Alexandria City	63	65	62	188	165	201	6	7	6
Virginia Subtotal	147	198	112	1,170	1,028	1,252	26	35	24
Area Totals	690	889	577	3,448	3,033	3,689	95	122	88

in the area. Tables A-1 through A-4 in Appendix A provide a breakdown by individual emission zones. These three pollutants were chosen because of their representativeness of the major pollutant source categories. The estimate of sulfur oxide pollution levels illustrates the impact of fuel-burning activities (where almost 70% of the sulfur pollution comes from the burning of coal) at private, commercial, or government-owned power plants. Carbon monoxide pollutant levels provide the best indication of the impact of motor vehicles on the regional air pollution pattern, since 98 per cent of all carbon monoxide emitted in the Washington area comes from motor vehicles. Diffusion model estimates of suspended particulate levels provides the best measure of the combined impact of all pollutant source categories, since, of the five pollutants covered in the emission inventory, particulate emissions are the most evenly-distributed by source category (no single source category accounts for more than 28 per cent of the total).

The second and perhaps more important reason for confining the diffusion model work to these three pollutants is the use and interpretation of the results. By predicting the patterns of dispersion of a few major pollutants, the diffusion model work provided a guide to the desirable extent of the region but did not dictate the exact boundary location. By way of example, if significant levels of one or more of the three pollutants extend into a county contiguous to the major urbanized area, this would be an indication that that county is being subjected to a pollutant load that constitutes a part of the total-area problem, and that the county should be considered for inclusion in the air quality control region. The final decision is then made by bringing

into consideration the involvement of that county in the overall activities of the urban area.

The total quantity of pollutants emitted in each of the reporting zones was converted to daily emissions under minimum, average, and maximum space-heating conditions and related to the land area of each zone. The resulting emission densities are presented graphically in Figures 10, 11, and 12 for an average space-heating day in tons per square mile per day.

The pattern of emission densities for each of the three pollutants are closely related to the pattern of urbanization in the central part of the area. The maximum emission densities occur in or close to the District of Columbia, but the density pattern in each case extends well into Montgomery and Prince Georges counties in Maryland and Fairfax County in Virginia. The emission density patterns for sulfur oxides and particulates are complicated by the existence of three major point sources outside of the highly urbanized area but still within the 6-county area. Figure 13 shows the location of these 3 major sources (northwestern Montgomery County, southeastern Prince William County, and southeastern Prince Georges County) as well as all other sources in the area emitting more than 100 tons per year of any single pollutant.

DIFFUSION MODEL RESULTS

While the geographical distribution of pollutant sources illustrates clearly the core of the air quality control region, it does not, by itself, provide any insight as to the extent of influence of the combined sources on the people and property located outside of the highly-urbanized portion of the greater Washington, D.C. complex. A study of air quality levels known or estimated to occur is useful in determining the area affected

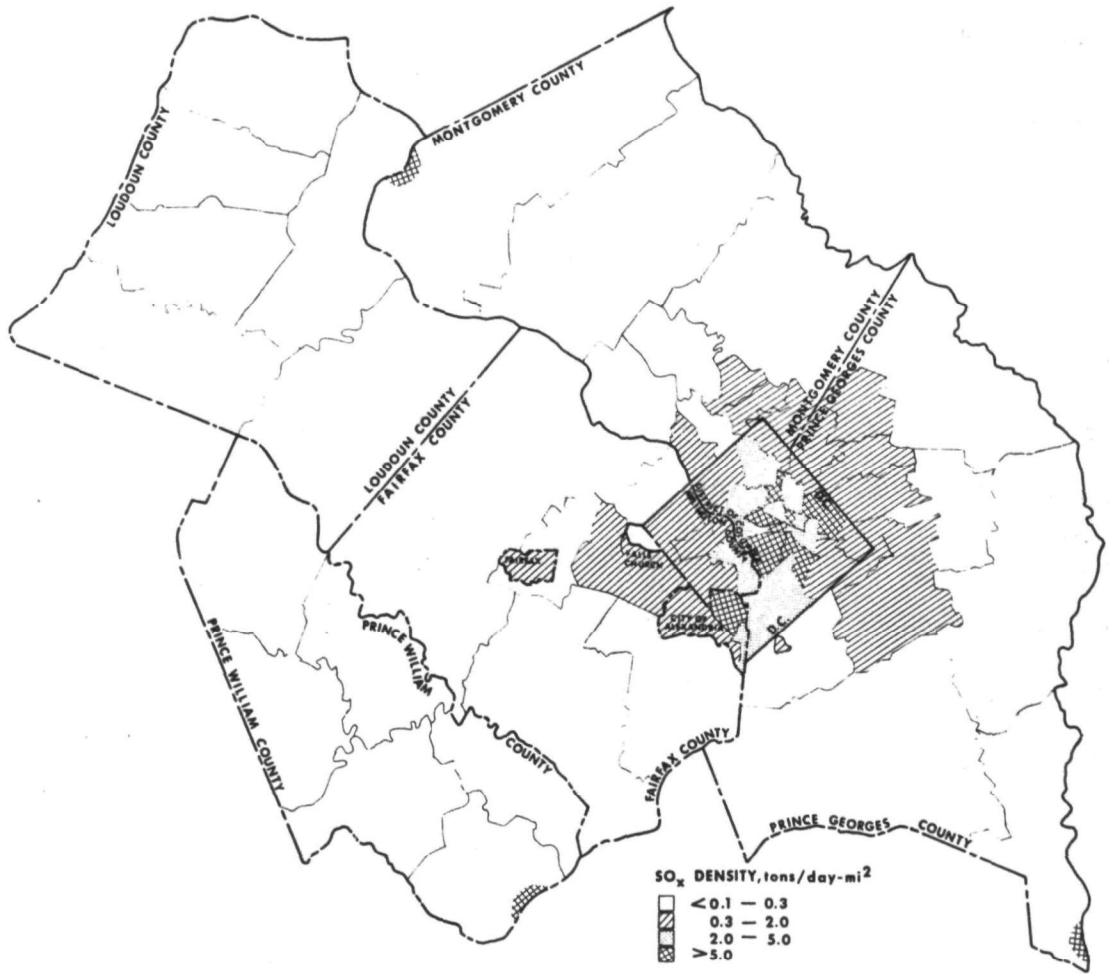


Figure 10. Sulfur oxides emission densities for an average space-heating day.

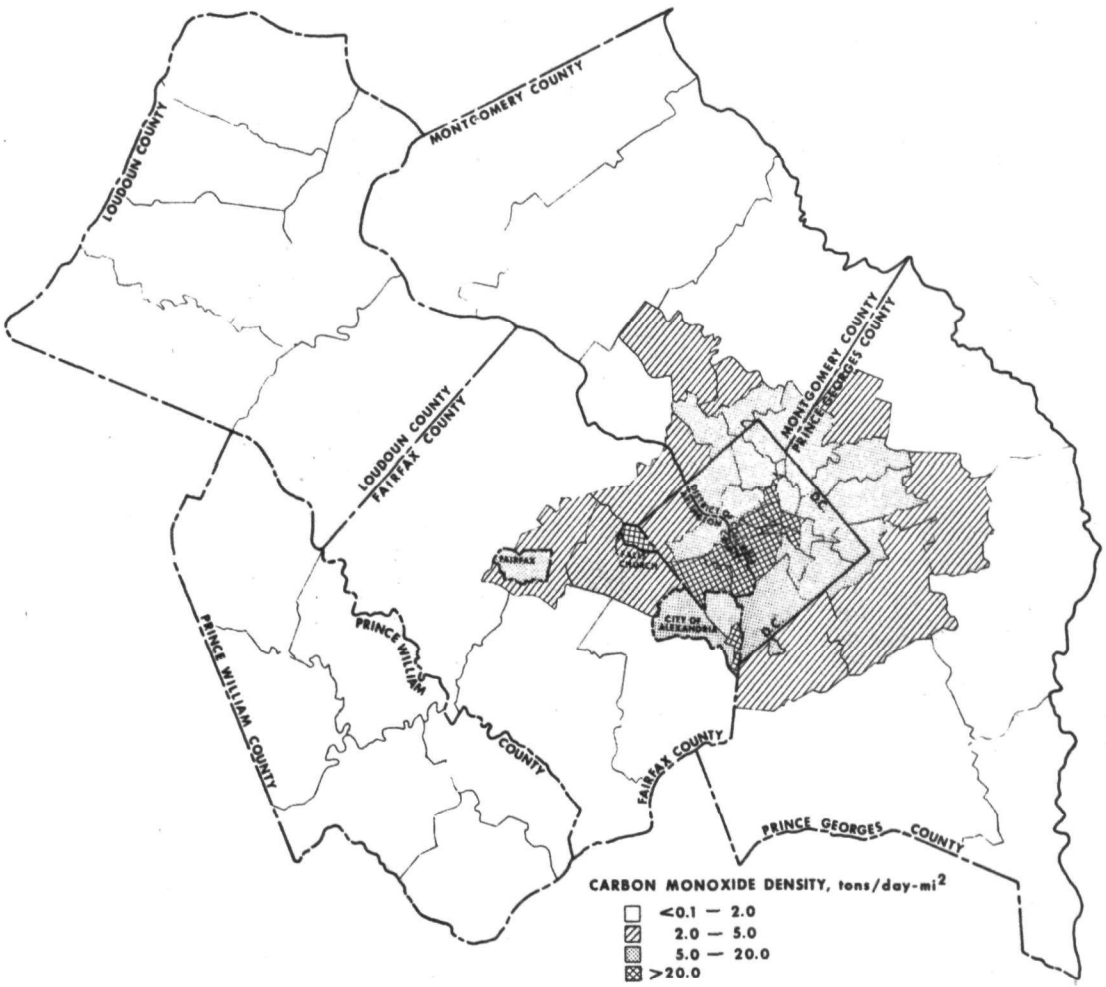


Figure 11. Carbon monoxide emission densities for an average space-heating day.

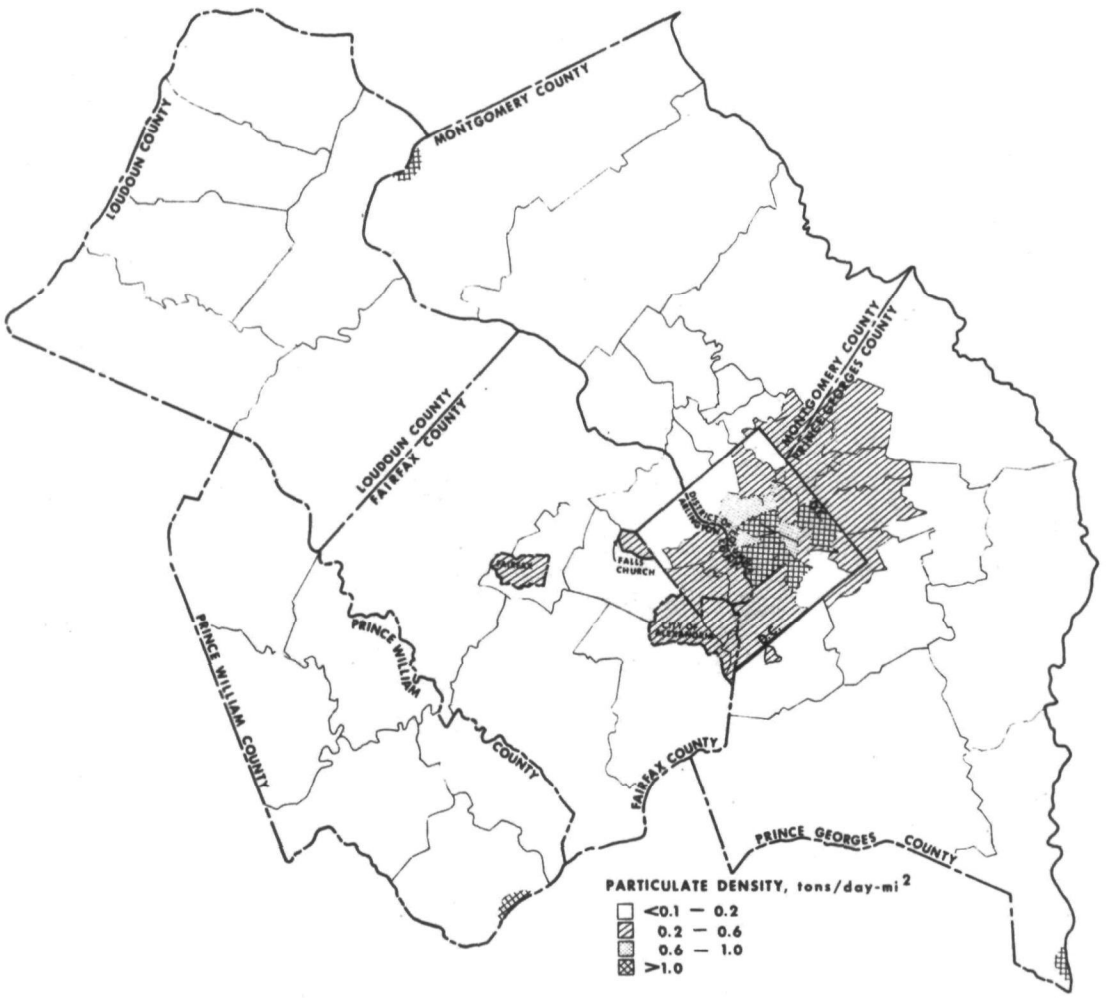


Figure 12. Particulate emission densities for an average space-heating day.

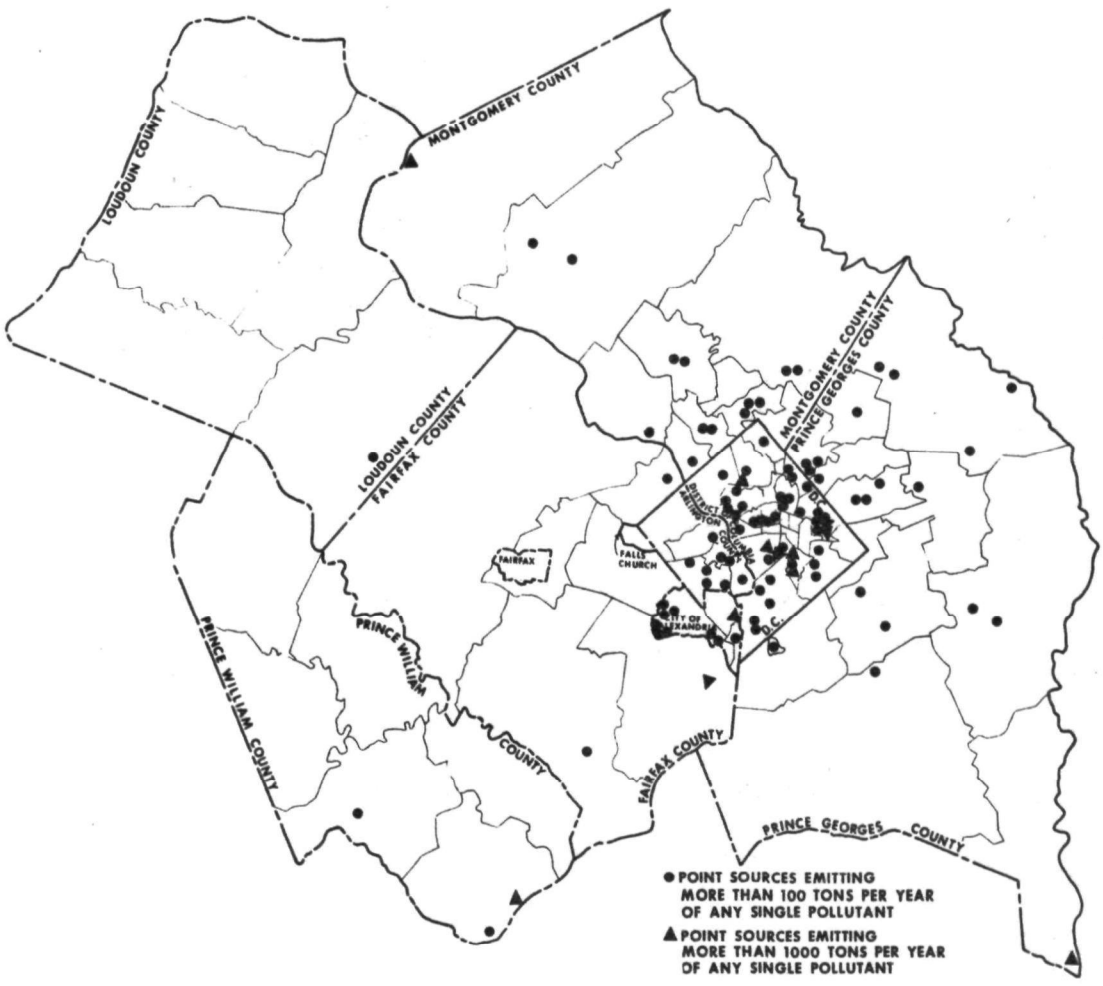


Figure 13. Point sources that emit 100 tons or more per year of a single pollutant.

by the pollution sources and thus subject to inclusion in the air quality control region. Such analyses can be based directly on air quality sampling data in those instances where the sampling program covers a large-enough area and has been in existence long enough to provide reliable patterns of air quality throughout the region under study. Unfortunately, such air quality data rarely exists, and it becomes necessary to develop estimates of prevailing air quality. The diffusion model is the technique by which such estimates are made on the basis of information on pollutant emissions, meteorological conditions, and the physical character of the urban complex. The diffusion model used in this study and the results obtained are covered in detail in Appendix B and summarized briefly below.

The model is based on the long-term Gaussian diffusion equation, described by Pasquill [5] and modified in recent years[6, 7] for application to the multiple-source situation of an urban complex. The basic equation assumes that the concentration of a pollutant within a plume has a Gaussian distribution about the plume centerline in the vertical and horizontal directions, with the standard deviations (σ) in the two directions being a function of distance from the source and certain dispension characteristics of the atmosphere referred to in terms of "stability classes." Graphs have been developed which give σ_z (vertical) and σ_y (horizontal) diffusion coefficients versus stability class and distance downwind. Refference 6 describes the Gaussian-based diffusion model and the inherent assumptions made when it is applied.

The diffusion model was applied for each of the three pollutants for the three different time periods - annual, winter, and summer. Table 3

and Figure 14 show the meteorological data required to apply the model for each of the three time periods. The mixing depths for the three time periods were derived as the average of the mean morning and afternoon readings, as shown in Table 3. Figure 14 shows the percent frequency of occurrence of surface wind direction from 1951 through 1960 at Washington National Airport for summer, winter, and annual averages. Combined with data on surface wind speed, this information is used in the diffusion model to weight the distribution of pollutant emissions on the 16 points of the compass.

Table 3. Average mixing depths for Washington, D.C. by season.

Season	Mixing Depths, meters		
	Morning Average	Afternoon Average	Average, morning and Afternoon
Winter	539	963	752
Summer	378	1884	1131
Annual	439	1503	971

Using the foregoing information on emissions and meteorology, concentrations were calculated for each of the three pollutants for each of the three time periods at a total of 97 ground-level receptor points (20, 30, 40, 50, 70, and 100 kilometers from an assumed center point at 16 compass directions, plus an estimate of the concentration at the center point itself).

The results are presented in Figures 15, 16, and 17. Figure 15 shows the average concentrations of SO_2 expected to occur during the three winter months. Figures 16 and 17 illustrate similar results for CO and

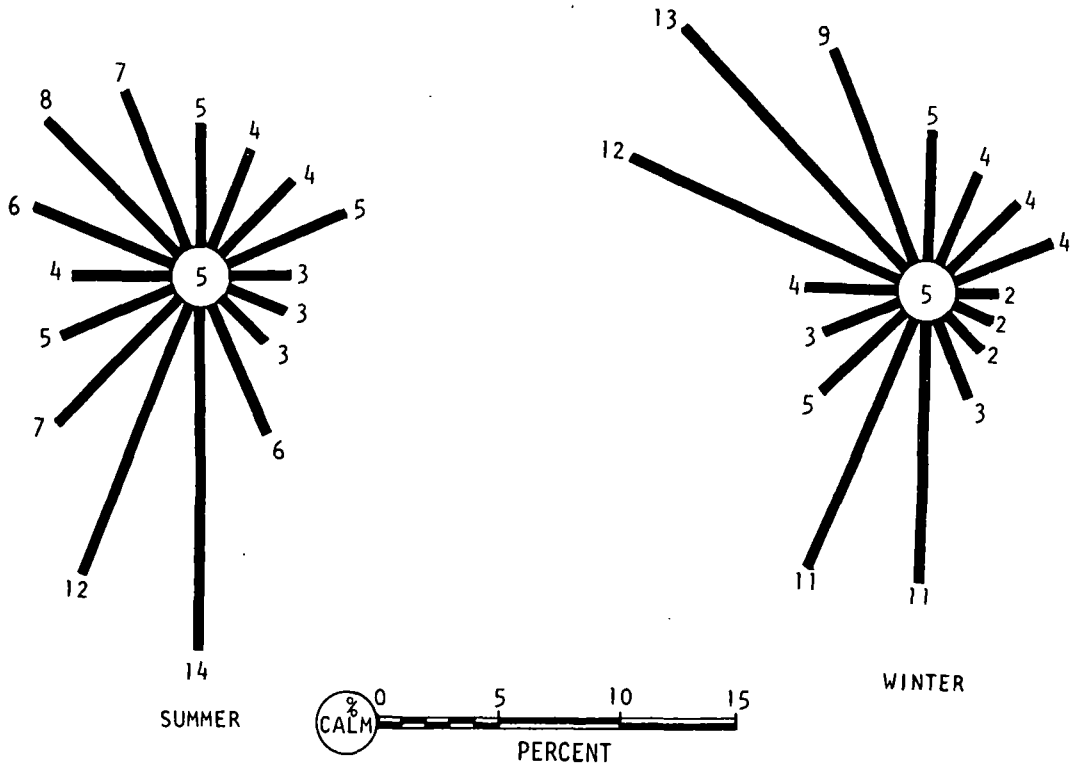
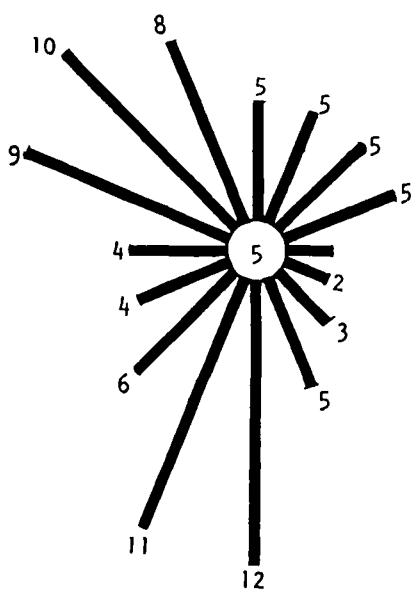


Figure 14. Percent frequency of wind direction for various averaging times, based on 1951-60 data from Washington's National Airport.



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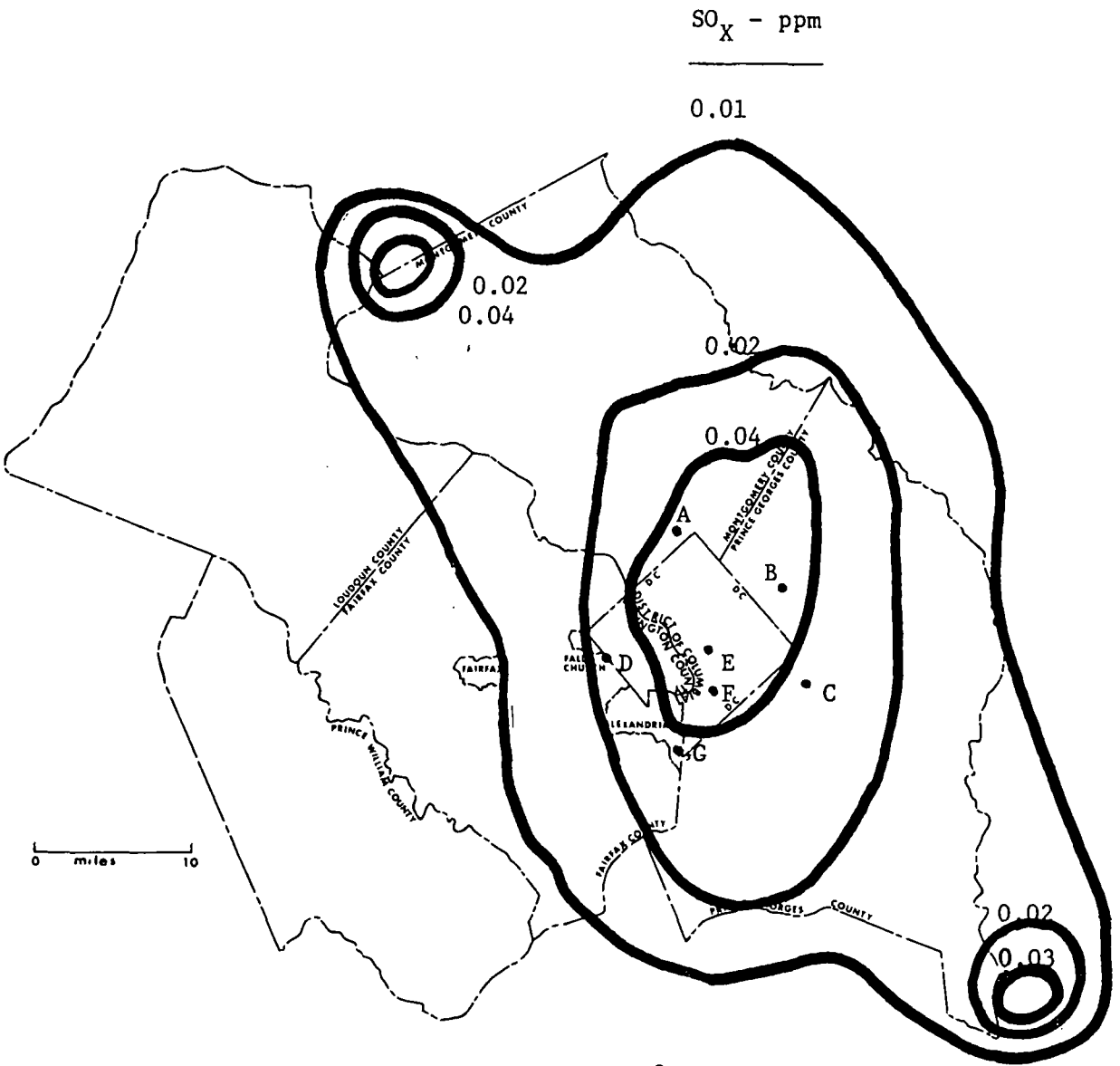
suspended particulates, respectively. The results for the latter two, however, are based on annual rather than winter conditions, since these conditions gave higher estimates of concentration than the other averaging times considered.

SULFUR DIOXIDE

Figures 1-3 in Appendix B shows the results of the diffusion model calculations for SO_2. Comparison with sampling data (Figure 15) suggests that the model over-estimates concentrations of this pollutant. This tendency to over-estimate SO_2 concentrations was assumed to result from the inability of this model in its present state to account for the degradation of SO_2 in the atmosphere into other sulfur compounds. Figure 15 incorporates a modification of the initial output of the model by applying an exponential decay factor involving an arbitrarily-assumed 6-hour half life. Comparison of the diffusion model results (as modified) with available monitoring data show the estimates to fall well within a factor of two of the measured concentrations.

The concentrations predicted by the model are interpreted generally as "above background" levels, since the model is not supplied with information on sources of the pollutant outside of the area initially surveyed. This is not considered an important factor with respect to SO_2, however, since background levels are generally low compared to the levels found in urban areas. The concentrations presented in Figure 15 can be viewed for the purposes of this report then as <u>total</u> SO_2 concentration.

Concentration contours are presented in Figure 15 down to a concentration of 0.01 ppm, the concentration at which human health effects



Aerometric Data[3] (above table)

STATION	CONCENTRATION, ppm
A	0.05
B	0.05
C	0.04
D	0.03
E	0.05
F	0.06
G	0.05

Figure 15. Estimated average winter day concentrations of SO_2 in ppm. Includes an assumed 6-hour half-life.

begin to occur. This contour line encloses all of the District of Columbia, Alexandria, Falls Church, Arlington County and Prince Georges County; most of Montgomery and Fairfax counties; and small portions of Loudoun County in Virginia and 5 bordering counties in Maryland. The encroachment of the 0.01 ppm contour into the 5 bordering Maryland counties has been discounted for one of two reasons: 1) two of the counties - Howard and Anne Arundel - are more intimately involved in the Baltimore than in the Washington urban area; 2) except for two large point sources of SO_2, the remaining three counties - Frederick, Calvert, and Charles - would be essentially unaffected by Washington area SO_2 sources. The Maryland portion of the region boundary would thus be coterminous with the outer reaches of Montgomery and Prince Georges counties. This decision is consistent with the recent regulation of the State of Maryland, in which these two counties were established as a region for air pollution control purposes.

CARBON MONOXIDE

The results of the diffusion model estimates of carbon monoxide concentrations on an annual basis are presented in Figures 4-6 in Appendix B. Aerometric data plotted on the same Figure indicate that the model routinely estimates concentrations 2 to 5 times lower than those reported at actual sampling sites. For the purpose of showing the pattern of CO levels, the model estimates are adequate; but choosing a cut-off level that has relevance in terms of those values routinely reported from sampling and those to be covered in the future criteria document is difficult because of the 2-5 factor mentioned above. The diffusion model does not reflect the built-up nature of the area in which most of

the CO is emitted and thus assumes that the pollutant has more immediate space and volume within which to disperse. Until the air into which the pollutant is being emitted moves away from the built-up part of the urban area, the pollutant is channeled through streets and around buildings. This fact is assumed to cause most of the discrepancy between estimated and measured concentrations of CO.

Based on the 2-5 difference, an average factor of 3.5 was applied to the diffusion model estimates to give "equivalent" CO concentrations. The resulting estimate of CO levels is shown in Figure 16. Contours have been plotted for 6, 4, 2, and 1 ppm of the pollutant. The results are shown only for annual conditions since there is little seasonal variation in the rate of CO emissions. Available information on CO indicates that an annual average concentration of one part per million is indicative of conditions which begin to affect people. Using this level as a guide to the region boundary, we arrive at essentially the same conclusion as in the case of SO_2. Even though the 1 ppm CO contour is slightly less encompassing that the 0.01 ppm SO_2 contour, they both suggest that the same major jurisdictions should be included in the region.

The results for CO reflect the prevailing wind direction toward the northeast, raising the question fo the relative air pollution impact of the Washington and Baltimore urban centers on each other and the possibility that they should be combined into one air quality control region. Diffusion model estimates of CO concentrations were chosen as a means to evaluate this possibility. An emission inventory for CO was conducted for the Baltimore urban area and subjected to diffusion model calculations extending to the center of the Washington, D.C. urban area. On an annual average

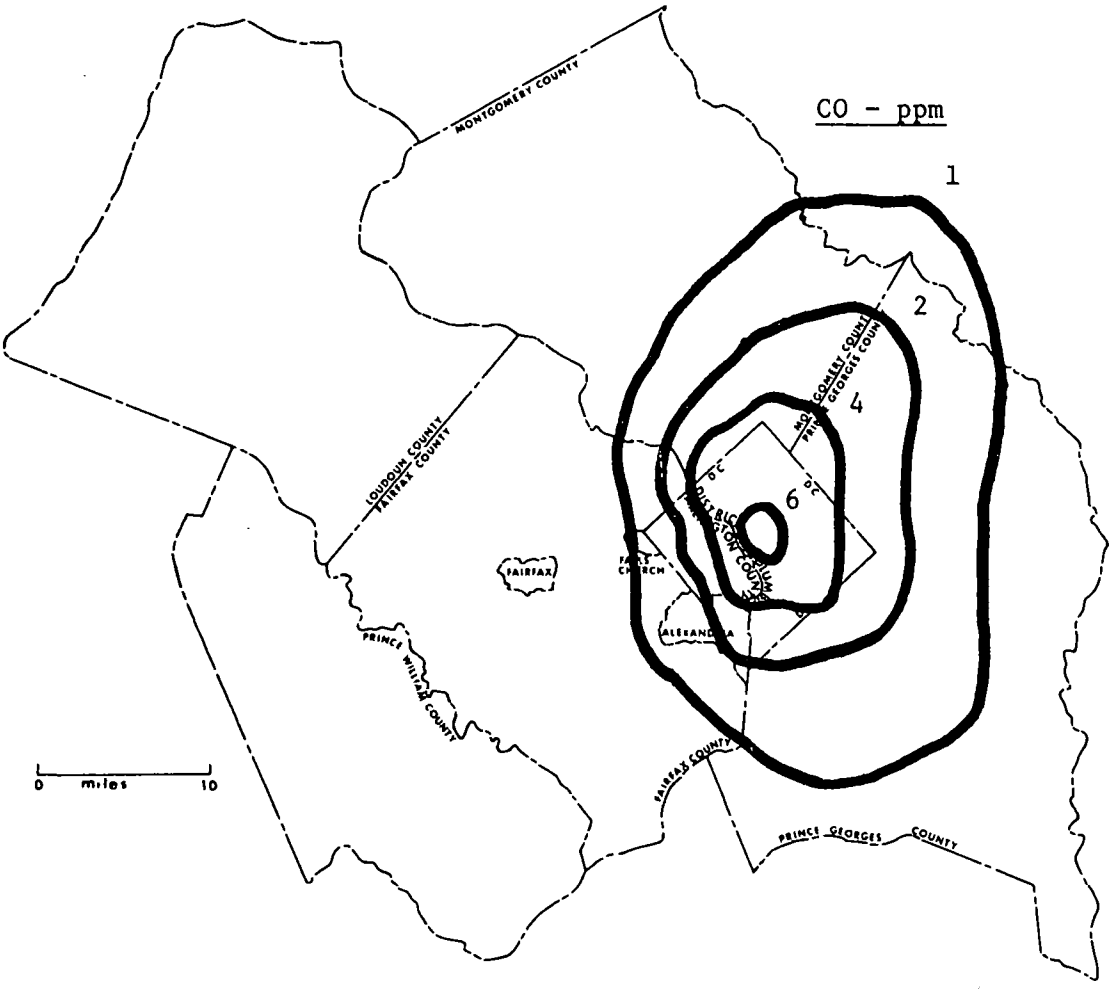


Figure 16. Equivalent carbon monoxide concentrations based on average annual emission levels.

basis, only one per cent of the CO measured at downtown Washington is predicted to come from Baltimore sources. In like manner, less than 7 per cent of the CO measured in Baltimore is predicted to emenate from Washington area sources.

It is recognized that under more critical, short-time-period meteorological conditions, the impact of these two urban areas on each other would be greater than that predicted on an annual average basis, but the designation of regions large enough to encompass the problem area during the less frequent occurrence of the higher concentrations would place undue hardship on the administering agency. Day-to-day air pollution control efforts in a region defined on the basis of long-term average conditions will tend to reduce the impact of sources in the region on the surrounding area. The "overlap" left untouched by this approach is more appropriately left to coordination between adjoining air quality control regions. The implementation plans of proximately-located air quality control regions should provide this needed coordination as part of their emergency action procedures.

There will always be a likelihood of sources of pollution just beyond the boundary selected for the region that contribute to air pollution levels in the region. As considerable as the impact of such a source might be, it may not warrant the inclusion of an additional whole county in the region. This situation should be treated whenever it occurs in the implementation plans for the region being affected by the source(s).

SUSPENDED PARTICULATES

The diffusion model estimates of suspended particulate concentrations are presented in Figure 17. However, the results do not include an

Suspended Particulates- g/M^3

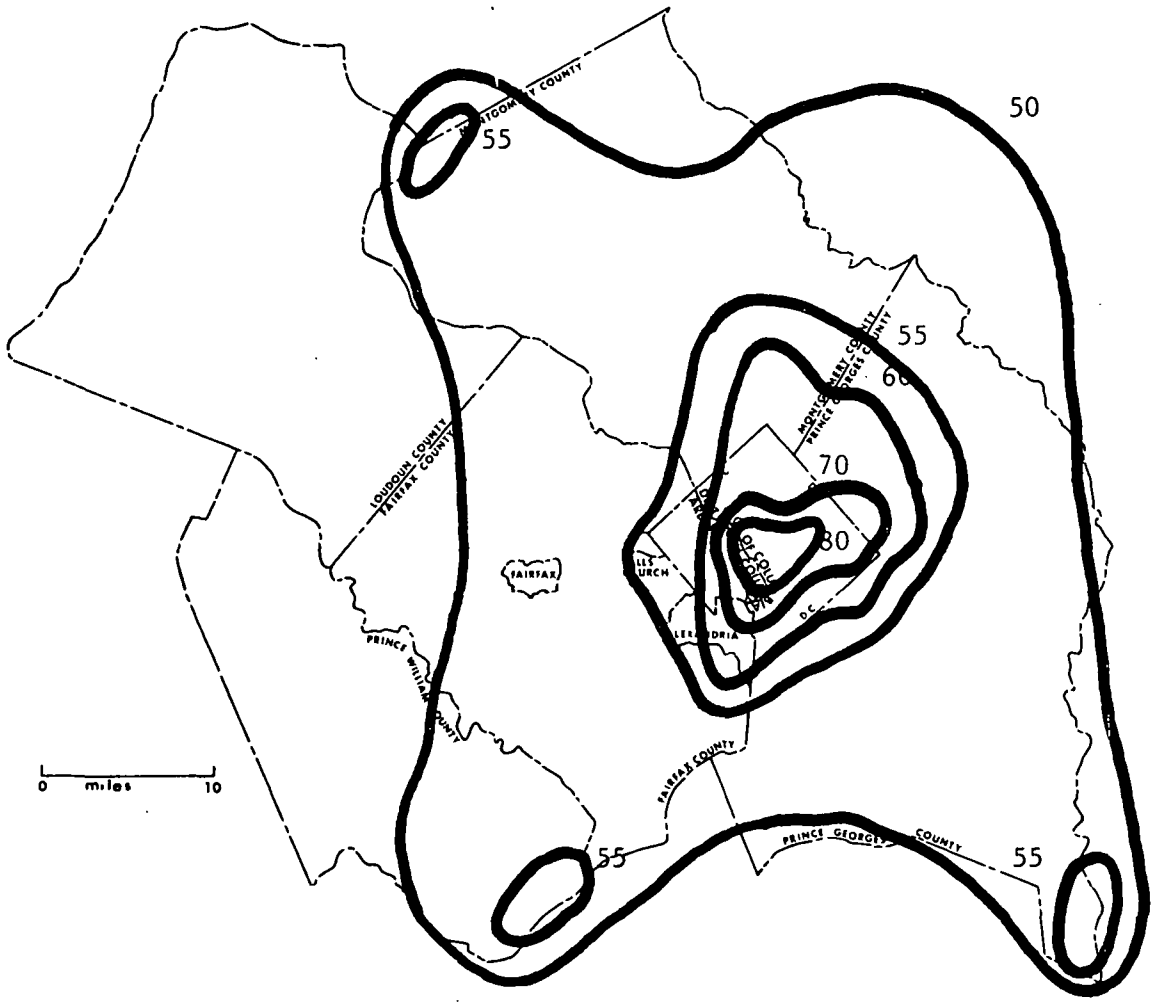


Figure 17. Estimated annual average concentrations of suspended particulates, above background, no deposition.

allowance for background concentrations, and they are based on an emission inventory that estimates total particulate emissions. The first would cause the model estimates to be lower than measured concentrations, and the second would cause the estimates to be higher than measured concentrations of suspended particulates. The close correlation between the model estimates and measured concentrations (Table 4) suggests that the two factors not incorporated in Figure 17 essentially compensate one another.

Although the results from the model calculations can be interpreted literally, they are just as meaningful for our purposes when interpreted in a relative sense. In Figure 18, the "relative" concentrations are plotted versus location along the east-west and the north-south axes of the urban area; also shown are the boundary locations along the axes for the jurisdictional entities. The graph for the north-south axis shows that the relative impact of particulate pollution sources within the region is insignificant at the outer edge of Prince Georges County to the south and Montgomery County to the north. Similarly, the east-west concentration profile shows that the relative impact is insignificant at the outer edge of Fairfax County to the west and Prince Georges County to the east. Taken together, these findings suggest that the Maryland counties of Montgomery and Prince Georges, the Virginia counties of Arlington and Fairfax, the Virginia cities of Fairfax, Falls Church, and Alexandria should be included in the air quality control region along with the District of Columbia. This conclusion is consistent with those based on SO_2 and CO analyses.

Table 4. Relationship of diffusion model results for suspended particulates to aerometric data.

Station Number[a]	Location	Concentration, mg/M^3		Ratio, Estimated to Measured
		Estimated	Measured	
14	Cheverly	70	78	0.90
15	Hyattsville	70	97	0.72
21	Alexandria	65	70	0.93
33	CAMP	100	101	1.00
41	Nat'l Airport	78	71	1.10
46	Seven Corners	58	61	0.95
58	NIH	60	65	0.93
59	Suitland	70	86	0.82

Average Ratio = 0.92

[a] See Reference 3 for exact location

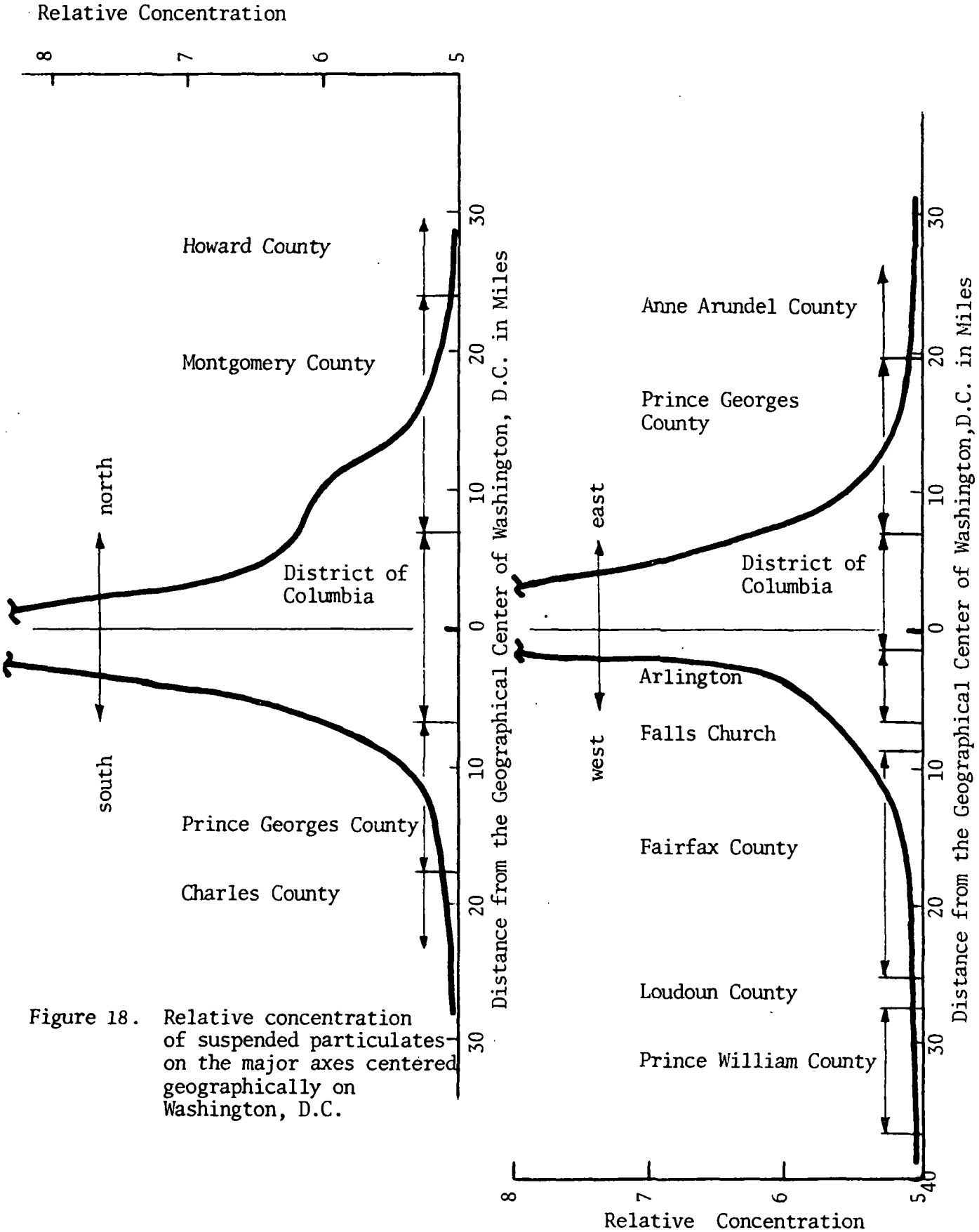


Figure 18. Relative concentration of suspended particulates on the major axes centered geographically on Washington, D.C.

References

1. Clean Air Act, 42USC 1857 et. seq. Section 107 (a) (2)

2. Statistics - Washington Metropolitan Area. Metropolitan Washington Council of Governments, Washington, D. C., pp. 138-9. January, 1968.

3. Technical Report, Washington, D. C. Metropolitan Area Air Pollution Abatement Activity USDHEW, PHS. November, 1967.

4. Technical Report, Washington, D. C. Metropolitan Area Air Pollution Abatement Activity. USDHEW, PHS. pp. 54-97, and C-1 through C-12. November, 1967

5. Pasquill, F. The estimation of the dispersion of windborne material, Meteorology Magazine, 90: 33-49. 1963.

6. Turner, D. B.; Workbook of Atmospheric Dispersion Estimates. PHS Publication No. 999-AP-26, 84 pp. National Center for Air Pollution Control, Cincinnati, Ohio. 1967.

7. Martin, D. O., A general atmospheric diffusion model for estimating the effects on air quality of one or more sources; Paper No. 68-148, 61st Annual Meeting, APCA, St. Paul, Minnesota. June, 1968.

8. Technical Report, Washington, D. C. Metropolitan Area Air Pollution Abatement Activity. National Center for Air Pollution Control, DHEW. Cincinnati, Ohio. pp. 11-20. November, 1967.

9. U. S. Weather Bureau data.

10. Technical Report, Washington, D. C. Metropolitan Area Air Pollution Abatement Activity. National Center for Air Pollution Control, DHEW. Cincinnati, Ohio. pp. 27-36. November, 1967.

11. Air Quality Criteria for Sulfur Oxides. PHS, DHEW, March, 1967.

A P P E N D I C E S

Appendix A. Emission Inventory Procedure and Results

Appendix B. Diffusion Model Description & Results

Appendix C. Demographic Data

APPENDIX A. EMISSION INVENTORY PROCEDURE

The recent conduct of an emission inventory as part of the Washington, D.C. Interstate Abatement Action[1] provided the information on emissions necessary to study the area prior to the designation of an air quality control region. The initial data were compiled during the 2-month period from February through March 1967. The Public Health Service rapid survey technique for emission inventories was used.[2] The inventory consisted of evaluating the consumption of gasoline, diesel fuel, coal, fuel oil, and natural gas and of determining emissions from refuse incineration, process industries, auto burning, aircraft flights, and evaporative losses. Emissions were determined directly from the fuel imput to the equipment for both automotive and stationary sources. Control equipment was also taken into account for emissions from coal combustion and process sources. Emission factors and average sulfur and ash contents are listed in table A-9. The general emission factors used were obtained from Public Health Service and New York State publications[3,4] and from various PHS staff estimates.

Annual consumption of all fuels and annual process emissions in each zone were determined for the years 1965 and 1966. Daily emissions were calculated for minimum, average, and maximum space-heating days and are reported in tables A-1 through A-4 as tons of pollutant per square mile. Tables A-5 through A-7 summarize the estimates of annual emissions of sulfur oxides, carbon monoxide, and particulates by source category and political jurisdiction.

The emission data were converted to show mean-day emissions for annual, winter, and summer seasons (Table A-8) to facilitate diffusion

model calculations of mean-day concentration for each of the three seasons. The conversion was accomplished by apportioning variable emissions to each of the seasons in accordance with information on monthly heating-degree days and then calculating the average-day emissions for each season.

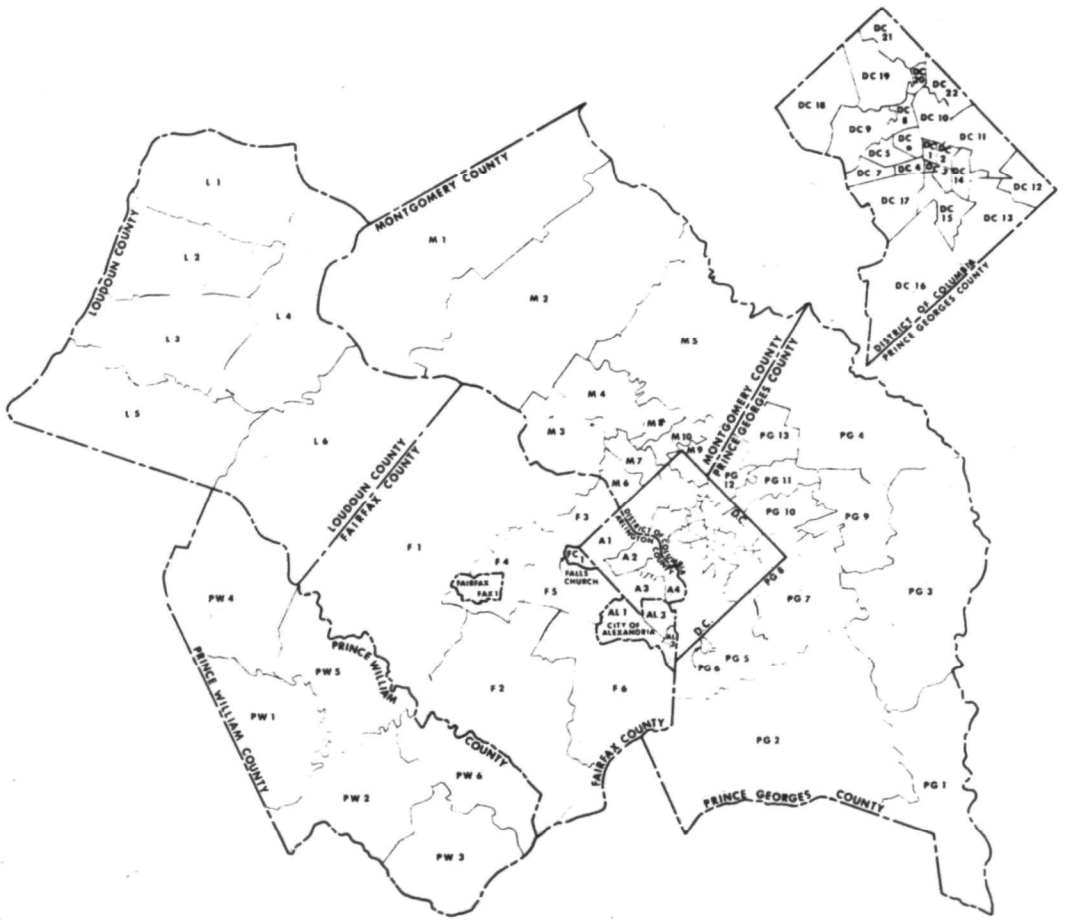


Figure A-1. Emission inventory zones.

Table A-1

Emission Densities on Minimum, Average, and Maximum Space-Heating Days for District of Columbia

Zone	Area, mi^2,	Sulfur oxides, tons/day-mi^2			Particulates, tons/day-mi^2			Carbon monoxide tons/day-mi^2
		Min.	Avg.	Max.	Min.	Avg.	Max.	Avg.
DC-1	0.7	0.2	6.1	8.5	0.3	1.0	1.9	48.3
DC-2	0.7	0.8	4.5	8.7	0.4	0.9	1.5	33.2
DC-3	0.8	0.3	2.4	6.6	0.3	0.6	0.8	53.7
DC-4	0.6	0.5	10.3	24.0	0.7	1.3	2.2	106.9
DC-5	0.8	0.7	12.8	30.1	0.5	1.3	2.3	87.9
DC-6	1.1	0.9	2.2	14.5	0.4	1.0	1.9	48.1
DC-7	1.0	0.5	4.7	10.6	0.4	0.6	1.0	63.0
DC-8	1.4	1.0	5.4	11.6	0.2	0.8	1.3	21.4
DC-9	3.5	0.3	4.5	10.5	0.3	0.6	1.0	16.1
DC-10	2.0	0.1	4.5	10.8	0.2	0.4	0.7	19.8
DC-11	7.0	6.1	5.8	7.5	2.2	2.1	2.2	16.0
DC-12	3.3	0.1	1.2	2.8	0.1	0.2	0.3	5.0
DC-13	5.6	Neg.	1.0	2.3	0.1	0.1	0.2	8.4
DC-14	1.1	0.1	3.1	6.6	0.2	0.5	0.9	14.5
DC-15	1.4	25.9	22.3	37.3	2.6	3.1	4.5	19.9
DC-16	6.4	0.1	2.7	6.3	0.1	0.2	0.5	6.8
DC-17	2.4	0.2	10.3	24.6	0.1	1.1	2.4	22.4
DC-18	5.0	0.1	0.8	1.8	0.1	0.1	0.2	7.2
DC-19	5.6	0.4	2.3	5.0	0.1	0.2	0.3	9.0
DC-20	1.8	0.2	1.5	3.2	0.1	0.3	0.6	11.8
DC-21	5.2	0.1	1.3	3.0	0.1	0.1	0.2	8.0
DC-22	4.0	Neg.	1.8	4.1	0.4	0.5	0.6	10.3

Table A-2

Emission Densities on Minimum, Average, and Maximum Space-Heating Days for Montgomery and Prince Georges Counties

Zone	Area, mi^2	Sulfur oxides, tons/day-mi^2			Particulates, tons/day-mi^2			Carbon monoxide, tons/day-mi^2
		Min.	Avg.	Max.	Min.	Avg.	Max.	Avg.
M-1	169.2	1.0	1.0	1.0	0.1	0.1	0.1	0.2
M-2	119.8	Neg.	Neg.	0.1	Neg.	Neg.	Neg.	0.3
M-3	25.4	Neg.	0.1	0.2	Neg.	Neg.	Neg.	1.3
M-4	27.0	0.1	0.2	0.4	0.1	0.1	0.1	4.7
M-5	100.3	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	1.0
M-6	10.5	0.1	0.3	0.6	Neg.	0.1	0.1	3.7
M-7	11.7	0.1	0.1	1.3	0.1	0.1	0.2	5.7
M-8	8.3	0.1	0.3	0.7	Neg.	0.1	0.1	4.7
M-9	6.6	0.2	0.8	1.8	0.1	0.2	0.3	10.0
M-10	7.7	0.1	0.9	2.0	0.1	0.1	0.2	7.2
PG-1	69.2	3.0	2.0	1.6	0.1	0.1	0.1	0.3
PG-2	126.2	Neg.	0.1	0.1	Neg.	Neg.	Neg.	0.5
PG-3	101.3	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.5
PG-4	78.6	Neg.	0.2	0.3	Neg.	Neg.	0.1	0.9
PG-5	20.0	Neg.	0.1	0.3	Neg.	Neg.	0.1	4.3
PG-6	0.7	0.2	1.9	4.3	0.1	0.2	0.5	8.3
PG-7	25.9	Neg.	0.3	0.6	Neg.	Neg.	0.1	3.8
PG-8	3.0	0.2	0.7	1.4	0.1	0.2	0.3	5.2
PG-9	28.4	Neg.	0.1	0.2	0.1	0.1	0.1	3.1
PG-10	11.0	0.1	0.5	1.1	0.2	0.2	0.2	6.6
PG-11	5.8	0.2	0.7	1.4	0.1	0.2	0.2	10.0
PG-12	6.0	0.2	0.9	1.9	0.1	0.2	0.3	6.5
PG-13	11.7	0.1	0.6	1.5	Neg.	0.4	0.7	3.6

Table A-3

Emission Densities on Minimum, Average, and Maximum Space-Heating Days for Arlington, Fairfax, Loudoun, and Prince William Counties

Zone	Area mi^2	Sulfur oxides, tons/day-mi^2			Particulates, tons/day-mi^2			Carbon monoxide, tons/day-mi^2
		Min.	Avg.	Max.	Min.	Avg.	Max.	Avg.
A-1	9.8	Neg.	0.4	0.8	Neg.	0.1	0.2	4.2
A-2	4.4	0.3	2.0	4.4	0.1	0.3	0.4	11.8
A-3	7.5	0.3	1.7	3.5	0.3	0.3	0.4	28.9
A-4	4.1	0.1	2.1	4.8	0.3	0.6	1.1	27.5
F-1	185.1	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.5
F-2	84.2	Neg.	Neg.	0.1	Neg.	Neg.	0.1	1.0
F-3	14.9	Neg.	0.2	0.5	Neg.	Neg.	0.1	2.2
F-4	21.1	Neg.	0.1	0.2	Neg.	Neg.	Neg.	2.2
F-5	23.2	0.1	0.3	0.7	0.1	0.1	0.1	3.8
F-6	63.0	Neg.	0.2	0.4	Neg.	0.1	0.1	1.5
L-1	64.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.2
L-2	67.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.1
L-3	72.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.1
L-4	80.5	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.2
L-5	107.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.1
L-6	128.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.1
PW-1	56.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.3
PW-2	71.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.4
PW-3	55.6	0.8	0.8	0.8	0.1	0.1	0.1	0.3
PW-4	0.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.4
PW-5	67.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.5
PW-6	48.0	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.	0.2

Table A-4

Emission Densities on Minimum, Average, and Maximum Space-Heating Days for Cities of Alexandria, Fairfax, and Falls Church

Zone	Area, mi^2	Sulfur Oxides, tons/day-mi^2			Particulates, tons/day-mi^2			Carbon monoxide, tons/day-mi^2
		Min.	Avg.	Max.	Min.	Avg.	Max.	Avg.
AL-1	9.0	0.2	1.0	2.1	0.3	0.3	0.5	7.6
AL-2	1.5	0.3	2.2	4.9	0.3	0.5	0.7	36.8
AL-3	5.2	11.5	9.9	11.1	0.5	0.5	0.6	12.7
FAX-1	2.6	0.1	0.5	0.9	0.2	0.3	0.4	26.6
FC-1	2.0	0.1	0.2	0.9	0.1	0.2	0.3	13.5

Table A-5

SULFUR OXIDE (SO_x)[a] EMISSIONS IN WASHINGTON, D. C. METROPOLITAN AREA, 1965 - 1966

TONS/YEAR

COUNTY OR CITY	GRAND Total	EMISSIONS BY SOURCE CATEGORY FROM FUEL BURNING					REFUSE DISPOSAL (ALL CATEGORIES)
		RESIDENTIAL	COMMERCIAL & GOVERNMENTAL	INDUSTRIAL	POWER PLANTS	TRANSPORTATION	
District of Columbia	60,412	10,372	31,034	1,662	15,711	1,233	400
Montgomery County	69,160	3,598	4,961	1,157	58,555	684	205
Prince Georges County	63,656	4,349	7,116	1,510	49,866	776	39
Maryland Subtotal	132,816	7,947	12,077	2,667	108,421	1,460	244
Arlington County	7,917	3,586	3,784	143	--	310	94
Fairfax County [b]	8,670	1,807	5,502	732	--	593	36
Loudoun County	512	211	201	30	--	62	8
Prince William County	15,850	251	285	34	15,123	139	18
Alexandria City	20,940	2,037	1,781	348	16,494	213	67
Virginia Subtotal	53,889	7,892	11,553	1,287	31,617	1,317	223
Area Total	247,117	26,211	54,664	5,616	155,749	4,010	867

[a] Reported as sulfur dioxide (SO_2)

[b] Includes cities of Fairfax and Falls Church, Virginia

Table A-6

CARBON MONOXIDE (CO) EMISSIONS IN WASHINGTON, D. C. METROPOLITAN AREA, 1965 - 1966

TONS/YEAR

COUNTY OR CITY	GRAND TOTAL	EMISSIONS BY SOURCE CATEGORY					
		FROM FUEL BURNING					REFUSE DISPOSAL (ALL CATEGORIES)
		RESIDENTIAL	COMMERCIAL & GOVERNMENTAL	INDUSTRIAL	POWER PLANTS	TRANSPORTATION	
District of Columbia	357,074	770	1,133	13	123	349,664	5,371
Montgomery County	219,846	407	228	7	348	218,527	329
Prince Georges County	254,625	491	204	9	326	252,423	1,172
Maryland Subtotal	474,471	898	432	16	674	470,950	1,501
Arlington County	102,964	93	166	1	--	102,108	596
Fairfax County[a]	190,284	67	697	11	--	188,824	685
Loudoun County	20,689	9	15	Neg.	--	20,585	80
Prince William County	44,641	13	5	Neg.	206	43,679	738
Alexandria City	68,553	146	92	2	199	67,117	997
Virginia Subtotal	427,131	328	975	14	405	422,313	3,096
Area Total	1,258,676	1,996	2,540	43	1,202	1,242,927	9,968

[a] Including the cities of Fairfax and Falls Church

Table A-7

PARTICULATE EMISSIONS IN WASHINGTON, D. C. METROPOLITAN AREA, 1965 - 1966

TONS/YEAR

COUNTY OR CITY	GRAND TOTAL	EMISSIONS BY SOURCE CATEGORY						
		FROM FUEL BURNING					INDUSTRIAL PROCESSES	REFUSE DISPOSAL (ALL CATEGORIES)
		RESIDENTIAL	COMMERCIAL & GOVERNMENTAL	INDUSTRIAL	POWER PLANTS	TRANSPORTATION		
District of Columbia	11,129	1,024	2,211	100	1,184	1,953	151	4,506
Montgomery County	6,531	534	360	51	4,159	982	45	400
Prince Georges County	7,747	620	1,846	65	2,253	1,350	734	879
Maryland Subtotal	14,278	1,154	2,206	116	6,412	2,332	779	1,279
Arlington County	1,883	251	429	17	--	639	18	529
Fairfax County	2,554	320	810	89	--	648	40	647
Loudoun County	327	45	19	1	--	165	--	97
Prince William County	2,455	61	38	5	1,685	199	1	466
Alexandria City	2,164	311	138	23	631	309	121	631
Virginia Subtotal	9,383	988	1,434	135	2,316	1,960	180	2,370
Area Total	34,790	3,166	5,851	351	9,912	6,245	1,110	8,155

Table A-8. Mean Day Emissions for Various Averaging Times
(Tons)

County or City	Sulfur Dioxide			Carbon Monoxide			Particulates		
	Annual	Winter	Summer	Annual	Winter	Summer	Annual	Winter	Summer
District of Columbia	175	281	90	978	861	1,046	30	43	25
Montgomery Co.	189	208	177	602	530	644	18	20	17
Prince Georges Co.	179	202	198	698	614	747	21	24	22
Maryland Subtotal	368	410	375	1,300	1,144	1,391	39	44	39
Arlington Co.	22	49	4	282	248	302	5	8	4
Fairfax Co.	17	38	3	521	458	557	7	12	6
Loudoun Co.	2	3	-	57	50	61	1	1	1
Prince William Co.	43	43	43	122	107	131	7	7	7
Alexandria City	63	65	62	188	165	201	6	7	6
Virginia Subtotal	147	198	112	1,170	1,028	1,252	26	35	24
Area Totals	690	889	577	3,448	3,033	3,689	95	122	88

Table A-9. GENERAL EMISSION FACTORS [1]

(tons/unit[a])

Source	SO_x	NO_x	Particulate	CO	HC
Residual oil (1,000 hp or more)	0.203[b]	0.052	0.004	Neg.	0.0016
Residual oil (1,000 hp or less)	0.203[b]	0.036	0.006	0.001	0.001
Distillate oil (1,000 hp or more)	0.024[b]	0.052	0.004	Neg.	0.0016
Distillate oil (1,000 hp or less)	0.024[b]	0.036	0.006	0.001	0.001
Anthracite coal (residential)	0.011[b]	0.004	0.010[c]	0.025	0.005
Anthracite coal (Commercial, Governmental)	0.011[b]	0.004	0.025[c]	0.025	0.005
Bituminous coal (Residential, commercial, Governmental)	0.019[b]	0.004	0.018[c]	0.025	0.005
Bituminous coal (industrial)	0.019[b]	0.010	0.018[c]	0.002	0.0005
Natural gas (Residential, commercial, Governmental)	0.0002	0.058	0.010	0.0002	Neg.
Natural gas (industrial)	0.0002	0.107	0.009	0.0002	Neg.
Gasoline	0.004	0.057	0.005	1.455	0.262
Diesel oil	0.020	0.111	0.055	0.030	0.090
Aircraft	(d)	(d)	(d)	(d)	(d)
Open-burning dump	0.0006	0.0003	0.024	0.043	0.040
Municipal incinerator	0.001	0.001	(e)	0.0004	0.0007
Residential, commercial, Governmental, industrial incineration	0.0002	0.0008	0.010	0.013	0.018
Backyard paper burning	0.0006	0.0003	0.002	-	0.073
Gasoline evaporation	-	-	-	-	0.060
Solvent losses (dry cleaning)	-	-	-	-	1.95

[a] Fuel oil, gasoline, and diesel fuel, 1,000 gallons; coal, tons; natural gas, 10 cubic feet; refuse, tons; dry cleaning, 1,000 people.

[b] Dependent on sulfur content of fuel: residential oil, 2.55% S; distillate oil, 0.3% S; anthracite coal, 0.6% S; bituminous coal, 1.0% S.

[c] Dependent on ash content of coal, type of firing unit, and type of control: anthracite coal, 10.0% A; bituminous coal, 7.0% A.

[d] Dependent on type of aircraft, see References 1 and 3 of this appendix.

[e] Dependent on type of control; see Reference 1 of this appendix.

References for Appendix A.

1. Technical Report, Washington, D. C. Metropolitan Area Air Pollution Abatement Activity. pp. 54-97, C-1 through C-12. November, 1967

2. Ozolins, G. and Smith R., Rapid Survey Technique for Estimating Community Air Pollution Emissions. Public Health Service, Publication No. 999-AP-29, Environmental Health Series, USDHEW, NCAPC, Cincinnati, Ohio, October 1966.

3. Mayer, M., A Compilation of Air Pollution Emission Factors for Combustion Processes, Gasoline Evaporation, and Selected Industrial Processes. USDHEW, PHS, DAP, TAB, Cincinnati, Ohio, May 1965.

4. Procedure for Conducting Comprehensive Air Pollution Surveys. New York State Department of Health, Bureau of Air Pollution, Control Services. Albany, New York. August 18, 1965.

APPENDIX B. DIFFUSION MODEL DESCRIPTION AND RESULTS

Title I, Section 107 (a) (2) of the Air Quality Act of 1967 (Public Law 90-148, dated November 21, 1967), calls for the designation of air quality control regions, based on a number of factors, including "atmospheric conditions," interpreted to mean that the boundaries of air quality control regions should reflect the technical aspects of air pollution and its dispersion. Within this guideline, however, the position has been taken that region boundaries cannot be seasonally dependant, nor should the boundaries be based on an extreme set of circumstances which might have a theoretical chance of occurrence. Hence the analysis of a region's atmospheric dilution potential is largely based on mean annual values, although summer and winter mean values are analyzed with respect to reviewing seasonal variations in meteorology and pollutant emissions.

With the realization that the meteorological analysis would help define tentative boundaries only and that final boundaries would be developed subsequently to reflect local governmental aspects, it was decided that the meteorological assessment should be as unpretentious as possible. Accordingly, the widely accepted long-term Gaussian diffusion equation, described by Pasquill[1], has been applied with a few modifications to accommodate certain requirements inherent to the delineation of regions. These modifications are discussed in the next section. In summary, the Gaussian diffusion equation is utilized to provide a geographical distribution of long-period mean ground-level concentrations of SO_2, CO, and particulates. The model used has the necessary flexibility to utilize information on emissions from both point and area-wide sources.

The assignment of emission data on an equivalent area basis also permits an analysis of the discrete effects from respective political jurisdictions, utilizing respective source inventories; this technique was used to determine the relative impact of Washington, D. C., and Baltimore, Maryland, on each other, as discussed earlier in this report.

To maintain simplicity, all pollutant sources were assumed to be at ground level; for CO this assumption is realistic. The same assumption is used for major point sources of SO_2 and particulates, since the distances of interest are sufficiently great to obviate the source-height effect for most receptors. The ground-level concentrations of SO_2 in the vicinity of the two large point sources of SO_2 (northwest Montgomery County and southeast Prince Georges County) are probably over-estimated by not considering stack height, making it necessary to discount the results in those two instances. Also, since there is no agreement to what constitutes an appropriate half-life and deposition rate for SO_2 and particulates, respectively, these factors were not applied to the computation of ground-level pollutant concentrations during the diffusion model analysis. As discussed earlier in the report (page 31) and briefly below, certain modifications have been applied to the model results to allow comparative interpretation.

Methodology

The diffusion model used to compute long-term average pollutant concentration distributions for respective pollutants is based on Pasquill's Gaussian diffusion equation[1], as modified by Martin[2]. Essentially, the diffusion model sums the effects (ground-level concentration) of a number of sources (area and point) for a specified number of receptors, averaged over a season or a year; the receptor points are at

distances of 20, 30, 40, 50, 70, and 100 kilometers from a defined central grid point for each of 16 compass directions. An average pollutant concentration is computed for the central grid receptor (designated in the downtown or central city area) for comparison to air quality measurements that might be available.

The meteorological data input to the model is screened to determine the representativeness of the data. Appropriate surface wind rose data are selected from U. S. Weather Bureau records; if necessary, special wind data tabulations are obtained from the National Weather Records Center (NWRC). The mean mixing depth for each region, for each respective time period (seasonal or annual), is determined on the basis of computed mixing depths documented by Holzworth (4,5) and recent tabulations furnished the Meteorological Program by NWRC.

Results

A comparison of calculated concentrations of CO to air quality data for Washington, D. C., shows reasonable agreement in relative terms, but the model consistently underestimates the concentration in comparison to measured values in the central urban area[6]. As is discussed in the text of this report, an empirically-derived correction factor has been applied to the model output to allow comparative use of the CO data.

For SO_2 the model has yielded a systematic over-calculation when compared to measured concentrations. This over-calculation is thought to result primarily from the fact that SO_2, an active gas, reacts in the atmosphere, leading to concentrations lower than those predicted by the model. As discussed in the body of this report, a "decay factor" has been applied to the model output to compensate for this difference. The

decay factor used here is based on an arbitrary assumption of a six-hour half-life for SO_2. In current work on additional regions the impact of varying assumptions on half-life is being analyzed.

For suspended particulates, the model gave unexpectedly good results when the finite values were compared to measured concentrations. The good correlation, however, is the result of two apparently compensating limitations of the model. The source term for particulates includes total emissions; as a result, the model treats settleable particulates as suspended and thus overestimates the concentration. At the same time the source term does not allow for sources outside the area under study, and the model estimates as a result do not include the incoming or background concentration. Because of these limitations, the model estimates for suspended particulates are interpreted in this report only in a relative sense.

Figures B-1 through B-7 present the unmodified results of the dif-calculations for SO_x and CO for the three time periods investigated and for suspended particulates on an annual basis.

While limitations inherent in the model are recognized, the model results can be appropriately modified and interpreted to provide reasonable spatial distributions of long-term (seasonal and annual) average pollutant concentrations, resulting from the respective source emissions (inventory provided) originating from within a region. The reliance upon existing jurisdictional arrangements in arriving at final region boundaries provides a certain geographical latitude within which the diffusion model results can fall without significantly altering the final outcome.

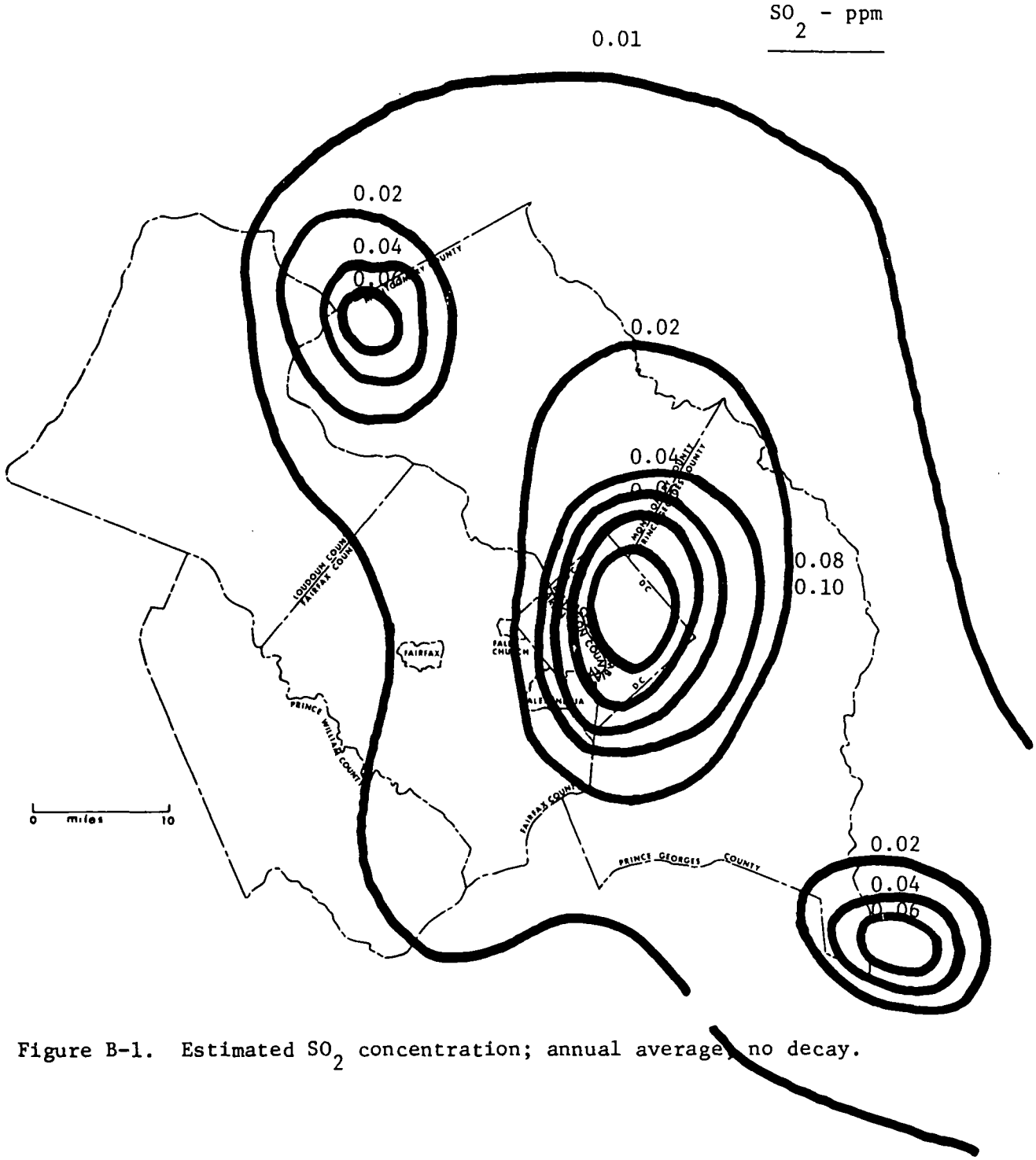


Figure B-1. Estimated SO_2 concentration; annual average, no decay.

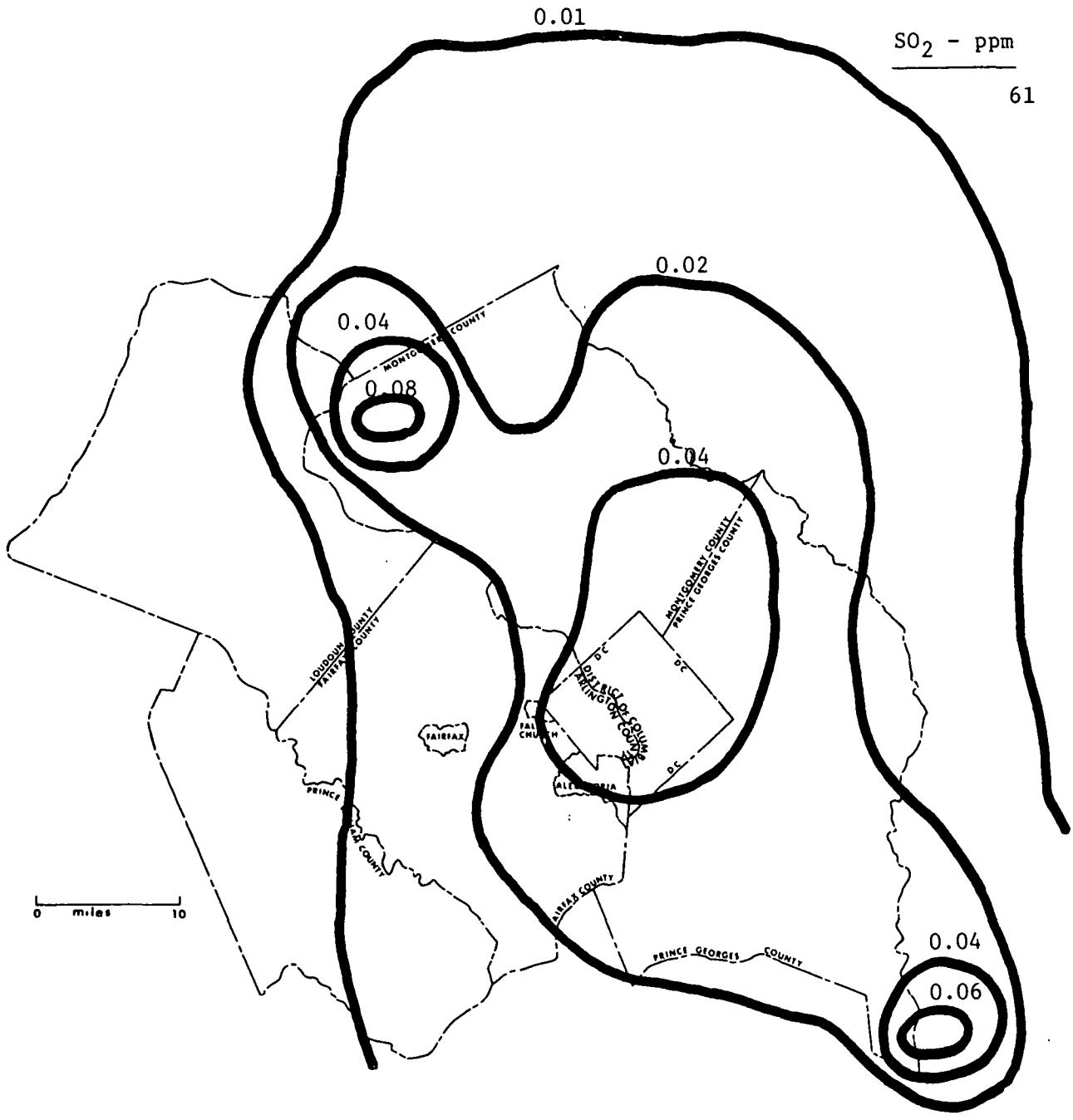


Figure B-2. Estimated SO_2 concentration; winter average; no decay.

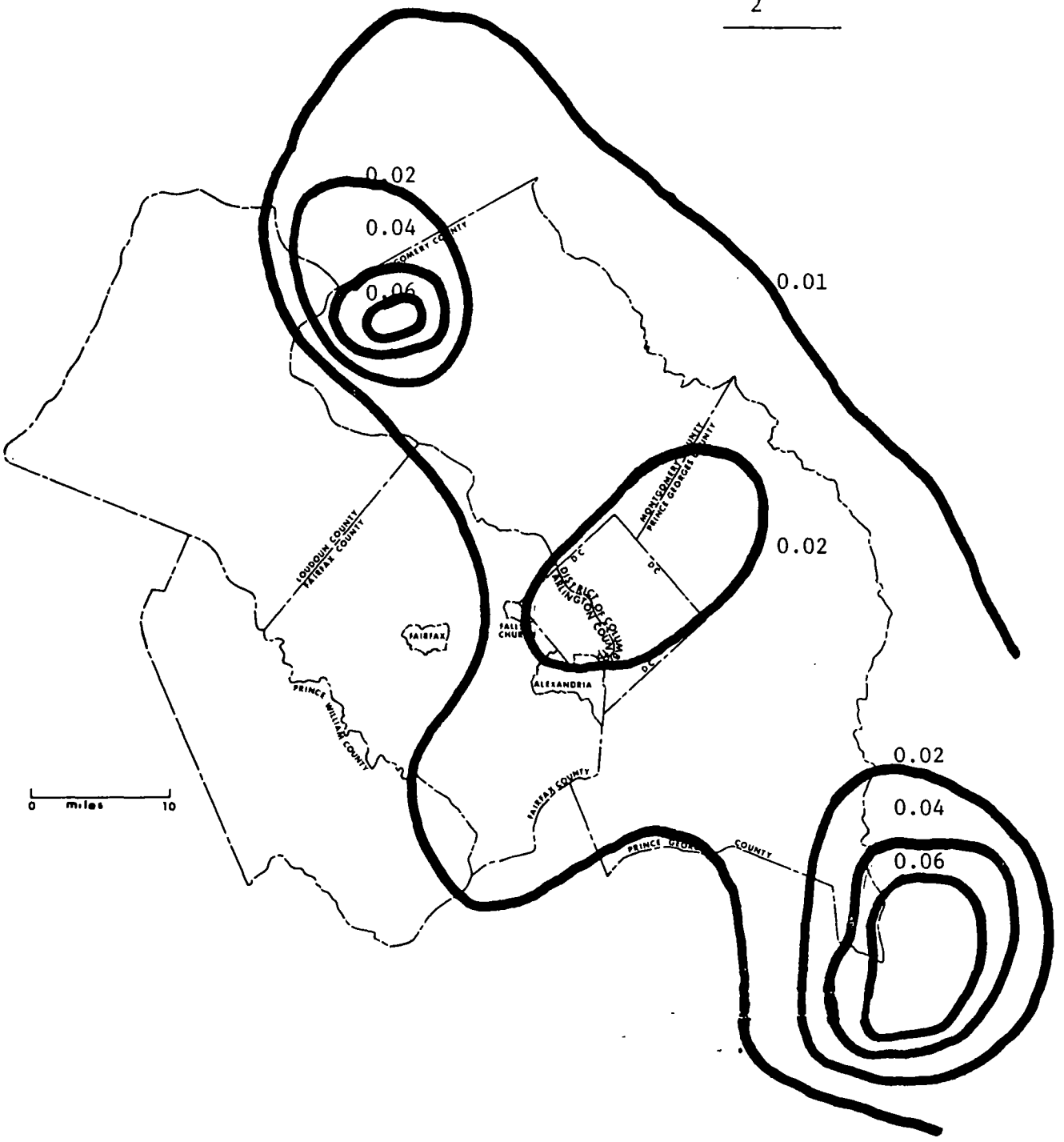
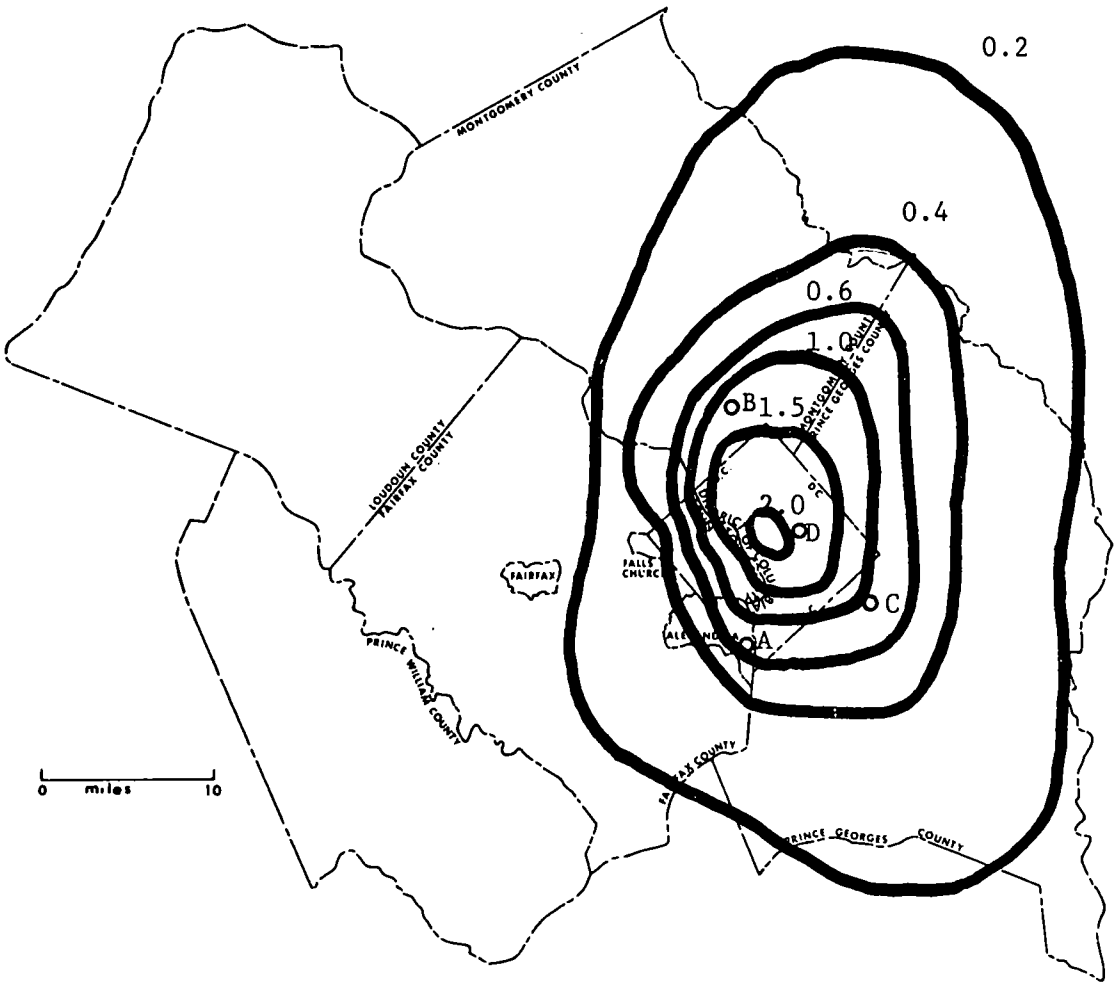


Figure B-3. Estimated SO_2 concentrations; summer average; no decay.

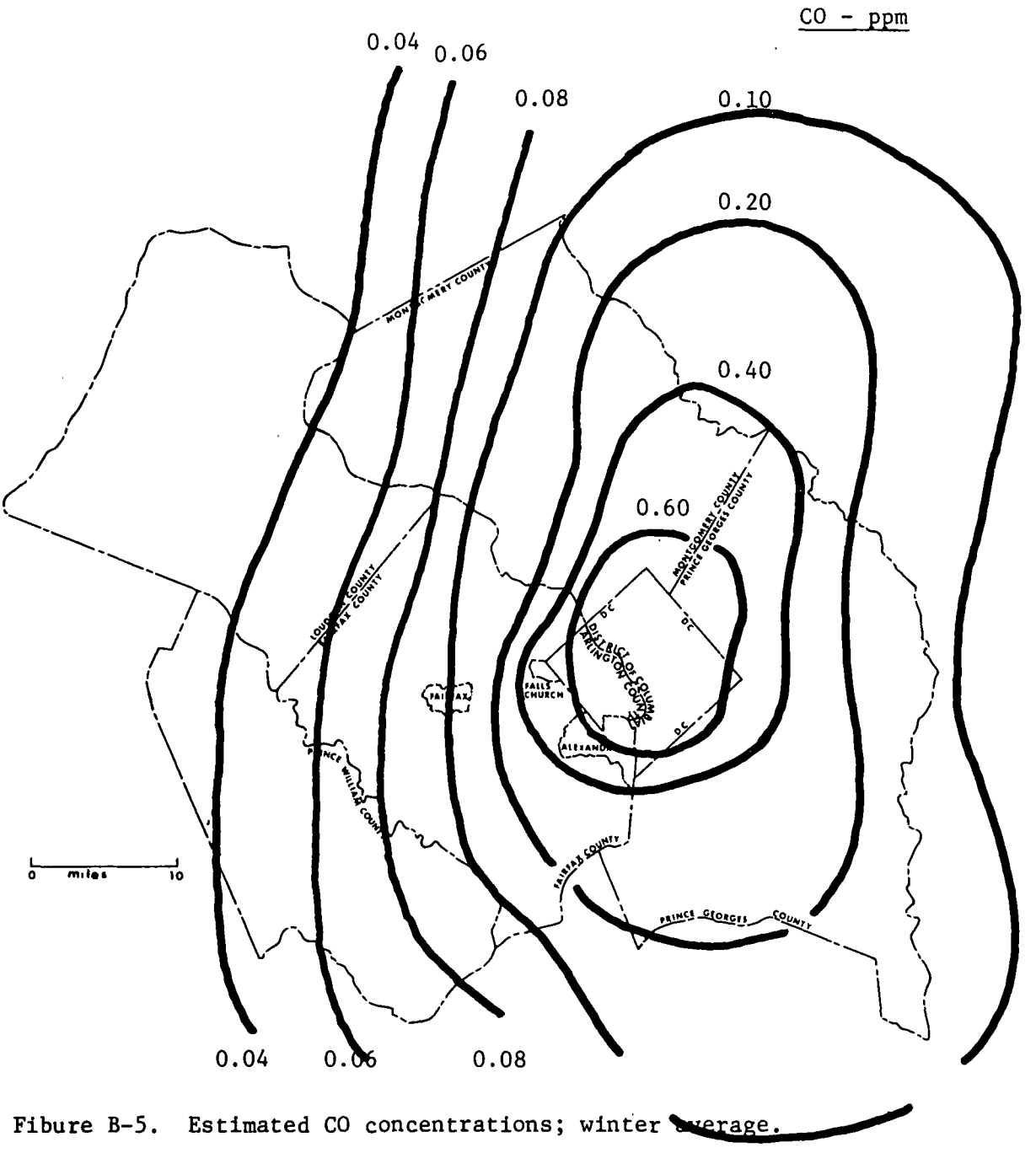
CO - ppm



Aerometric Data[3]

Station	Concentration, ppm
A (Alexandria)	5
B (NIH)	5
C (Suitland)	5
D (CAMP)	5

Figure B-4. Estimated CO concentrations; annual average.



Fibure B-5. Estimated CO concentrations; winter average.

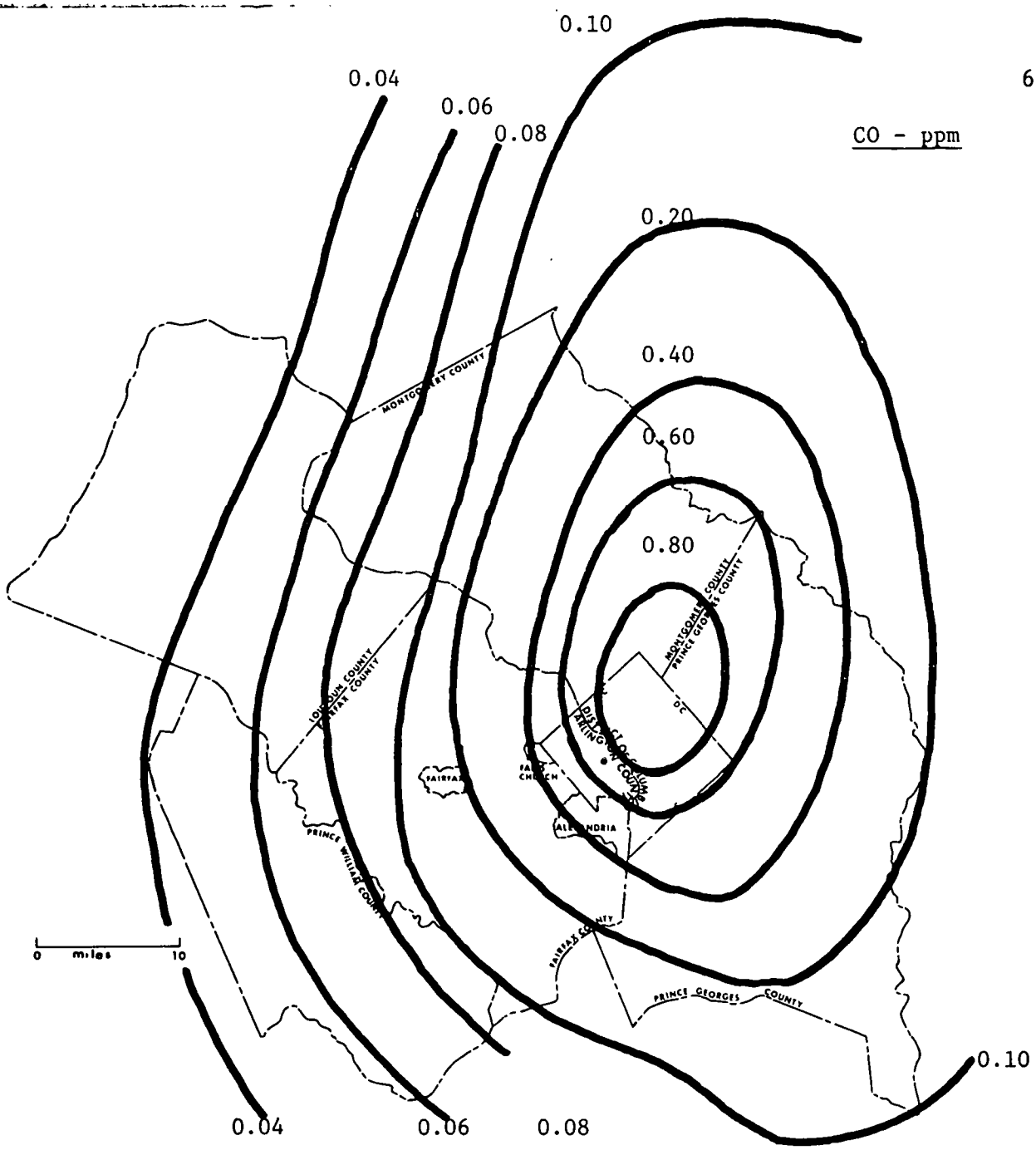


Figure B-6. Estimated CO concentrations; summer average

Suspended Particulates- g/M^3

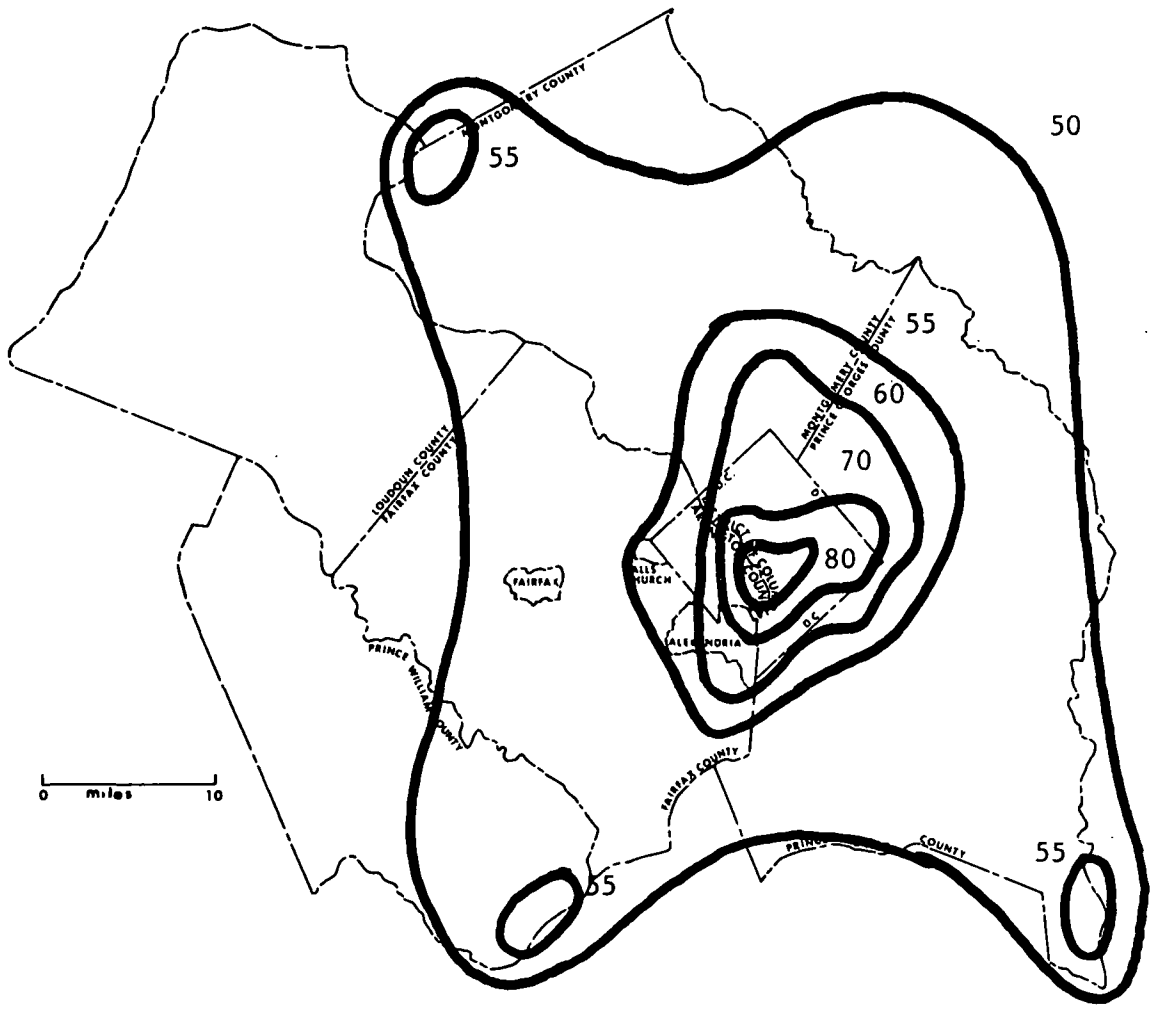


Figure B-7. Estimates suspended particulate concentration; annual average; no background; no deposition.

References for Appendix B.

1. Pasquill, F.; Atmospheric Diffusion. Van Nostrand Co., New York, N. Y. page 190. 1962.

2. Martin, D. O.; A general atmospheric diffusion model sources, Paper No. 68-148 presented at the Air Pollution Control Association's 61st Annual Meeting, St. Paul, Minnesota. June 23-27, 1968.

3. Turner, D. B.; Workbook of Atmospheric Dispersion Estimates. PHS Publication No. 999-AP-26, 84 pp. National Center for Air Pollution Control, Cincinnati, Ohio. 1967.

4. Holzworth, G. C.; Estimates of mean maximum mixing depths in the contiguous United States, Mon. Weather Rev. 92: pp. 235-242. May, 1964.

5. Holzworth, G. C.; Mixing depths, wind speeds and air pollution potential for selected location in the United States, J. Appl. Meteor. 6: pp. 1039-1044. December, 1967.

6. Technical Report, Washington, D. C., Metropolitan Area Air Pollution Abatement Activity. National Center for Air Pollution Control, DHEW. Cincinnati, Ohio. page 152. 1967

APPENDIX C. DEMOGRAPHIC DATA

This appendix consists of tables and figures showing various parameters of Washington, D. C., urban area. Some of these data are referred to in the body of this report, and some are not. It all has relevance to the National Capital Area and is included in this report for possible future use.

Table C-1 . General Information on Counties in the Washington, D.C. Air Quality Control Region[1]

County	District of Columbia	Montgomery	Prince Georges	Arlington
County Seat	Washington	Rockville	Upper Marlboro	Fairfax
Basic Trading Area	Washington	Washington	Washington	Washington
Major Trading Area	Washington	Washington	Washington	Washington
Land Area (Sq. Miles)	61	496	484	26
Population (1950)	802,178	164,401	194,182	135,449
(1960)	763,956	340,928	357,395	163,401
est. (1968)	815,000	455,000	595,000	188,000
Households (1968 est.)	269,000	122,300	155,800	62,700
Total Retail Trade 1966 ($1000)	1,750,425	786,386	736,215	417,053
Shopping Goods Sales 1966 ($1000)	408,597	148,546	123,332	98,513
Food Store Sales 1966 ($1000)	271,644	186,199	174,792	77,465
Drug Store Sales 1966 ($1000)	97,825	25,059	31,915	19,829
Passenger Car Registrations	218,760	211,713	223,639	147,680
Total Wholesale Trade (1963) ($1000)	2,437,765	433,713	387,962	350,595
Manufactures: Total Employees	22,262	7,091	9,166	1,470
Value Added ($1000)	256,813	61,124	98,127	12,820
Agriculture: Number of Farms	None	737	1,087	8
Total Value of Products Sold ($1000)	N.A.	10,036	6,858	72

Table C-2 . General Information on Counties in the Washington, D.C. Air Quality Control Region[1]

County	Fairfax	Loudoun	Prince William
County Seat	Fairfax	Leesburg	Manassas
Basic Trading Area	Washington	Washington	Washington
Major Trading Area	Washington	Washington	Washington
Land Area (Sq. miles)	399	517	347
Population (1950)	96,611	12,826	22,612
(1960)	248,897	12,959	50,164
est. (1968)	391,000	32,000	92,500
Households (1968 est.)	99,700	8,400	21,900
Total Retail Trade 1966 ($1000)	296,461	38,411	81,524
Shopping Goods Sales 1966 ($1000)	65,331	2,505	8,536
Food Store Sales 1966 ($1000)	90,575	9,420	19,529
Drug Store Sales 1966 ($1000)	18,742	2,019	4,113
Passenger Car Registrations	90,420	8,600	9,940
Total Wholesale Trade (1966) ($1000)	117,618	6,330	5,143
Manufactures:			
Total Employees	6,625	294	380
Value Added ($1000)	60,786	2,526	3,891
Agriculture:			
Number of Farms	428	947	479
Total Value of Products Sold ($1000)	2,889	10,761	3,028

Table C-3. General Information on Major Incorporated Municipalities in the Washington, D.C. Air Quality Control Region 1

City	Rockville	Hyattsville	SMSA	Falls Church
County	Montgomery	Prince Georges	N.A.	N.A.
Basic Trading Area	Washington	Washington	Washington	Washington
Major Trading Area	Washington	Washington		Washington
Ranally City Rating	3S	4S	N.A.	3S
Economic Activity Code	Dr - Commuter & Retail	Dr- Commuter & Retail	Government	Dr - Commuter & Retail
Population: 1960	26,090	15,168	2,076,610	10,192
est. 1968	37,000	17,700	2,720,000	12,500
Households (est. 1968)	9,000	5,200	779,300	3,500
Total Retail Trade (1966) ($1000)	108,780	69,000	4,489,162	79,465
Shopping Goods Sales (1966) ($1000)	13,173	2,000	913,081	7,399
Total Wholesale Trade	36,420	22,529	2,058,972	22,869
Manufactures: Total Employees	1,227	294	22,262	241
Value Added ($1000)	11,409	2,670	256,813	1,848

TABLE C-4 .
GENERAL INFORMATION ON MAJOR INCORPORATED
MUNCIPALITIES IN THE WASHINGTON D.C. AIR QUALITY CONTROL REGION[1]

City	WASHINGTON	ALEXANDRIA	FAIRFAX
County	N.A.	N.A.	N.A.
Basic Trading Area	Washington	Washington	Washington
Major Trading Area	Washington	Washington	Washington
Ranally City Rating		3-SS	
Economic Activity Code	Government	DR - Commuters & Retail	None
Population: 1960	763,956	91,032	13,585
] est. 1968	815,000	115,000	24,000
Households (est. 1968)	269,000	36,100	6,000
Total Retail Trade (1966) ($1000)	1,750,425	229,965	73,257
Shopping Goods Sales (1966) ($1000)	408,597	47,959	2,363
Total Wholesale Trade	2,437,765	103,623	8,420
Manufactures:			
Total Employees	22,147	3,336	14
Value Added ($1000)	256,813	33,708	72

TABLE C-5 .
1950-1966
TOTAL CAR REGISTRATION BY JURISDICTION FOR WASHINGTON SMSA[2]
(Excluding Loudoun and Prince William Counties)

Year	Mont. County	Pr. Geo. County	Arl. County	Fairfax County	Falls Church	Dist. of Columbia
1950	66,757	65,968	40,644			206,378
1951	75,475	75,397	42,287			202,254
1952	80,385	83,088	43,928			204,766
1953	87,223	88,426	45,514			203,545
1954	95,327	96,113	48,312	42,222		206,786
1955	107,757	107,297	53,259	49,395		216,168
1956	116,045	114,051	56,511	57,997	3,280	207,262
1957	124,474	120,466	59,218	65,079	3,462	205,077
1958	131,886	127,360	62,624	68,239	3,657	204,647
1959	144,049	139,873	64,774	74,051	3,864	208,169
1960	157,160	151,166	67,957	81,958	3,912	213,395
1961	166,984	160,279	71,334	89,342	3,908	215,633
1962	178,607	174,668	74,534	98,182	4,194	218,284
1963	192,538	193,923	77,469	109,287	4,446	227,030
1964	207,390	214,618	79,411	119,603	4,845	235,760
1965	223,148	238,298	83,007	131,675	5,183	243,782
1966			82,199	141,039	5,611	258,954

TABLE C-6.
1950-1966
PASSENGER CAR REGISTRATION BY JURISDICTION FOR WASHINGTON SMSA [2]
(Excluding Loudoun and Prince William Counties)

Year	Mont. County	Pr. Geo. County	Arl. County	Dist. of Columbia
1950	59,601	58,144	38,114	167,109
1951	67,099	66,910	39,461	163,081
1952	71,870	72,898	42,311	164,858
1953	78,158	77,238	44,653	163,615
1954	85,333	83,713	47,652	167,543
1955	96,323	95,525	52,518	179,691
1956	103,580	98,878	55,492	171,617
1957	111,325	104,954	58,324	170,698
1958	118,102	110,939	61,465	170,980
1959	129,306	121,321	63,564	174,618
1960	141,189	131,676	66,778	179,405
1961	150,489	138,890	70,157	181,986
1962	161,459	151,507	73,068	185,011
1963	174,048	167,675	75,796	192,659
1964	187,148	186,369	77,026	200,270
1965	200,337	207,112	81,259	209,618
1966			80,310	217,026

Table C-7. New housing starts by 5-year periods and per cent increase. [3]

Jurisdiction	Number of Housing Starts		Percentage change, 1962-66 over 1950-54.
	1950-1954	1962-1966	
Montgomery Co.	28,122	26,527	-5.6
Prince Georges Co.	25,135	72,787	+190
District of Columbia	22,480	33,777	+50
Alexandria City	4,444	12,734	+164
Arlington Co.	10,400	10,323	0
Fairfax Co.	20,769	41,558	+100
Loudoun Co.	604	2,971	+392
Prince William Co.	163	10,107	+6,100

TABLE C-8 . 1930-1960 RANKING OF 20 LARGEST METROPOLITAN AREAS

Rank	Area	Population				Percent Change		
		1960	1950	1940	1930	1950-60	1940-50	1930-40
1.	New York-N.E. New Jersey	14,759,429	12,911,994	11,660,833	10,859,433	14.3	10.7	7.4
2.	Chicago-N.W. Indiana	6,794,461	5,586,096	4,890,674	4,733,777	21.6	14.2	3.3
3.	Los Angeles-Long Beach	6,742,696	4,367,911	2,916,403	2,327,166	54.4	49.8	25.3
4.	Philadelphia, Pa.	4,342,897	3,671,048	3,199,367	3,137,040	18.3	14.7	2.0
5.	Detroit, Michigan	3,762,360	3,016,197	2,377,329	2,177,343	24.7	26.9	9.2
6.	Boston, Massachusetts	2,589,301	2,410,572	2,209,608	2,168,566	7.4	9.1	1.9
7.	San Francisco-Oakland	2,783,359	2,240,767	1,461,804	1,347,772	24.2	53.3	8.5
8.	Washington, D. C.-Md.-Va.	2,001,897	1,464,089	967,985	672,198	35.9	51.3	44.0
9.	Pittsburgh, Pa.	2,405,435	2,213,236	2,082,536	2,023,269	8.7	6.3	2.9
10.	St. Louis. Mo.-Ill.	2,060,103	1,719,288	1,464,111	1,387,075	19.8	17.4	5.6
11.	Cleveland, Ohio	1,796,595	1,465,511	1,267,270	1,243,129	22.6	15.6	1.9
12.	Baltimore, Md.	1,727,023	1,405,399	1,139,529	1,036,753	22.9	23.3	9.9
13.	Houston, Texas	1,243,158	806,701	528,961	359,328	54.1	52.5	47.2
14.	Minneapolis-St. Paul, Minn.	1,482,030	1,151,053	967,367	882,226	28.8	19.0	9.6
15.	Dallas, Texas	1,083,601	743,501	527,145	458,629	45.7	41.0	14.9
16.	Milwaukee, Wisconsin	1,194,290	956,948	829,639	777,621	24.8	15.3	6.7
17.	Cincinnati, Ohio-Ky	1,071,624	904,402	787,044	756,281	18.5	13.0	4.1
18.	Buffalo, New York	1,306,957	1,089,230	958,487	911,737	20.0	13.6	5.1
19.	Seattle, Everett, Wash.	1,107,213	844,572	593,734	515,378	31.1	42.2	15.2
20.	Atlanta, Georgia	1,017,188	726,989	558,842	360,000	39.9	30.1	55.2
	TOTALS	61,259,097	49,695,504	41,388,658	38,134,761	25.9 Av.	26.0 Av.	14.0 Av.

Source: U.S. Census of Population, 1930-1960.

References for Appendix C.

1. Rand McNally Commercial Atlas, and Marketing Guide. 99th ed. 1968.

2. Statistics - Washington Metropolitan Area. Metropolitan Washington Council of Governments, page 146, January, 1968.

3. Statistics - Washington Metropolitan Area. Metropolitan Washington Council of Governments, pp. 138-9, January, 1968.

4. Statistics - Washington Metropolitan Area. Metropolitan Washington Council of Governments, page 35, January, 1968.