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POPULATION EXPOSURE TO OXIDANTS AND NITROGEN DIOXIDE IN LOS ANGELES VOLUME III: LONG-TERM TRENDS, 1965-1974

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POPULATION EXPOSURE TO OXIDANTS AND NITROGEN DIOXIDE IN LOS ANGELES VOLUME III: LONG-TERM TRENDS, 1965-1974

by

Yuji Horie and Anton S. Chaplin

Technology Service Corporation
2811 Wilshire Boulevard
Santa Monica, California 90403

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1. INTRODUCTION

This report represents one of three volumes on the subject of population exposure to photochemical air pollution in the Los Angeles Basin. Volume I is an executive summary which highlights the important results described in detail in Volumes II and III. Volume II, entitled "Population Exposure to Oxidants and Nitrogen Dioxide in Los Angeles -- Weekday/Weekend and Population Mobility Effects," focuses on these aspects of the overall study.

The purpose of this volume is to report upon the trends in photochemical air pollution in the Los Angeles Air Basin from two new aspects, characterization of air quality relative to the standards and quantification of population exposure to air pollution. Most of the past analyses of air quality data are expressed in concentration units such as ppm (parts per million) and $\mu g/m^3$ (micrograms per cubic meter). In this report, emphasis is placed on quantification of excessive air pollution (above the air quality standards) during the 10-year period, 1965-1974.

The air quality standards have been set to protect the public health (primary standards) or the public welfare (secondary standards). Quantification of the observed air quality in relation to the primary standard should indicate explicit adverse impacts with respect to public health. Therefore, hourly O_x air quality data are examined in relation to the primary National Ambient Air Quality Standard (NAAQS, 160 $\mu g/m^3$ or approximately 8 pphm for one-hour average concentration). Annual average NO_2 concentrations are compared to the primary NAAQS (100 $\mu g/m^3$). Because there exists no NAAQS for short-term NO_2 concentrations, hourly NO_2 air quality data are examined in relation to the California Ambient Air Quality Standard (CAAQS, 470 $\mu g/m^3$ or approximately 25 pphm for one-hour average concentration). Short-term NO_2 and O_x air quality are expressed in percentage of the time the standard was exceeded and in mean duration of the excess air pollution in hours per day.

Air quality data collected at ten air monitoring stations measuring oxidants and eight measuring nitrogen dioxide were examined together with population statistics prepared by the Southern California Association of Government (SCAG). A population of 8.6 million was associated with the oxidant monitoring data, and the nitrogen dioxide monitoring network was judged to represent 6.9 million people.

The air quality and population data were interfaced by using a grid network of 58 receptor points for the oxidant analysis and 45 receptor points for the nitrogen dioxide analysis. The receptor network provides complete area coverage, but more detail is given to areas of high population density. The oxidant and nitrogen dioxide air quality of each grid point of the receptor network was estimated from the actual monitoring data by spatial interpolation. Thus, each receptor point represents a local population as well as its air quality. The estimates of population and air quality were then used to characterize the air pollution of the region.

The estimates of population exposure were determined for the total population as well as subpopulations consisting of the elderly, school-age, and non-white.

The ten years of O_x and NO_2 data were examined in terms of five 2-year periods: 1965 and 1966, 1967 and 1968, 1969 and 1970, 1971 and 1972, and

1973 and 1974. The spatial variations of short-term O_x and NO_2 air quality during each of the five 2-year periods are presented in isopleth maps of the percentage of days the standard was exceeded and of the mean duration of excess air pollution in hours per day. The spatial variations of long-term NO_2 air quality are similarly presented in terms of isopleth maps of annual average concentration.

The population exposure for total population and subpopulations are examined by the use of population-at-risk distributions for short-term O_x and NO_2 and population dosage distributions for long-term NO_2, as well as aggregated indices of regionwide exposure for both pollutants. The population-at-risk distribution describes the percentages of the population exposed to a concentration above the standard for a given fraction of time. The population dosage distribution describes percentages of the population exposed to various concentration levels of air pollution.

2. OVERVIEW OF POPULATION AND AIR QUALITY IN THE LOS ANGELES BASIN

Among the nation's 247 Air Quality Control Regions (AQCR's), the Los Angeles AQCR is special in that it is defined by its geographical boundaries (mountains and ocean), whereas the great majority of AQCR's are defined by their administrative boundaries (state and county lines). Figure 2.1 depicts the topographical features of the Los Angeles Basin. The AQCR (the area surrounded by solid lines) covers six different counties: all of Orange and Ventura counties, and part of Santa Barbara, Los Angeles, San Bernardino, and Riverside Counties.

The difference between the AQCR boundaries and the county boundaries makes it difficult to obtain the demographic data specific to the AQCR. In the analysis of population exposure to air pollution, the spatial distribution of population as well as the population size must be known. During our search for the population data to be used for the population exposure analysis, we found that the Regional Statistical Areas (RSA's) developed by the Southern California Association of Governments (SCAG) were a proper spatial unit for aggregating the population data.[1]

Figure 2.2 depicts the location of air monitoring stations that were used for the present study. For oxidants (O_x), 10 air monitoring stations whose data quality met the EPA recommended criteria of at least 75% of the total number of possible observations were used for the 10-year (1965-1974) trend analysis of air quality and population exposure, while for nitrogen dioxide (NO_2), eight air monitoring stations were used. Considering the

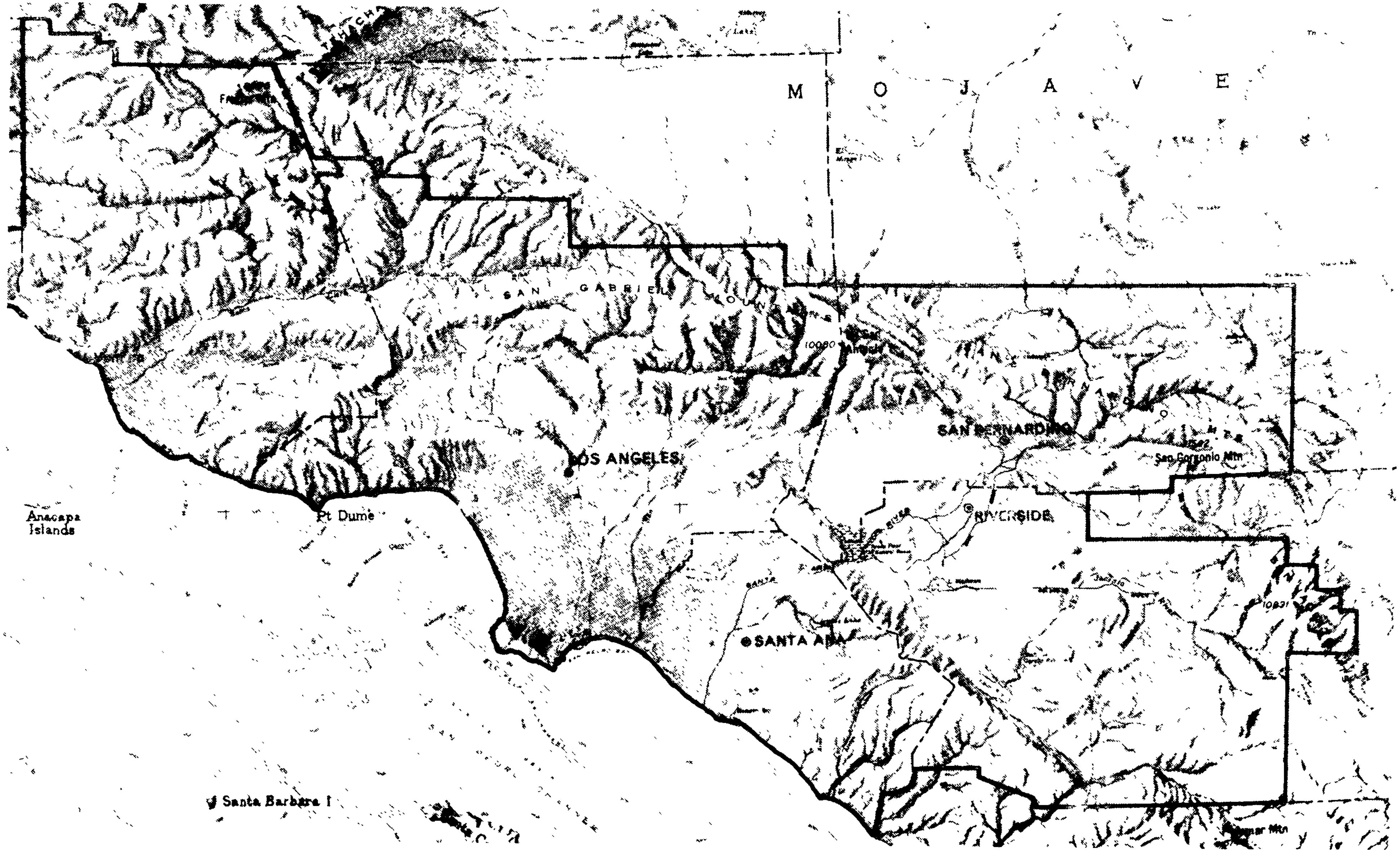


Figure 2.1. TOPOGRAPHICAL FEATURES OF THE LOS ANGELES BASIN.

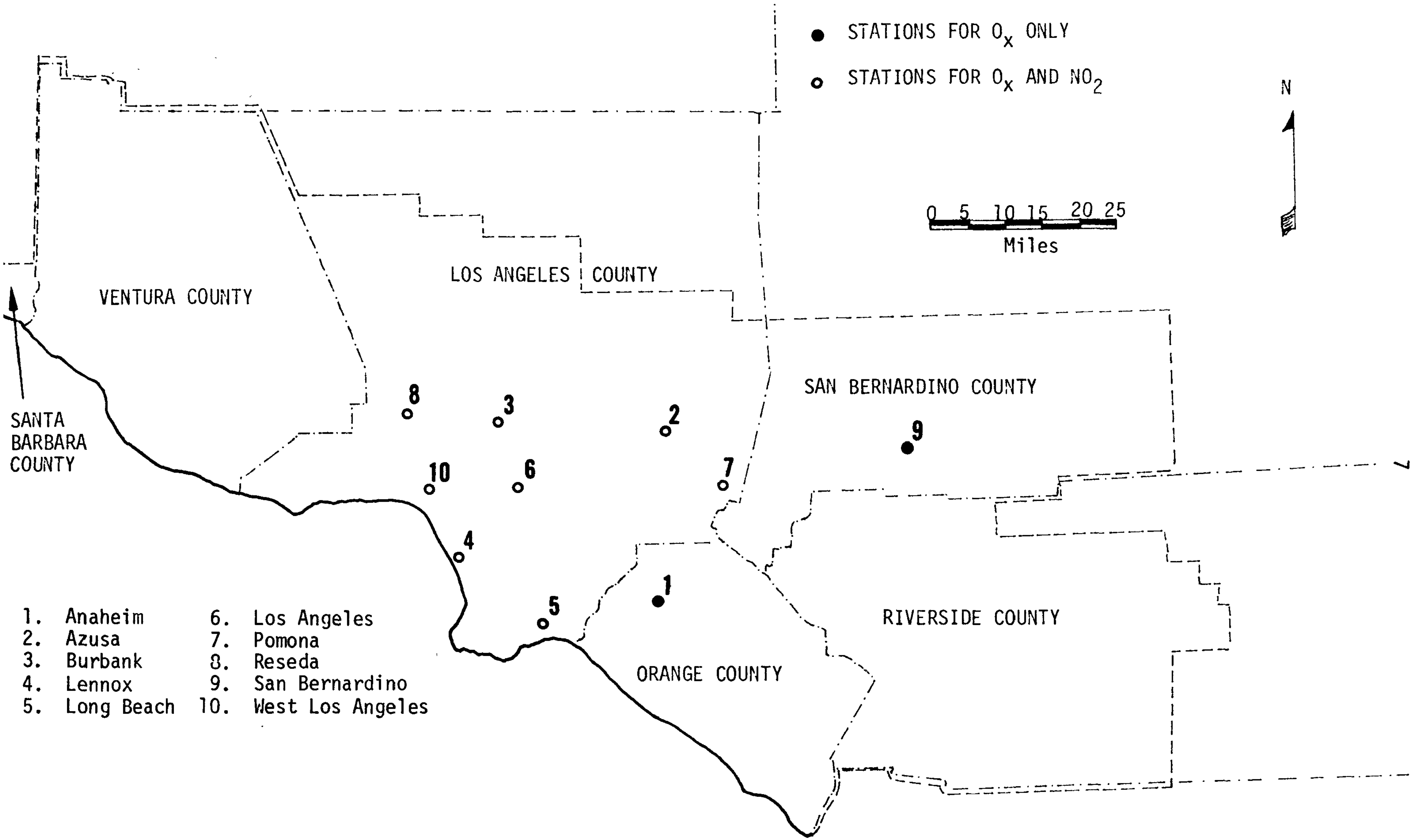


Figure 2.2 LOCATION OF MONITORING STATIONS USED FOR 10 YEAR TREND ANALYSIS

area coverage at these stations, the study area for the O_x trend analysis was determined as shown in Figure 2.3. Because fewer stations are used for the NO_2 trend analysis, only the Los Angeles County portion is used in the O_x study area. As seen from Figure 2.3, the two study areas are considerably smaller than the Los Angeles AQCR. However, the resident population is not much smaller than that of the AQCR.

2.1 POPULATION PROFILE

The Southern California Association of Governments (SCAG) provides survey statistics of total populations for 1960, 1970, and 1975, and the projected population to 1980 (Table A1). All of the statistics are aggregated into each of 55 Regional Statistical Areas (RSA's) which cover the six counties of Ventura, Los Angeles, Orange, San Bernardino, Riverside, and Imperial (Figure 2.4). Of the 55 Regional Statistical Areas, 25 RSA's were used for the O_x trend analysis, and 17 RSA's for the NO_2 trend analysis (Figure 2.3).

Assuming that an air monitoring station represents an area circumscribed by half of the distance to a neighboring station, inclusion (or exclusion) of peripheral RSA's in (or from) the study region was determined by considering the distance between the outer-most station and the center of each of those RSA's. As a result, the study region for O_x covers the southern portion of Los Angeles county and western portions of Orange and San Bernardino counties. The study region for NO_2 covers only the southern portion of Los Angeles county.

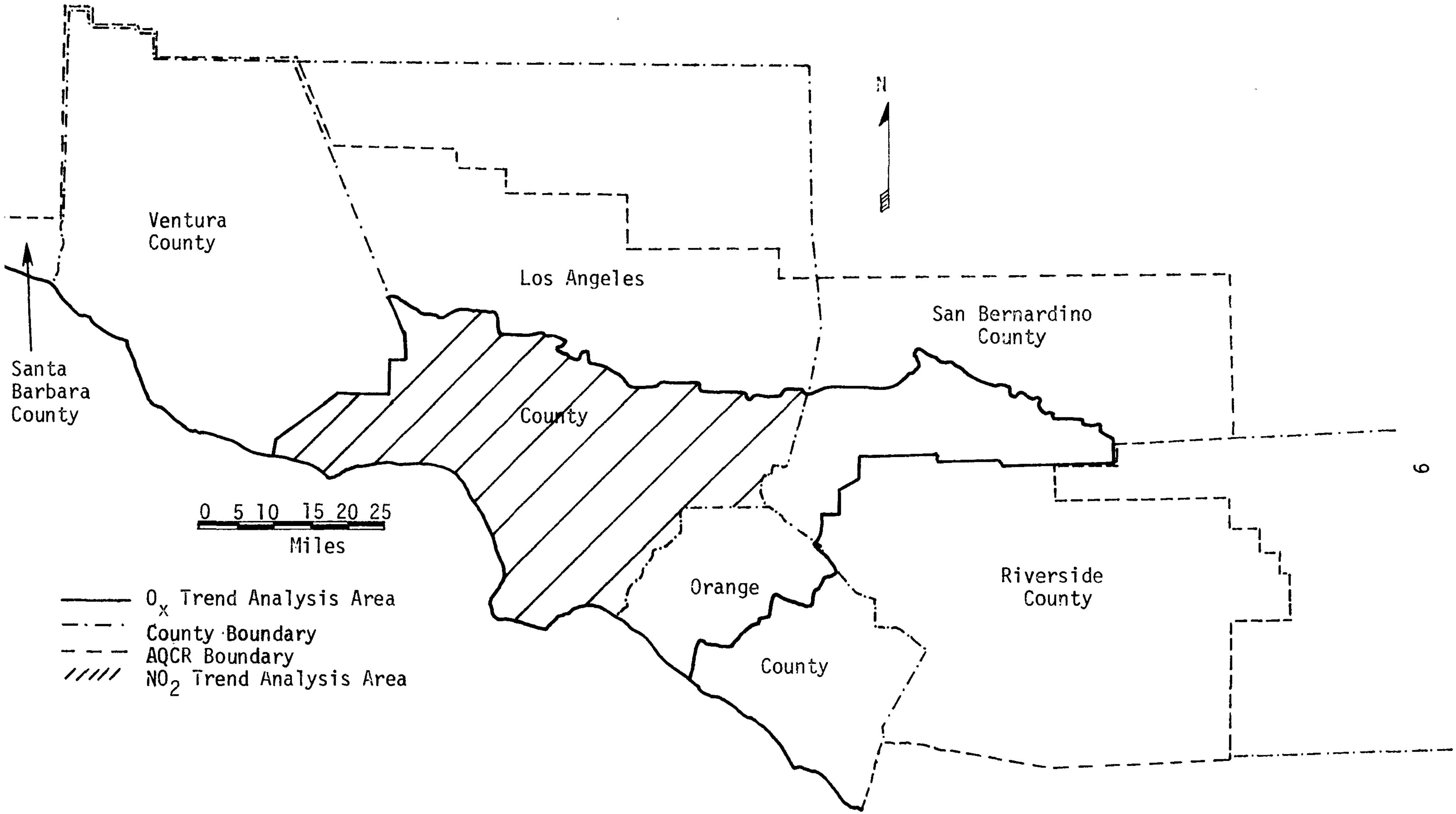


Figure 2.3 BOUNDARIES SHOWING TREND ANALYSIS AREAS AND LOS ANGELES AQCR.

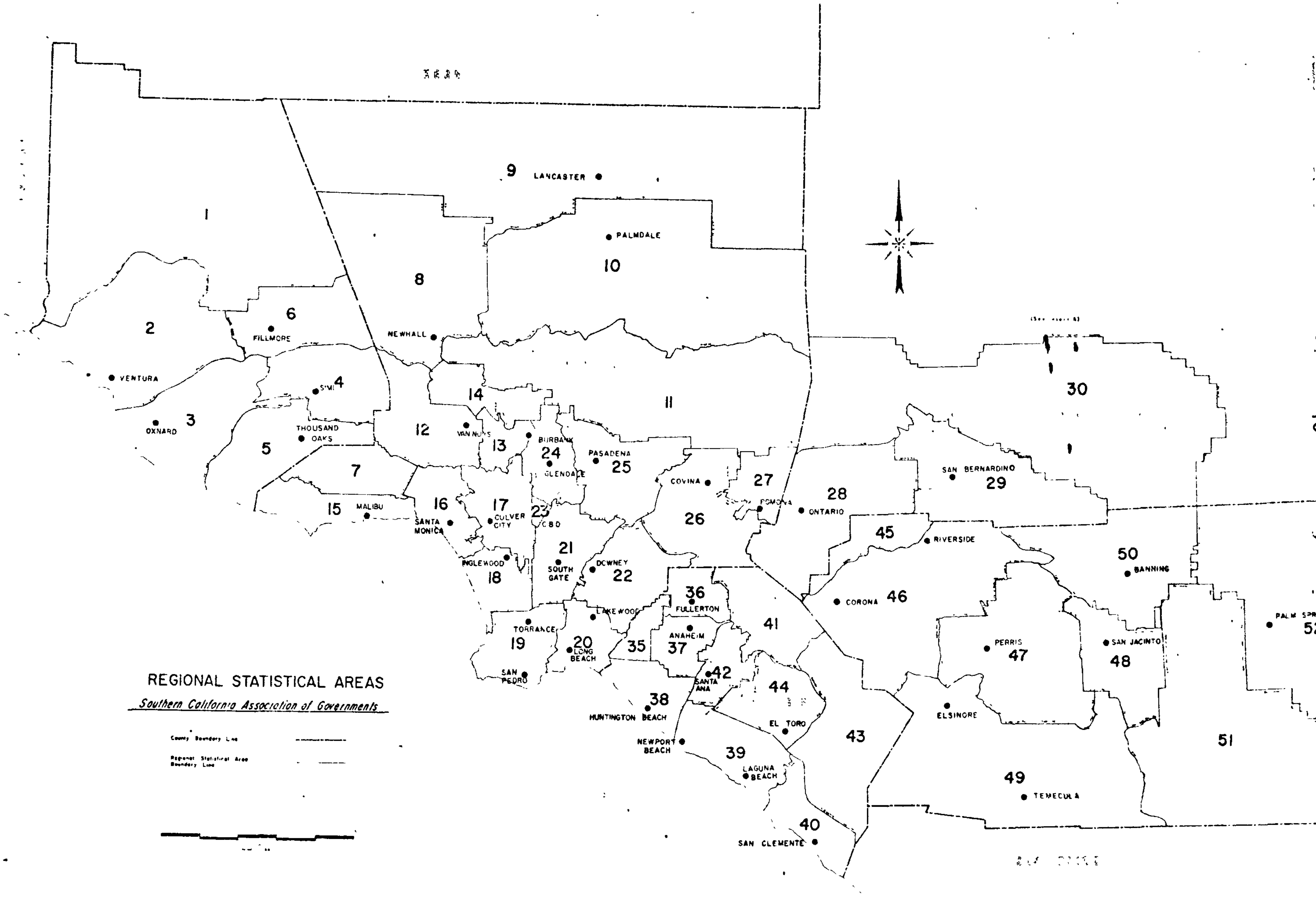


Figure 2.4. REGIONAL STATISTICAL AREAS DEVELOPED BY SOUTHERN CALIFORNIA ASSOCIATION OF GOVERNMENTS

Because we also need to know the number of people in each sub-population for each 2-year period, the aggregated statistics of School-age (5-17 years old), Elderly ($\geq$65 years old), Non-white, and Worker population for each RSA were computed from the 1970 census tract data by using the conversion table prepared by SCAG, which provided the number of census tracts belonging to each RSA (Table A2).

It is found that there is a slight discrepancy between SCAG's estimates of total population and those computed from the 1970 census tract data.[2] Because of the greater reliability in SCAG's estimates for this particular region than our estimates computed from the census data, we decided to use the SCAG's figures of total population. The size of total population in each RSA for each 2-year period was estimated by interpolating those of SCAG's estimates in 1960, 1970, and 1975 into the middle of the 2-year period. For example, the total population in the 1967/68 period was estimated by interpolating those in 1960 and 1970 into 1967.5. The size of each sub-population in each RSA was then computed by multiplying the total population of that 2-year period with the percentage of that sub-population to the total population in that RSA in 1970.

The characteristics of the two study areas are given in Table 2.1. The sizes of total population in the Los Angeles AQCR, the O_x trend analysis area, and the NO_2 trend analysis area are 9.8, 8.5, and 6.9 million people, respectively. School-age population constitutes about 24% of the total population and Elderly population about 9% of the total population in the two study areas. Non-white population constitutes about 13% of the total population in the O_x trend analysis area and 15% of the total population in the NO_2 trend analysis area.

The spatial distribution of total population density is shown in Figure 2.5. A high population density area centers at the Los Angeles CBD and extends to the southern half of the Los Angeles County and portions of Orange and San Bernardino Counties. The lowest population density if found in the mountainous areas (Figs. 2.1 and 2.5).

Table 2.2 presents the summary of Total Population in the two study areas during the 10-year (1965-1975) period. It can be seen that the population growth in Total Population was slower during the 1970-75 period than during the 1965-70 period. In particular, the NO_2 trend study area, i.e., Los Angeles County experienced a negative growth in both Total Population and All Workers during the 1970-75 period. The spatial variations of change in population during the 10-year period are shown in Figure 2.6. It can be seen that the growth in total population is more pronounced in the fringe areas than the urban core areas consisting of Los Angeles and Long Beach cities.

2.2 AIR POLLUTION PROFILE

A percentile concentration distribution is used in this study to characterize annual short-term (one hour) exposures of the population to O_x and NO_2 air pollution. The short-term exposure of the population is characterized by two parameters: (1) the frequency with which ambient

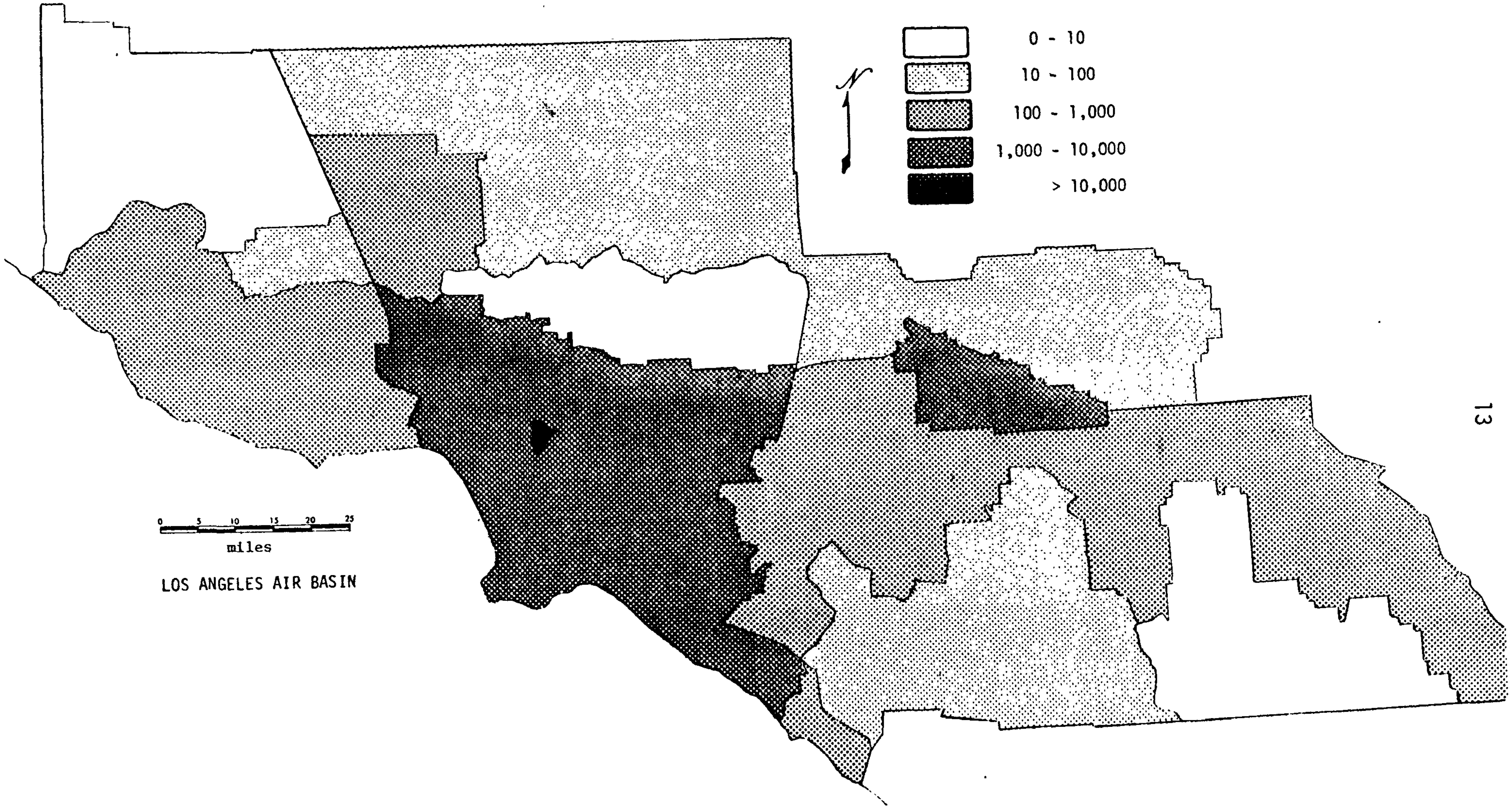


Figure 2.5. POPULATION DENSITY IN PERSONS PER SQUARE MILE IN 1970.

Table 2.1 Characteristics of the Two Study Areas[a]

Study Area	Land Area (Sq. Miles)	Total Population	School-Age (5-15 years)	Elderly (≥65 years)	Non-White
O_x Trend Analysis	2,316	8,548,431	2,110,291	761,027	1,084,202
NO_2 Trend Analysis	1,509	6,858,390	1,626,711	642,152	1,018,418

a: 1969-1970 population estimates

Table 2.2 Total Population in the Two Study Areas in 1965, 1970, and 1975.

	Total Population		
Study Area	1965	1970	1975
O_x Trend Analysis	7,798,629	8,631,745	8,742,324
NO_2 Trend Analysis	6,431,723	6,905,798	6,869,628

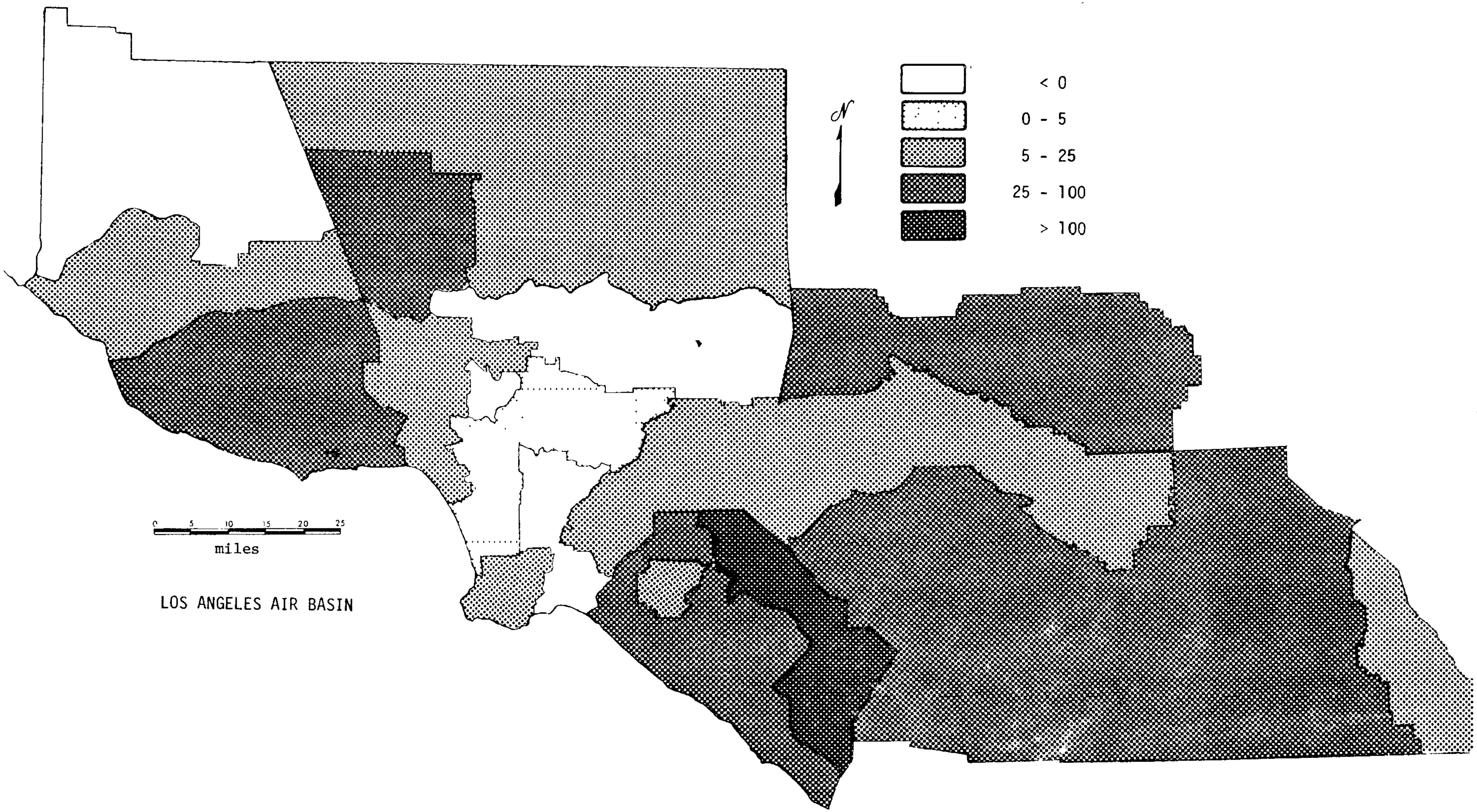


Figure 2.6. PERCENT CHANGE IN POPULATION 1965 TO 1975.

concentrations exceed the air quality standard or a multiple of the standard, and (2) the mean duration of the excess air pollution above the threshold in hours per day. Annual average concentrations are used to characterize the long term exposure to NO_2.

For the trend analyses of air quality and population exposure, the "Ten-Year Summary of California Air Quality Data 1963-1972" and its supplement for the 1973-1974 periods were used.[3,4] In an attempt to minimize meteorological effects on the trends in air quality and population exposure, a long period, 1965 to 1974, was chosen. However, this extended study period left us very few air monitoring stations that had reported statistically valid air quality data (75% or more of the possible observations) continuously over that period. In order to pressure historical continuity at a minimum number of monitoring stations, the data were examined in five 2 year periods: 1965/66, 1967/68, 1969/70, 1971/72, and 1973/74.

For a station that reported statistically valid air quality data for both of the two years, the two-year average air quality is given by an arithmetic average of the two annual statistics (percentile concentration for analysis of short-term exposures to O_x and NO_2, and annual arithmetic mean concentrations for analysis of long-term exposure to NO_2). For a station that reported statistically valid air quality data for only one of the two years, the two-year average air quality is given by the annual concentration of the valid year. In this manner, 10 stations were saved for the ten-year trend analysis for O_x and eight stations for NO_2.

The percentile concentration statistics for each of the trend stations are all presented in Appendix B (Tables B1 through B4). Tables B1 and B2 summarize 0_x hourly concentrations and 0_x daily maximum hourly concentrations as percentile concentration distributions. The percentile concentrations of stations outside the Los Angeles county, i.e., Anaheim and San Bernardino, were corrected by multiplying their values with the correction factor of 0.80.[5] This factor has been recommended by the California Air Resources Board in order to account for differences in California 0_x measurement techniques outside of LA county. The percentile concentration statistics of Tables B1 and B2 are further compacted in Table 2.3 which presents characteristics of the air quality observed at each air monitoring station in terms of the percent of days on which the NAAQs for 0_x was violated, and of the mean duration in hours of such violations. It can be seen from the table that all the trend stations show air quality improvement for oxidant over the 10-year period. The coastal stations (Anaheim, Lennox, Long Beach, West. L.A.) show a greater reduction in the percent of days exceeded than the inland stations (Azusa, Burbank, Pomona, Reseda, San Bernardino).

Table 2.3 Percent of Days the NAAQS for O_x was Exceeded and the Mean Duration in Hours (x.x) in Each of the Five 2-Year Periods

NO.	STATION	1965/66	1967/68	1969/70	1971/72	1973/74
1	ANAHEIM	41.4 (4.8)	35.4 (3.8)	25.0 (4.3)	16.6 (2.9)	16.6 (3.4)
2	AZUSA	69.8 (7.6)	68.7 (7.0)	68.7 (7.0)	62.1 (6.5)	56.1 (6.5)
3	BURBANK-PALM	61.0 (6.4)	64.0 (6.5)	60.0 (6.0)	50.0 (5.2)	46.6 (5.7)
4	LENNOX	2[illegible].9 (3.5)	25.0 (3.4)	25.0 (2.9)	11.5 (2.5)	5.9 (3.3)
5	LONG BEACH	22.3 (3.6)	17.0 (2.7)	12.4 (1.9)	11.8 (2.0)	7.7 (2.5)
6	L.A. DOWNTOWN	62.1 (5.8)	55.1 (5.4)	50.0 (4.8)	39.4 (4.2)	42.7 (4.6)
7	POMONA	64.7 (6.6)	64.0 (6.9)	61.0 (6.8)	50.0 (5.3)	47.5 (5.9)
8	RESEDA	65.4 (7.5)	60.0 (7.2)	59.7 (6.8)	50.0 (5.8)	46.9 (6.6)
9	SAN BERNADINO	43.1 (6.0)	41.6 (6.2)	42.0 (7.3)	36.2 (6.0)	42.0 (6.6)
10	WEST L.A.-WSTWOOD	53.3 (5.1)	55.8 (5.4)	44.7 (5.4)	28.4 (3.0)	28.4 (3.5)

Table B3 and B4 summarize NO_2 hourly concentrations and NO_2 daily maximum hourly concentrations in a percentile concentration distribution for each of the two-year periods. These percentile concentration statistics are further compacted in Table 2.4 which presents characteristics of the air quality observed at each trend station in terms of the percent of days on which the California standard for NO_2 hourly concentrations was violated, and of the mean duration in hours of such violations. There is no obvious trend in both percent of days exceeded and mean duration at any station except Azusa which shows a steady increase in the percent of days exceeded. The stations in the urban core areas (Burbank, Long Beach, L.A. Downtown, West L.A.) appear to have a greater percent of days exceeded than those in the fringe areas (Azusa, Pomona, and Reseda).

The annual arithmetic mean concentrations of NO_2 at each of the eight trend stations are presented in Table 2.5. Again, there is no obvious trend in annual mean concentration at any station except Azusa which shows a steady increase in the annual arithmetic mean concentration. The West L.A. station also shows somewhat of an increasing trend. For the rest of the stations, the first and last two-year periods had a lower value in the annual mean concentration than the three two-year periods in between. It should be noted that except for the Azusa station in 1965/66 and 1967/68, all the stations violated the NAAQS for NO_2 (100 $\mu g/m^3$ or approximately 5 pphm) over the entire 10-year period.

2.3 INTERFACING POPULATION AND AIR QUALITY DATA

The task of interfacing the population data and the air quality data starts with a search for a proper regional map on which the monitoring

Table 2.4 Percent of Days the California Standard for NO_2 was Exceeded and the Mean Duration in Hours (x.x) in Each of the Five 2-Year Periods

NO.	STATION	1965/66	1967/68	1969/70	1971/72	1973/74
1	AZUSA	.8 (2.0)	2.2 (1.7)	2.3 (3.2)	3.9 (2.7)	3.7 (2.1)
2	BURBANK-PALM	7.4 (3.6)	20.8 (4.5)	16.9 (3.9)	11.8 (3.2)	6.1 (2.0)
3	LENNOX	5.0 (2.3)	14.4 (4.3)	5.5 (2.3)	6.1 (3.0)	4.2 (2.1)
4	LONG BEACH	5.0 (2.9)	14.4 (3.4)	10.7 (3.2)	8.2 (3.2)	5.6 (1.6)
5	L.A. DOWNTOWN	13.6 (2.5)	10.9 (2.8)	7.6 (3.0)	14.6 (3.2)	6.1 (3.3)
6	POMONA	1.3 (1.1)	4.7 (3.0)	4.6 (3.4)	3.9 (3.4)	2.1 (2.4)
7	RESEDA	2.2 (2.1)	5.4 (3.6)	3.0 (2.9)	5.5 (2.9)	2.5 (1.8)
8	WEST L.A.-WSTWOOD	8.8 (2.7)	10.0 (2.4)	7.1 (2.3)	10.0 (2.4)	8.3 (2.4)

Table 2.5 Annual Arithmetic Mean Concentrations for NO_2 in Each of the Five 2-Year Periods.

NO.	STATION	1965/66	1967/68	1969/70	1971/72	1973/74
1	AZUSA	4.45	4.80	5.70	6.20	6.25
2	BURBANK-PALM	6.90	9.80	9.40	8.55	7.25
3	LENNOX	6.15	7.50	6.75	6.65	6.35
4	LONG BEACH	5.90	7.90	7.70	6.85	6.75
5	L.A. DOWNTOWN	7.45	6.85	7.00	8.45	7.05
6	POMONA	6.30	7.45	8.05	7.75	7.05
7	RESEDA	5.00	6.15	6.35	7.00	6.05
8	WEST L.A.-WSTWOOD	6.10	6.65	6.55	6.90	7.05

stations and the receptor points can be located.[6] A receptor point is used to aggregate the local populations in the areas in which they reside. For the Los Angeles AQCR, a regional map showing the boundaries of the Regional Statistical Areas (RSA's) was available (Fig. 2.4). A number of receptor points were assigned to each RSA according to the size of the population and the land area. The criteria used for determining the number of receptor points assigned to each RSA is as follows:

1. Regardless of the size of the population and/or the land area, each RSA is represented by at least one receptor point.

2. An additional receptor point is assigned for each increment of area by 200 square miles or each increment of resident population by 200,000. For example, an RSA having a resident population of 500,000 and a land area of 70 square miles is represented by 3 receptor points (1 for RSA and 2 for population of 400,000), while another RSA having a population of 150,000 and an area of 300 square miles is represented by 2 receptor points (1 for RSA and 1 for land area of 200 square miles).

The number of people at eac receptor point is computed in the following manner: the total population in each RSA is computed by making a linear interpolation between the SCAG estimates for two time points. For the study year 1971/72, the interpolation is made of 1970 and 1975 data into 1971.5. Then, the number arrived at by interpolation is divided by the number of receptor points in that RSA and the result is assigned to each receptor point. For subpopulations such as school-age, elderly, and non-white population, the number of people of a given subpopulation at each receptor point are given by the product of (total population) x (percent of subpopulation) where the percentage is computed from the 1970 census data for the RSA to which the receptor point belongs.

A diagram of how to create a demographic network is shown in Figure 2.7. The regional map of RSA's prepared by SCAG is stored numerically on a tape through the use of a digitizer. Using the UTM coordinates given in SAROAD format or the site addresses (Appendix C, Table C1) the air monitoring stations are located on the digitized map through a coordinate transformation[7] (Fig.2.2). In order to determine a scale factor for the coordinate transformation, the locations of the Los Angeles Downtown station and the Azusa station are determined from their site addresses. The receptor points are located at their proper places within the corresponding RSA. The receptor locations are shown in Fig. 2.8 and their X-Y coordinates are found in Appendix C, Table C2.

To know the exposure of a person to air pollution, the spatial location of the person and the air quality of his location must be known as a function of time. In the present study, however, we are not interested in the actual exposures of individual persons to air pollution, but rather in the ensemble of potential exposures of a large population, say 10,000 people. For this purpose, an appropriate estimate of air quality at each receptor point should be sufficient to make an estimate of population exposure at that particular locale, if the assumption is made that the population size and sub-population composition will be quasi-stationary over each of the five study periods. This assumption should be best for the analysis of exposure

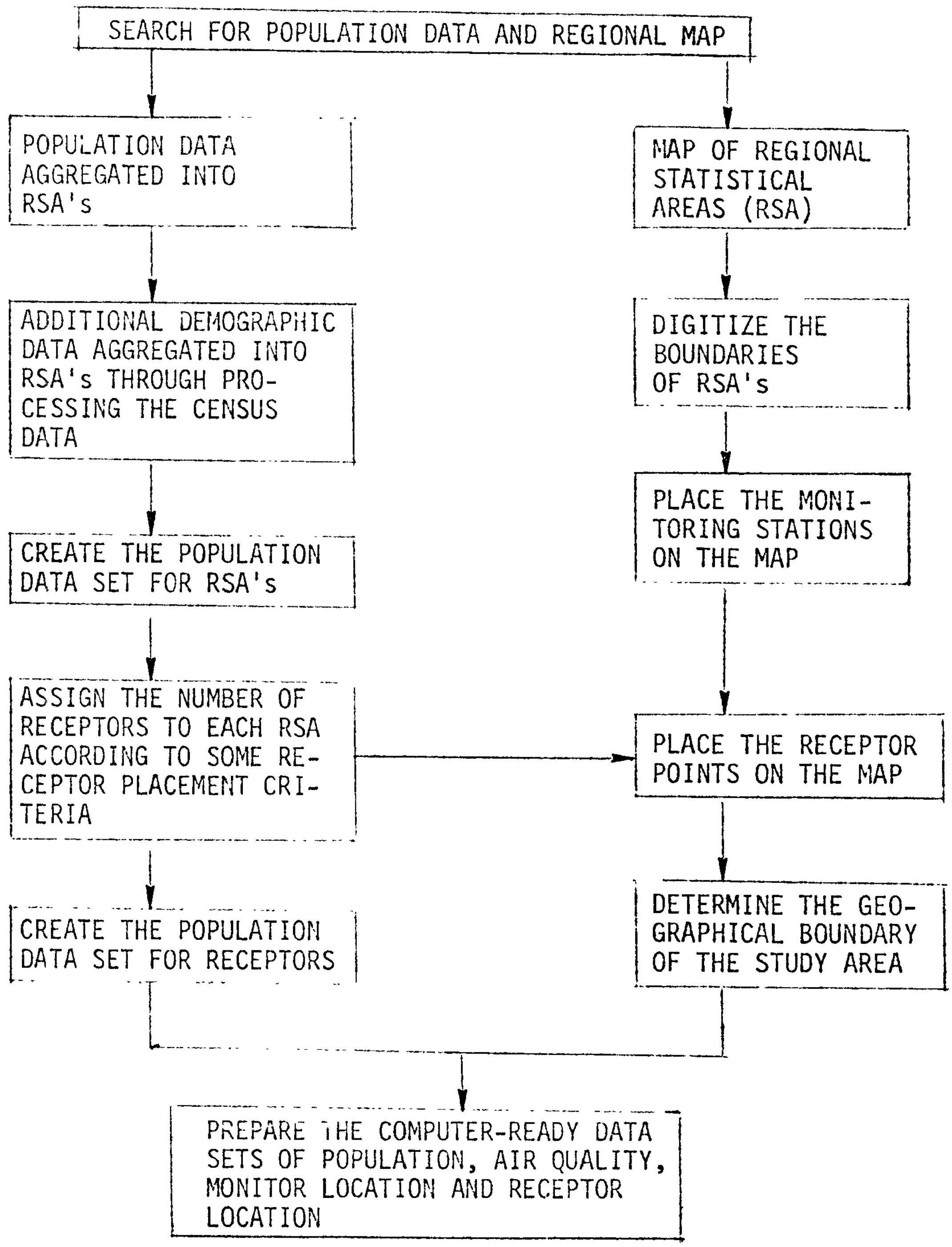


Figure 2.7 Diagram of Creating a Demographic Network for Metropolitan Los Angeles AQCR.

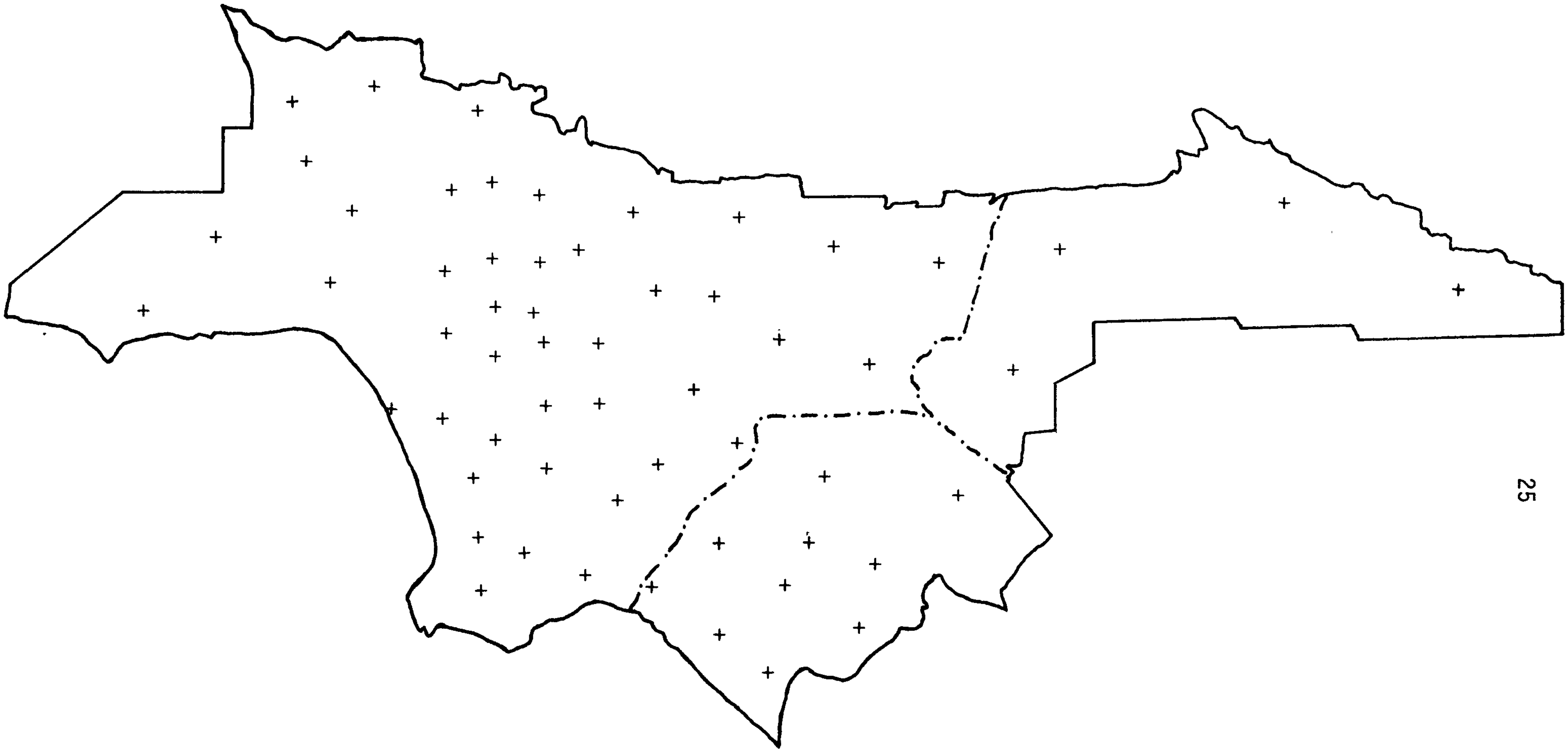


Figure 2.8 Locations of the 58 Receptor Points Assigned to the Study Region.

of elderly and school-age populations because these populations tend to be locationally fixed, i.e., stay close to their resident locations most of the time. While the stationary assumption is not strictly valid for populations such as workers who spend a substantial part of their time at places where the air environment may be quite different from that of their residential locations, a special analysis for 1973 air quality and population data[8] has found that these effects can be largely ignored.

As mentioned earlier, the spatially distributed population is aggregated at each receptor point. The air quality at a receptor point was estimated by interpolating the observed air quality at the three nearest neighboring monitoring stations to that point as[6]

$$\left.\begin{aligned} C_j &= \sum_{i=1}^{3} C_i d_i^{-2} \Big/ \sum_{i=1}^{3} d_i^{-2} && \text{for } d_i \neq 0 \\ C_j &= C_i && \text{for } d_i = 0 \end{aligned}\right\} \qquad (2.1)$$

where C_j is the concentration estimated at j-th receptor point (x_j, y_j), C_i(i-1,2,3) are the concentrations observed at the three nearest neighboring stations, i-th (i=1,2,3) air monitoring stations (x_i, y_i) around the j-th receptor point, and d_i is the distance between the i-th monitoring station and the j-th receptor point, i.e.,

$$d_i = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}\,. \qquad (2\text{-}2)$$

Using the above interpolation formula repeatedly, the bi-annual statistics of percentile concentrations for analysis of short-term exposures to 0_x and NO_2 and of arithmetic mean concentrations for analysis of long-term exposure to NO_2 were computed for every receptor point from the bi-annual statistics of air quality data observed at the air monitoring stations. By comparing the percentile concentrations with the NAAQS, a risk frequency that indicates a percentage of the time the NAAQS was exceeded was determined at each receptor point. An isopleth map of the risk frequency is used in this report to describe a spatial change in short-term population exposures to 0_x and NO_2 over the study region during the 10 year period. A spatial change in long-term population exposure to NO_2 is expressed by an isopleth map of the annual mean concentration.

By stratifying the population according to the magnitude of risk frequency, the short-term exposures of the population to 0_x and NO_2 are summarized in a population-at-risk distribution that describes percentages of the population exposed to a concentration above the NAAQS for a given fraction of time. The long-term exposure of the population to NO_2 is summarized in a population dosage distribution that describes percentages of the population exposed to various levels of an annual mean concentration.

Finally, the regional index of short-term exposures to 0_x and NO_2 is given by the population weighted average of a risk frequency while that of long-term exposure to NO_2 by the population weighted average of an annual mean concentration. In actual computations, however, these regional indices were computed by numerically integrating the corresponding distribution functions. A mathematical definition and/or derivation of each quantity used in this report is presented in Appendix E.

3. TRENDS IN OXIDANT AIR QUALITY AND POPULATION EXPOSURE

Trends in O_x air pollution in the Los Angeles AQCR are analyzed in this section with respect to the spatial patterns, the population exposure distributions, and the aggregated indices of air quality and population exposure. The air quality data used for the analysis were obtained from the summary statistics of the following ten monitoring stations: Anaheim, Azusa, Burbank, Lennox, Long Beach, L.A. downtown, Pomona, Reseda, San Bernardino, and West L.A. (Fig. 2.2).[3,4]

As shown in Figure 2.3, the trend study area consists of the heavily populated portion of three counties: Los Angeles, Orange, and San Bernardino. Although the land area of the O_x trend study regions is only a quarter of the Los Angeles AQCR, the population of the trend study areas is more than 70% of the AQCR population (Table 2.1).

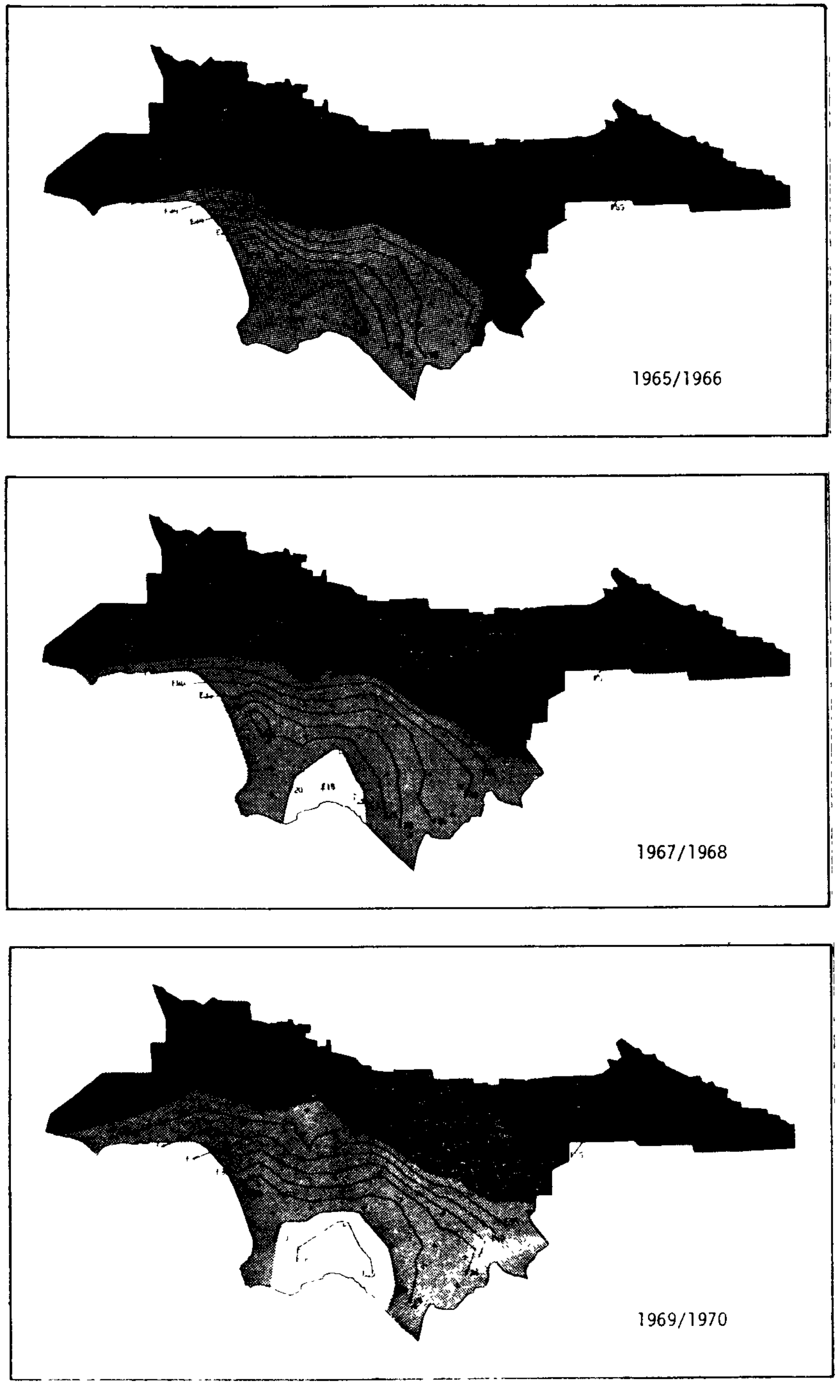
The population size of every Regional Statistical Area (RSA) was computed for each two-year period by interpolating the SCAG estimates of RSA population in 1960, 1970, and 1975 into the midpoint of the two-year period (e.g., 1965/66 as 1965.5). Sizes of subpopulations (elderly, school-age, and non-white) at every receptor point were computed by taking the product of the local total population at that receptor point and the percentage of the subpopulation to the total population in 1970 (Table A2). During the 10-year period, some RSA's in Los Angeles county lost a part of their population while RSA's in Orange County gained a substantial number of people.

3.1 SPATIAL CHANGE IN O_X AIR QUALITY

The spatial variation of oxidant air quality and its change with time were examined by computing isopleths of risk frequency. Figure 3.1 shows the spatial variation of daily risk frequency (i.e., percent of days the NAAQS was exceeded) and the changes in the spatial variation pattern over the ten-year period (see also Fig. D1 in Appendix D). It can be seen that improvement in oxidant air quality took place everywhere in the study area. A careful observation of the figure shows that there were two stages in the air quality improvement.

The earlier stage of the improvement appears to have taken place during the period from 1965 to 1970 and is characterized by the emergence of the area where the NAAQS was exceeded less than 20% of the days. This lower pollution area appeared in the 1967/68 period around Long Beach and enlarged considerably in the 1969/70 period. The later stage of the improvement appears to have taken place during the period from 1971 to 1974 and is characterized by the shrinkage of the area where the NAAQS was exceeded more than 50% of the days. This most polluted area remained around Azusa. In this later stage, the area where the NAAQS was violated less frequently than every five days covered the southern half of the study area.

A possible explanation of these observations is as follows: The emission control strategy implemented during the period from 1965 to 1970 reduced hydrocarbon emissions significantly in the study area but at the same time increased NO_x emissions significantly.[9] As a



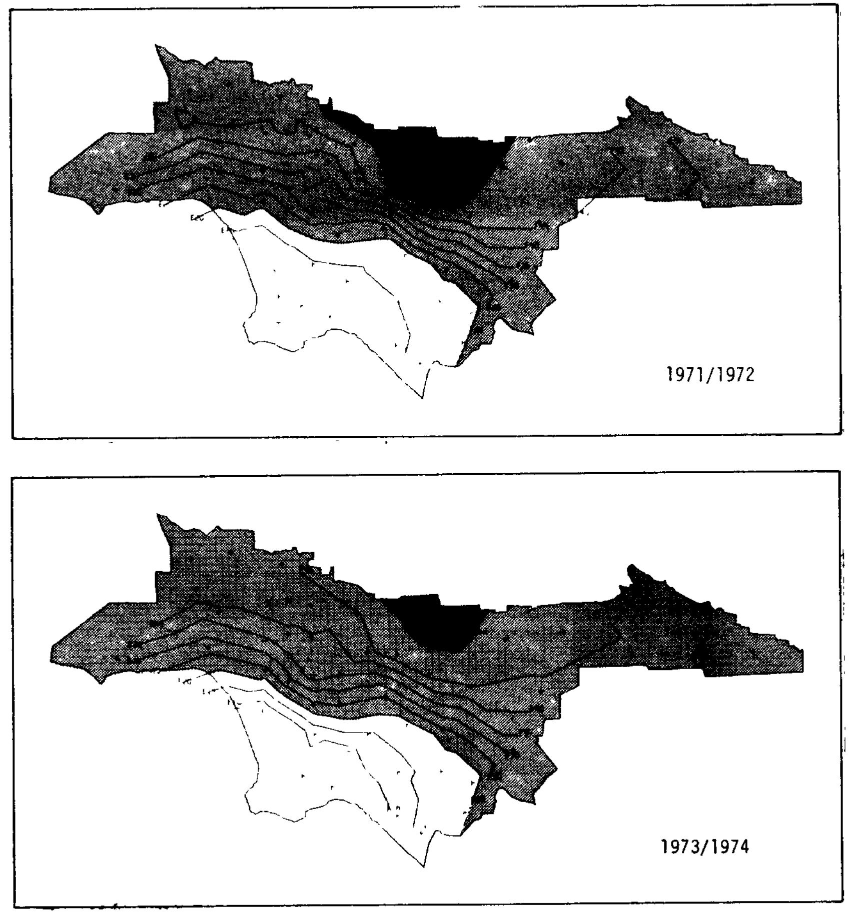
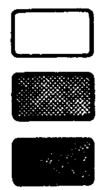


Figure 3.1. PERCENT OF DAYS ON WHICH THE NAAQS FOR OXIDANT WAS EXCEEDED DURING FIVE 2-YEAR PERIODS.



result of these emission changes, the HC/NO_x ratio should have acted to delay O_x formation and pushed the O_x maxima further inland. Therefore, the significant improvement in O_x air quality was observed in the coastal region but not so in the inland region downwind of the urban area of the cities of Los Angeles and Long Beach. During the period from 1971 to 1974, the increase in the NO_x emissions was slowed because new car emission standards for NO_x took effect in 1971. The decline in hydrocarbon emissions continued during this later period. The compounded effects of the slowed growth in NO_x emissions and the continued reduction in HC emissions were probably responsible for the moderate and uniform improvement in O_x air quality throughout the study region.

The air quality improvement also accompanied a reduction in daily exposure of the population on days when the standard was violated. Mean duration of violations per day was computed by taking a ratio of the daily risk frequency to the hourly risk frequency. The isopleths of mean duration in hours per day are shown in Fig. 3.2 for each of the five two-year periods. A more detailed isopleth map is presented in Figure D2 in Appendix D. The first half of the ten-year period, i.e., 1965/66 to 1969/70 showed a reduction in average duration around Long Beach. However, the second half of the ten-year period, i.e., 1969/70 to 1973/74 did not show any substantial change in mean duration. The mean durations in the inland areas are persistently longer than five hours per day during the entire ten-year period.

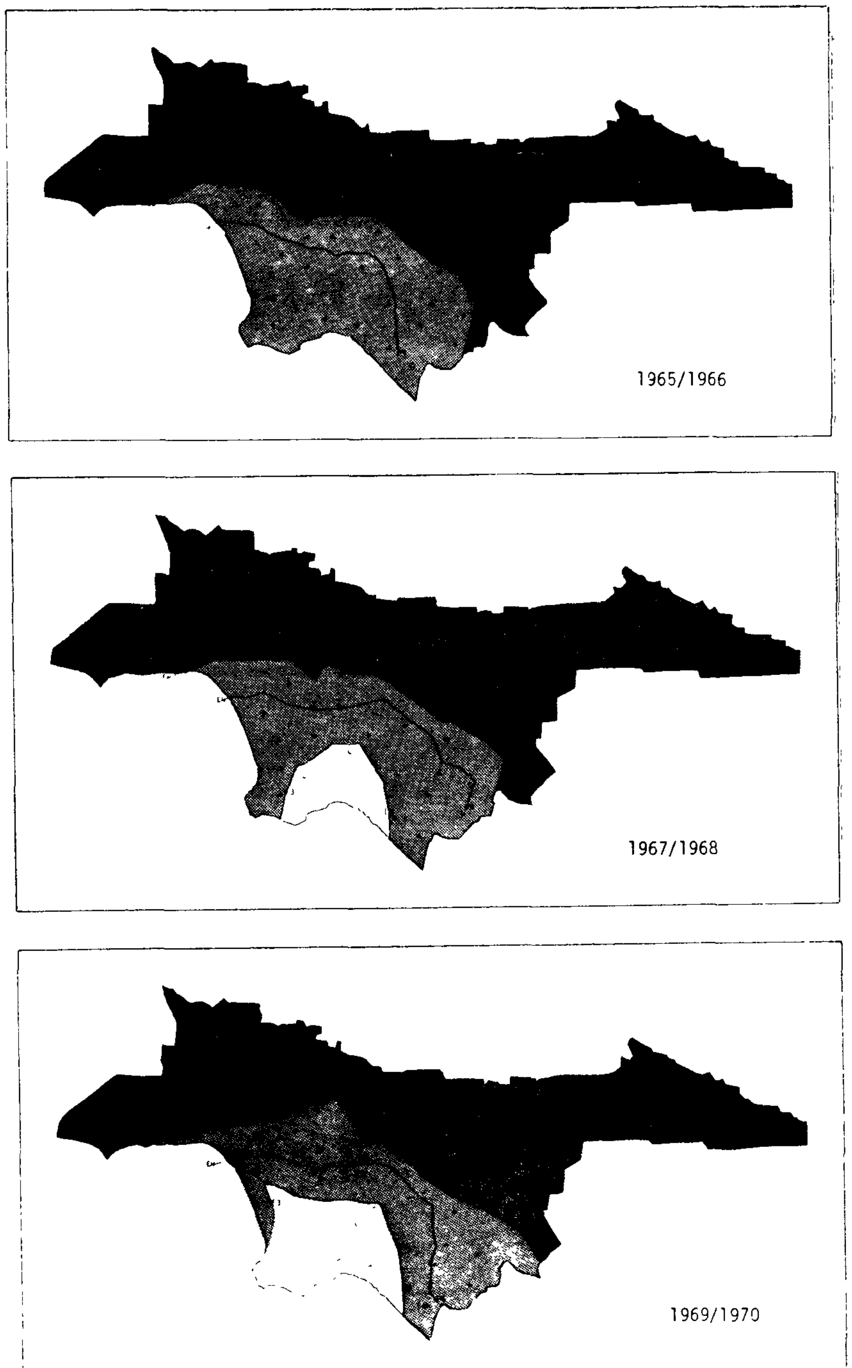
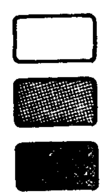


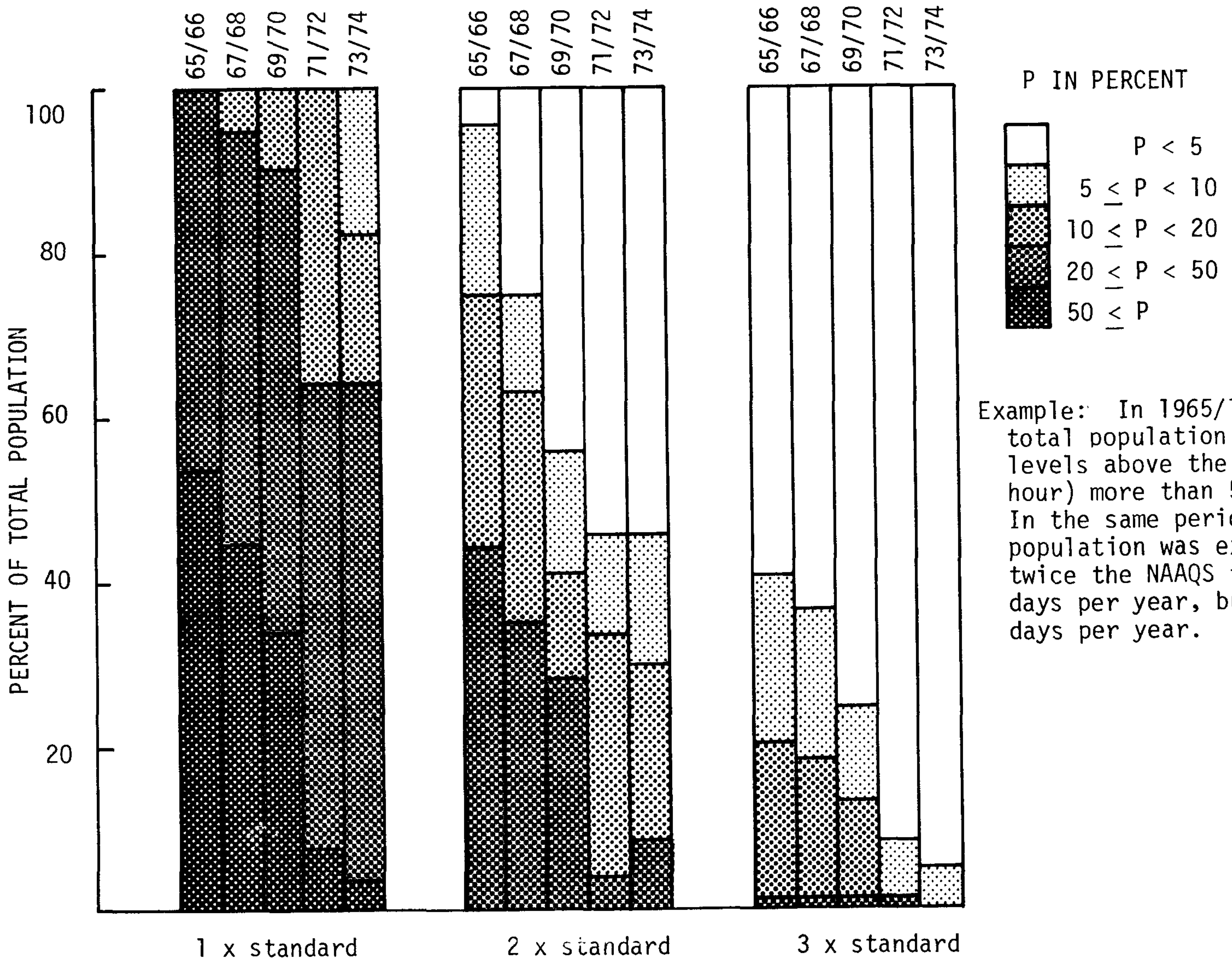
Figure 3.2. AVERAGE DURATION (HOURS) ON DAYS WHEN THE NAAQS FOR OXIDANT WAS EXCEEDED DURING FIVE 2-YEAR PERIODS.



3.2 REGIONWIDE TREND IN POPULATION EXPOSURE TO O_X

The implications of the air quality improvements on population exposure to O_x in the Los Angeles Basin are summarized in Fig. 3.3 by the percentages of the population exposed to O_x above the NAAQS at various percents of time. The reduction in population exposure to oxidant air pollution is greatest at a high exposure level. For example, the percentage of the population exposed more than 50% of the time dropped from 53 percent in 1965/66 to a mere 5 percent in 1973/74. The resident locations of these people are found in Fig. 3.1. The percentage of the population who were exposed less than 20% of the time was zero percent in 1965/66 but increased to 35 percent in 1973/74. Figure 3.3 also shows a similar reduction in population exposure to higher oxidants concentrations (above the level of twice and three times the standard).

The improvement in oxidant air quality during the ten-year period is shown in Figure 3.4 in the form of a population-at-risk distribution. The numerals 1, 2, 3, 4, and 5 indicate, respectively, the 1965/66, 67/68, 69/70, 71/72, and 73/74 periods. The reduction in population exposure to O_x is demonstrated in the figure by the shift of curves toward the lower left corner. The population-at-risk distribution for subpopulations: school-age (2), elderly (3), and non-white (4) are shown in Fig. 3.5. These figures show that the exposure patterns of school-age and elderly populations are similar to that of total population which is designated by numeral 1. However, the exposure pattern of non-white population is somewhat different from those of other populations.



Example: In 1965/1966 about 53% of the total population was exposed to O_3 levels above the NAAQS (8 pphm for one hour) more than 50% of the days per year. In the same period about 44% of the total population was exposed to O_3 levels at twice the NAAQS for at least 20% of the days per year, but less than 50% of the days per year.

Figure 3.3. CHANGES IN POPULATION EXPOSURE TO O_x DURING FIVE 2-YEAR PERIODS.

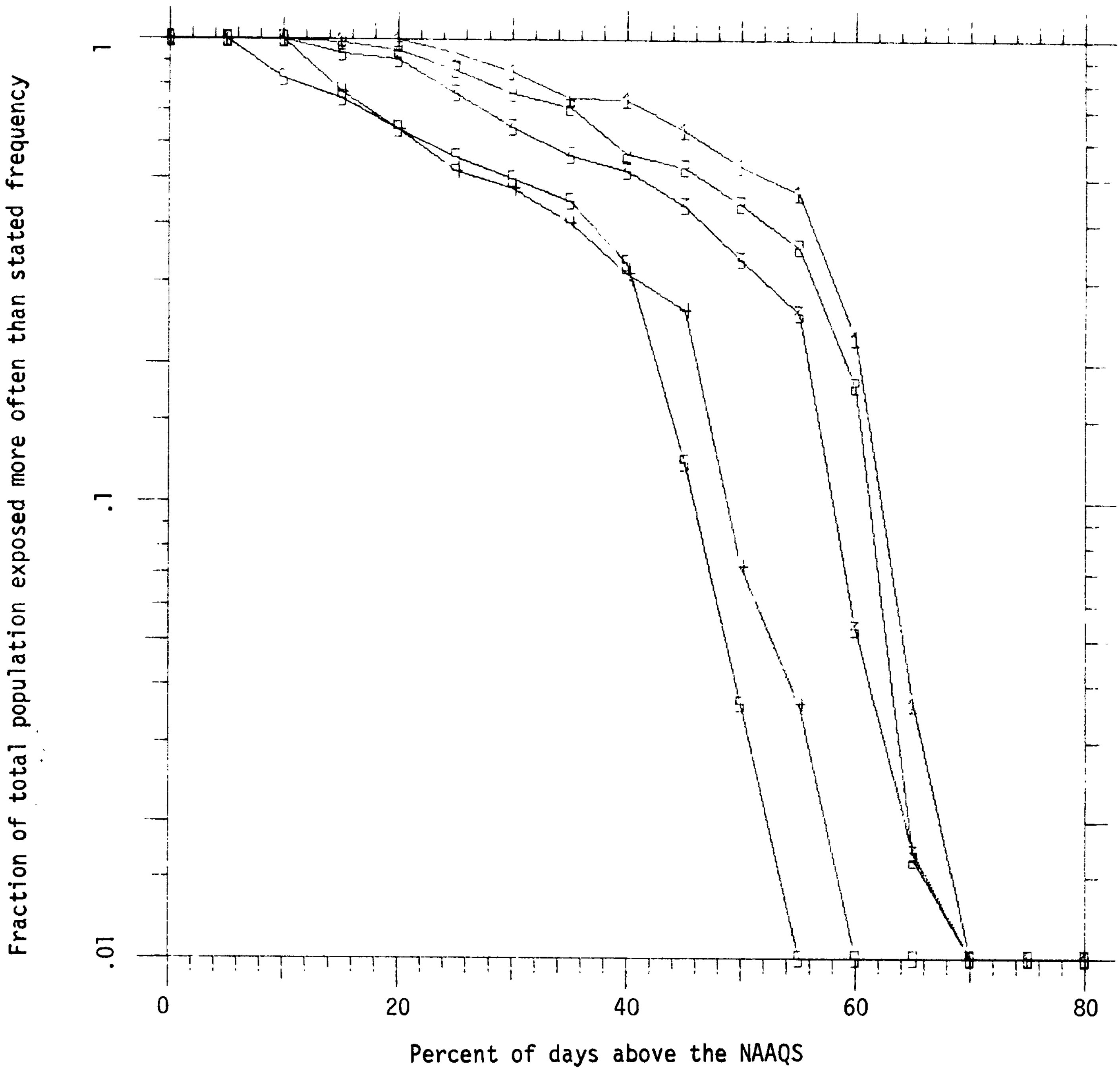


Figure 3.4. POPULATION EXPOSED TO O_x DAILY MAXIMUM HOURLY CONCENTRATION ABOVE THE NAAQS MORE OFTEN THAN STATED FREQUENCY DURING THE FIVE 2-YEAR PERIODS (1 FOR 65/66, 2 FOR 67/68, 3 FOR 69/70, 4 FOR 71/72, AND 5 FOR 73/74).

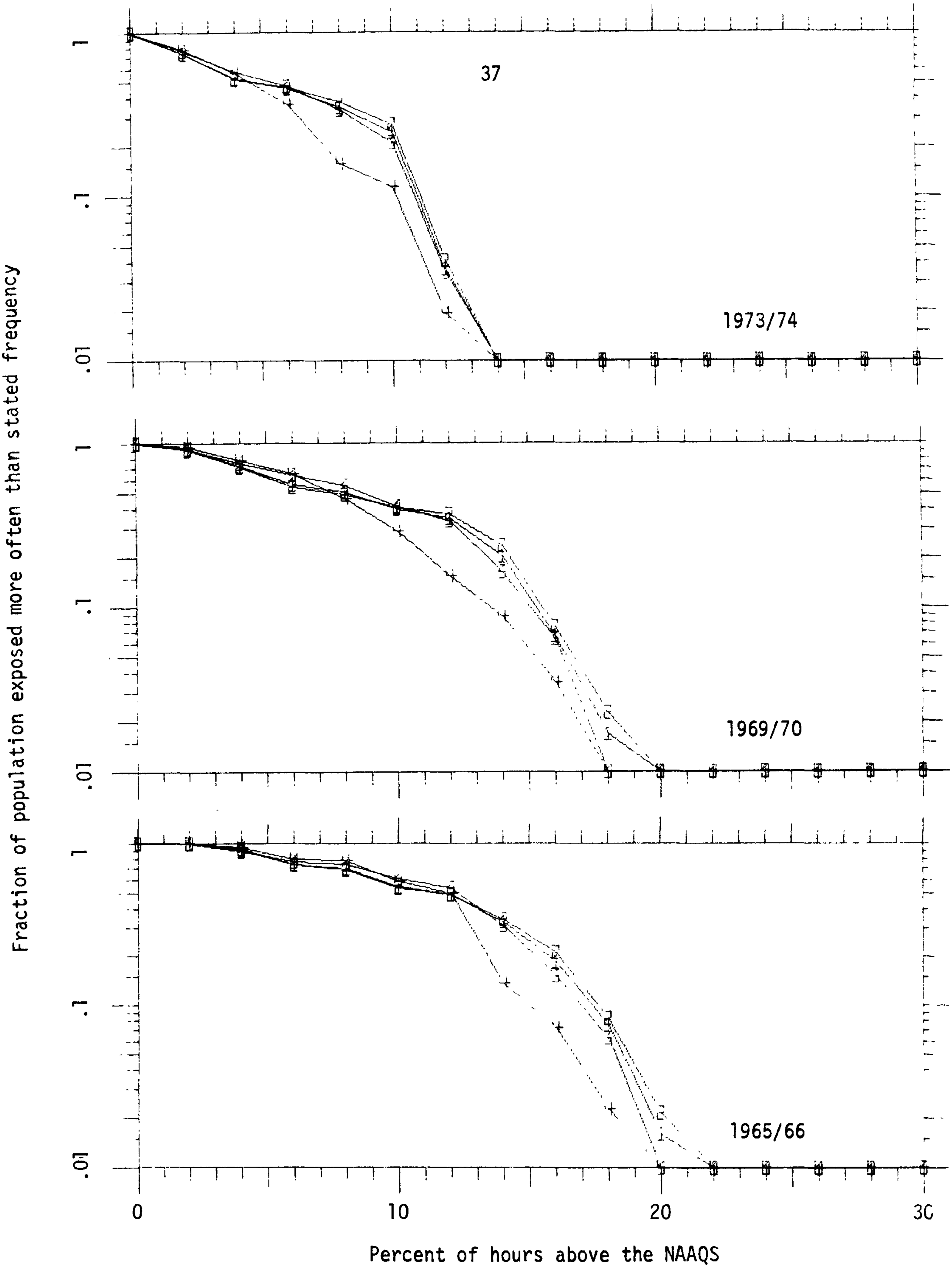


Figure 3.5. POPULATION-AT-RISK DISTRIBUTION FOR O_x DURING 1965/66, 1969/70, AND 1973/74 FOR TOTAL (1), SCHOOL-AGE (2), ELDERLY (3), AND NON-WHITE (4) POPULATION.

In order to examine the difference in population exposure between non-white population and other populations, the histograms of population exposure to O_x above the NAAQS were obtained from Figure 3.5 for non-white population and total population. It can be seen from Figure 3.6 that the percentage of non-white population exposed at the highest and the lowest risk frequency is lower than those of other populations while its percentage exposed at a risk frequency in the middle range is higher than those of other populations. This is due to the higher density of non-white populations in the central portions of the Los Angeles region where O_x concentrations are intermediate. This difference in exposure pattern between non-white population and other populations increased from 1965/66 to 1973/74. This discovery of a subtle difference in exposure of different populations could not be made by the method used by other researchers who computed only a long-term pollution dosage or an average concentration for a variety of social classes such as those by income level and those by race.[10,11,12]

The regionwide trend of oxidant air quality is shown in Fig. 3.7 by using three different indices: population weighted average concentration, area weighted average concentration, and station average concentration. At the higher percentile concentrations (99th and 90th percentile), there is a strong downward trend in all three indices. This is contrasted to a flat trend at the 50th percentile concentrations. Figure 3.7 also shows that the population weighted average concentration is persistently lower than the area weighted average concentration. This indicates that oxidant concentration levels are not positively correlated with population density. Because emissions of precursor pollutants such

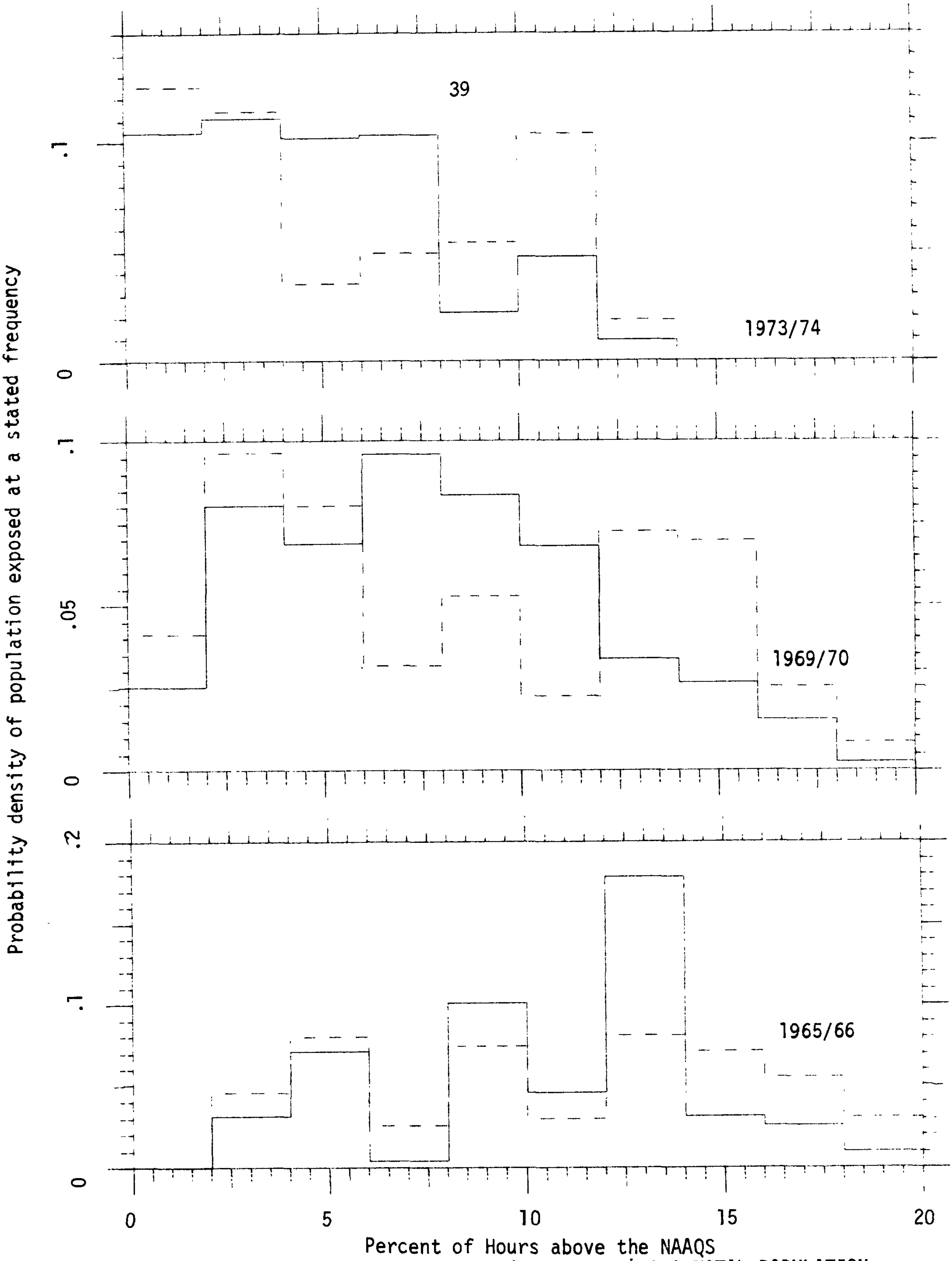


Figure 3.6 EXPOSURE OF NON-WHITE (SOLID LINE) AND TOTAL POPULATION (DASHED LINE) TO O_X ABOVE THE NAAQS DURING 1965/66, 1969/70, AND 1973/74.

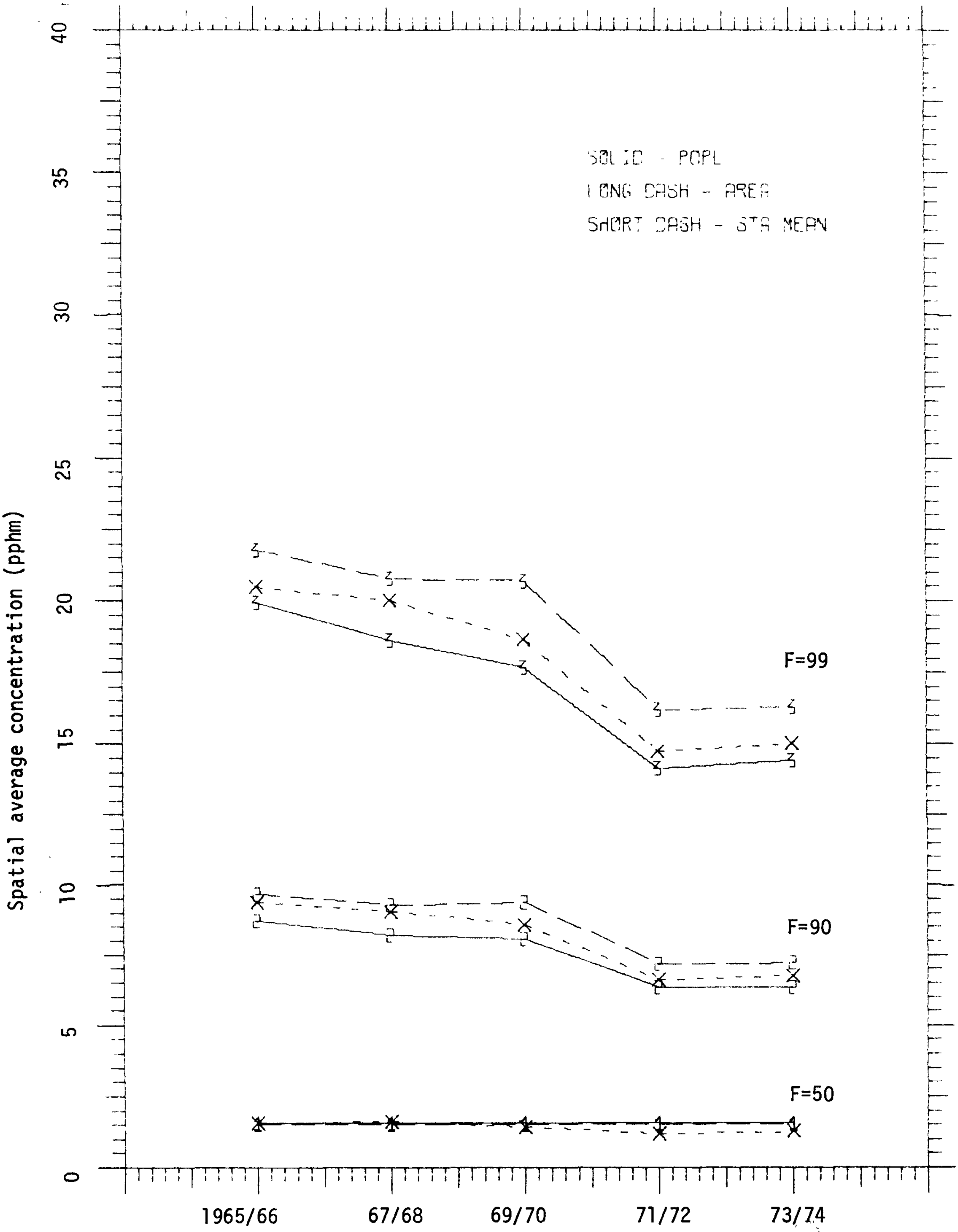


Figure 3.7 OXIDANT TRENDS AT THE 50th, 90th, AND 99th PERCENTILE IN THREE AVERAGE CONCENTRATIONS (POPULATION WEIGHTED, AREA WEIGHTED, AND STATION AVERAGE).

as hydrocarbons and oxide of nitrogen are positively correlated with population density in most urbanized areas, the above finding serves as evidence that oxidants within an air shed may be poorly correlated with local emission levels.

It should also be noted in Fig. 3.7 that the station average concentration is located between the population weighted average concentration and the area weighted average concentration. This is evidence that the ten monitoring stations used for the trend analysis are properly arranged in space to report, without a particular bias, the air environment of people at various locations within the study area.

The regionwide trend in population exposure to O_x is shown in Fig. 3.8 by the average hourly risk frequency. The average hourly risk frequency was computed for three different thresholds: CS = 1 x NAAQS, CS = 2 x NAAQS, and CS = 3 x NAAQS. Figure 3.8 shows that the percentage of hours at which an average person was exposed to O_x above the NAAQS dropped from about 12% in 1965/66 to about 6% in 1971/72 and 73/74, while that exposed to O_x three times the NAAQS dropped from about 0.7% in 1965/66 and 67/68 to about 0.15% in 1973/74. Therefore, it can be said that the rate of improvement in population exposure is greater for the higher concentration threshold than for the lower concentration threshold (factor of 7 vs. factor of 2), while the absolute improvement is greater for the lower threshold than for the higher threshold (6% vs. 0.45%).

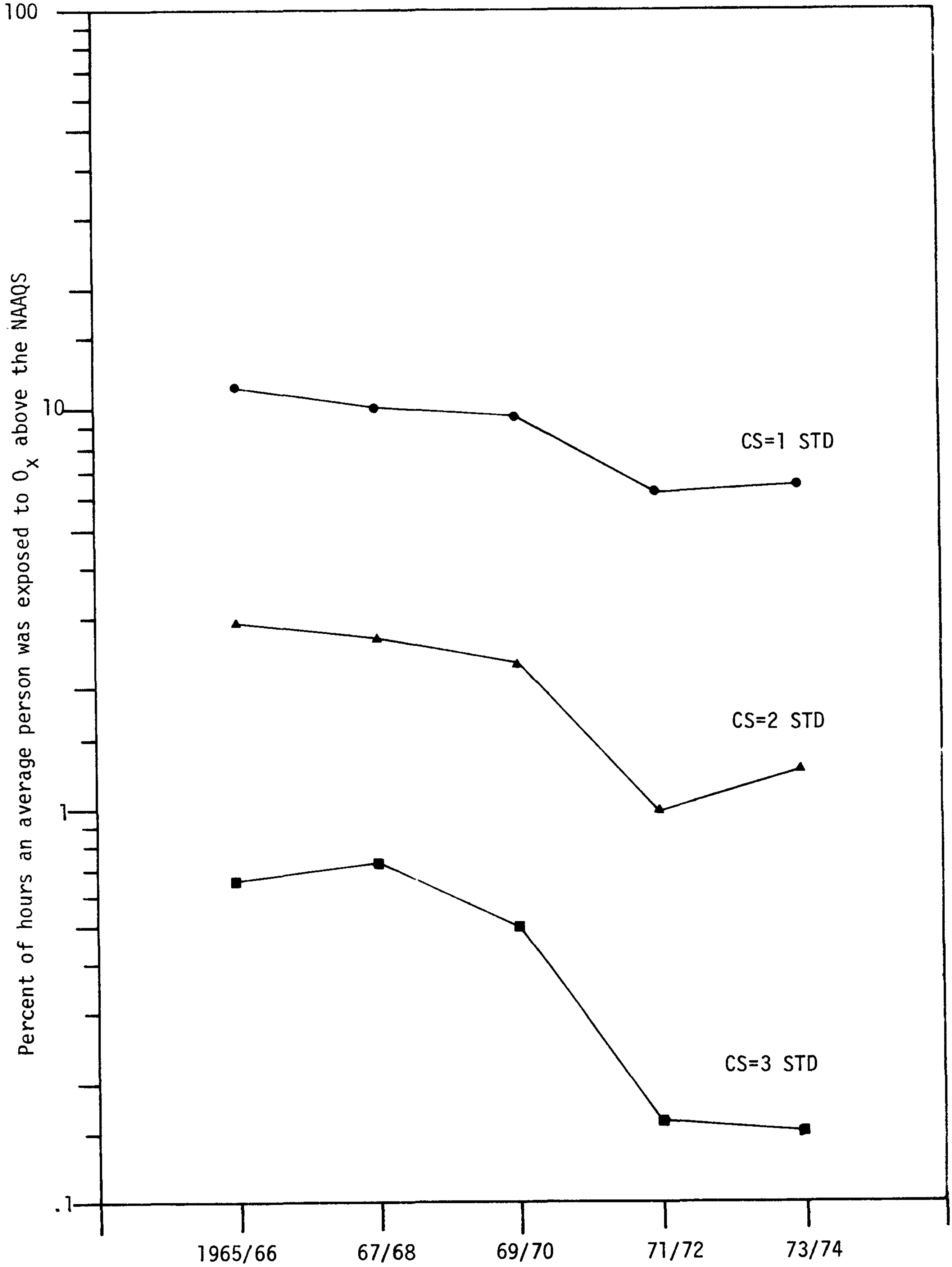


Figure 3.8 OXIDANT TREND IN POPULATION EXPOSURE INDEX WITH THE THRESHOLD EQUAL TO NAAQS, 2xNAAQS, AND 3xNAAQS.

The regionwide trend in population exposure to O_x is summarized in Table 3.1 by the number of days the NAAQS was exceeded and by the mean duration of standard violations in hours per day. The number of days on which an average person in the study area was exposed to O_x above the NAAQS decreased from 176 days per year in 1965/66 to 144 days per year in 1969/70, and to 105 days per year in 1973/74. The mean duration of such exposure of the average person also decreased from 5.1 hours per day in 1965/66 to 4.6 hours per day in 1969/70, and to 4.3 hours per day in 1973/74. The regionwide trend in population exposure to O_x above twice the standard is also found in Table 3.1. The average number of days on which the threshold of twice the standard was exceeded decreased markedly from 70 days per year in 1965/66 to 45 in 1969/70, and to 26 in 1973/74. However, the average mean duration decreased only a little from 3.1 hours per day in 1965/66 to 2.9 hours per day in 1973/74.

Table 3.1 Regionwide Trend in # Days NAAQS for O_x was Exceeded for the Average Person and the Mean Duration in Hours per day

Threshold	Index	1965/66	1967/68	1969/70	1971/72	1973/74
1 X STD 160 μg/m^3	# Days Exceeded Per Year	176	162	144	109	105
(8 pphm)	Mean Duration in Hours	5.1	4.8	4.6	3.8	4.3
2 X STD 320 μg/m^3	# Days Exceeded Per Year	70	59	45	26	26
(16 pphm)	Mean Duration in Hours	3.1	3.1	2.8	2.1	2.9

4. TRENDS IN NO_2 AIR QUALITY AND POPULATION EXPOSURE

The National Ambient Air Quality Standard (NAAQS) for NO_2 is given only for an annual arithmetic mean concentration. There is no NAAQS for a short-term (hourly or daily) average concentration of NO_2. However, recent epidemiological studies indicate that there are some adverse effects on the public health of short-term exposure to high ambient NO_2 concentrations.[13,14] The adverse effects suspected are increased susceptibility and severity of acute respiratory disease such as increased coughing and Klebsiella pneumonia.

Therefore, the trends of NO_2 air pollution are analyzed for both annual arithmetic mean concentrations and hourly average concentrations. The analysis of population exposure to annual mean concentrations is made with respect to "dose rate" defined by Eq. E-3 (Appendix E). As seen from the defining equation, the dose rate of a person is given by the annual arithmetic mean concentration at his residence location (static population assumption). To make an analysis of population exposure to hourly NO_2 concentrations, a threshold(s) has to be determined. The California standard for a NO_2 hourly average concentration, C_S = 470 μg/m³ or approximately 25 pphm was chosen for the threshold.

The trend study area for NO_2 is smaller than that for O_x and is confined to the heavily populated southern half of Los Angeles County. Over this study area, there are only eight monitoring stations that provide air quality data usable for the analysis of trends in NO_2 air quality and in population exposure to NO_2.

Figure 4.1 depicts the mean and the range of concentrations measured at the eight stations during the ten-year period. A comparison between the NAAQS for NO_2 and the range of annual mean concentrations indicates that almost all the stations violated the national standard, particularly, since 1969. In both the annual mean concentrations an l the 99th percentile concentrations, the middle years 1967/78 to 1971/72 were more polluted than the two end years 1965/66 and 1973/74.

4.1 SPATIAL CHANGE IN SHORT-TERM NO_2 AIR QUALITY

The spatial variation of NO_2 air quality and the change of the spatial pattern with time are depicted in Figure 4.2 (also in Figure D3) by the percentage of days on which the California standard was exceeded and Figure 4.3 (also in Figure D4) by the mean duration of concentrations above the standard in hours per day. The area exceeding the California standard more frequently than 6% of the days was approximately matched with the area of Downtown Los Angeles in 1965/66, extended to almost the entire study are in 1967/68, 69/70, and 71/72, and was confined to the San Fernando Valley in 73/74 (Figure 4.2).. The area with a mean duration longer than three hours per day was confined to the north-central part of the San Fernando Valley in 1965/66, extended to the majority of the study region in 1967/68, 69/70, and 71/72, and then

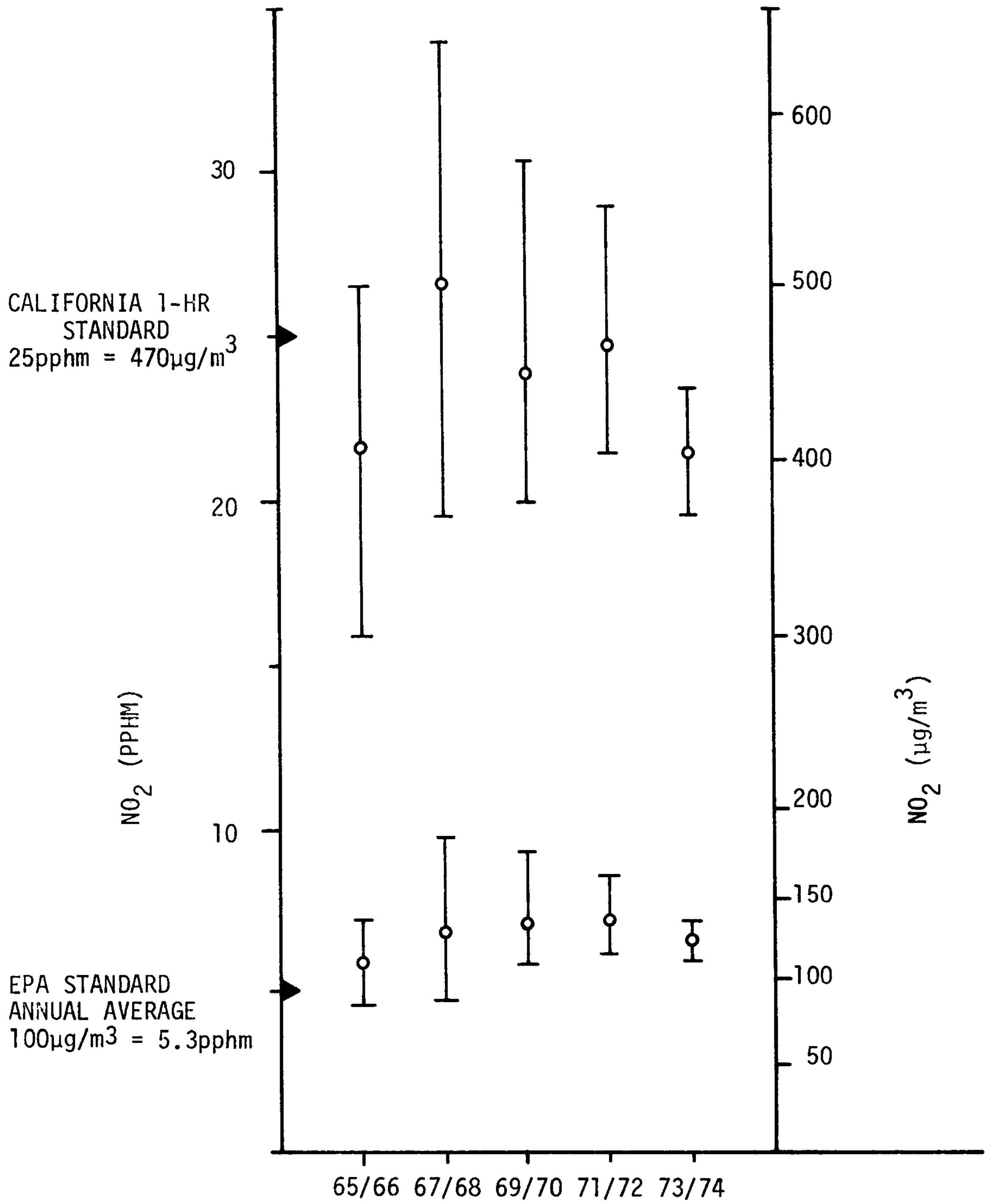
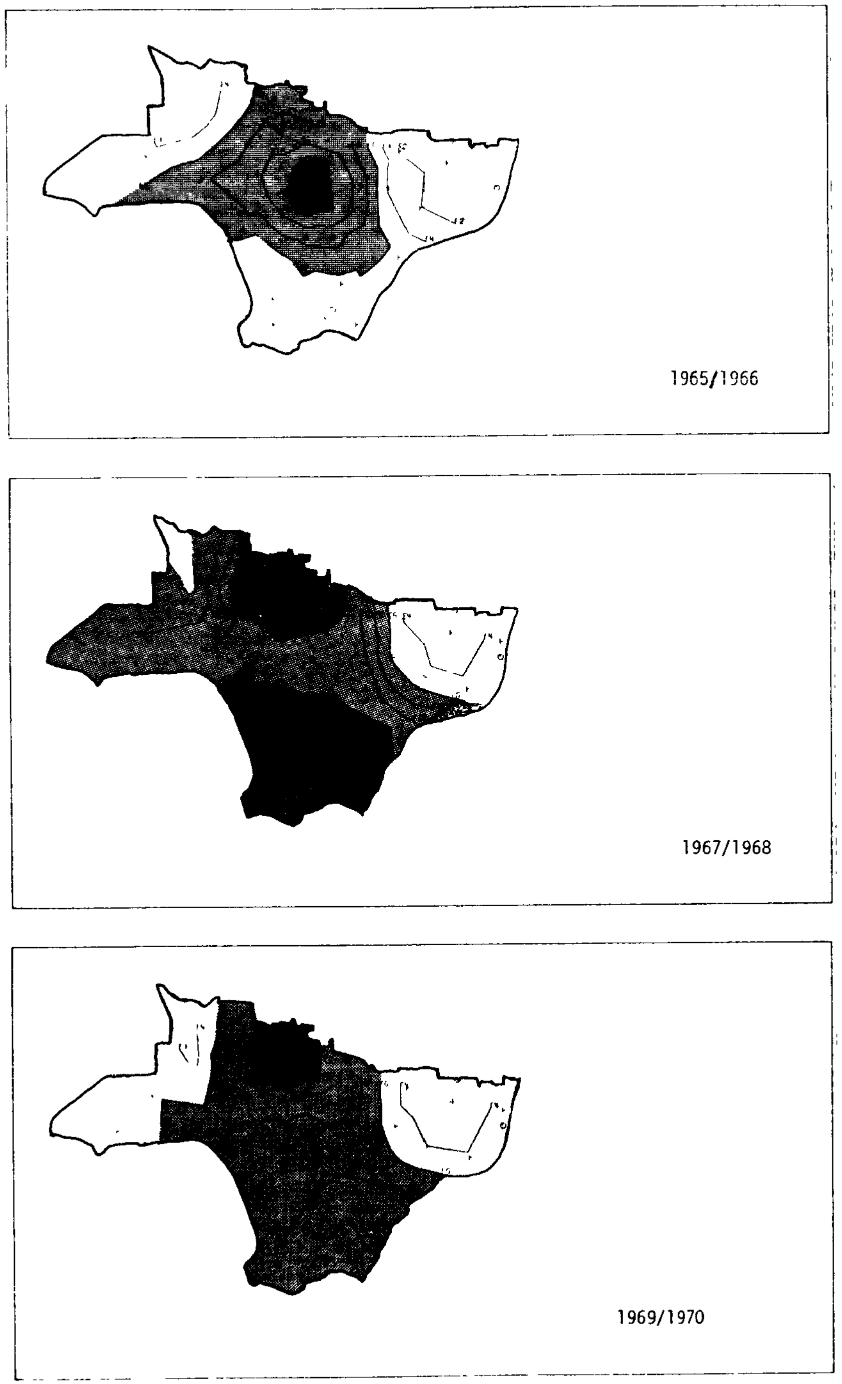


Figure 4.1. THE AVERAGE VALUE AND THE RANGE OF VALUES FOR EIGHT MONITORING STATIONS SHOWING NO_2 TRENDS IN ANNUAL MEAN CONCENTRATIONS (LOWER SEGMENT) AND IN 99th PERCENTILE CONCENTRATIONS (UPPER SEGMENT).



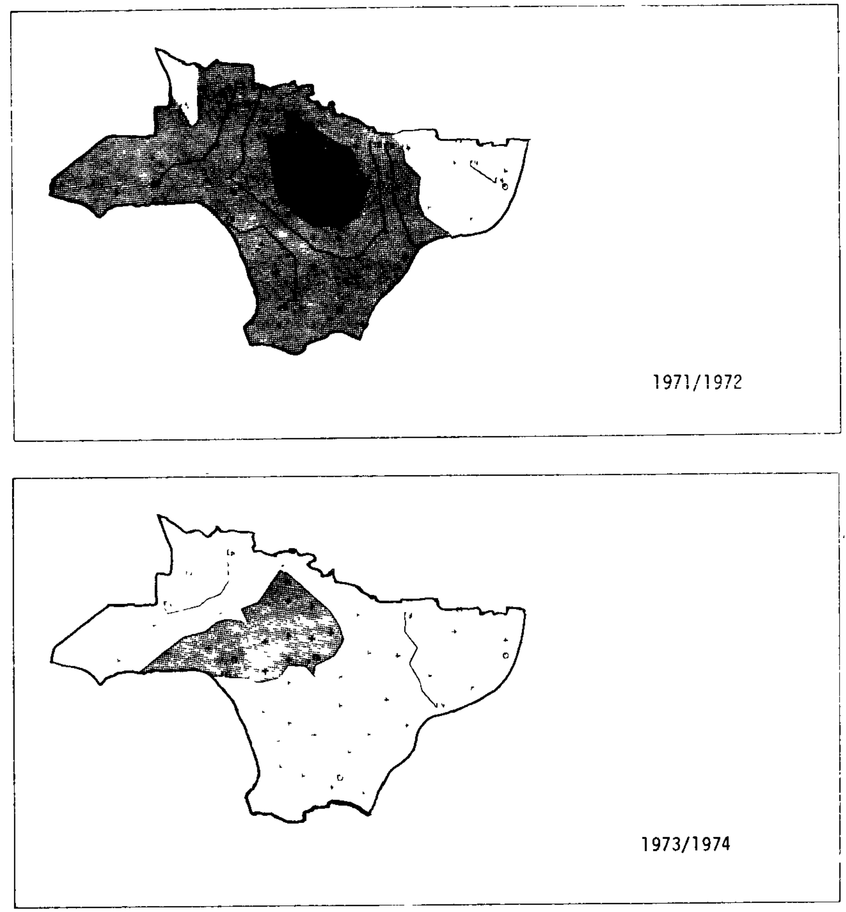
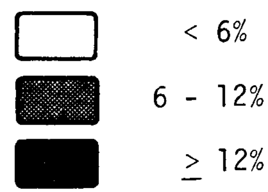
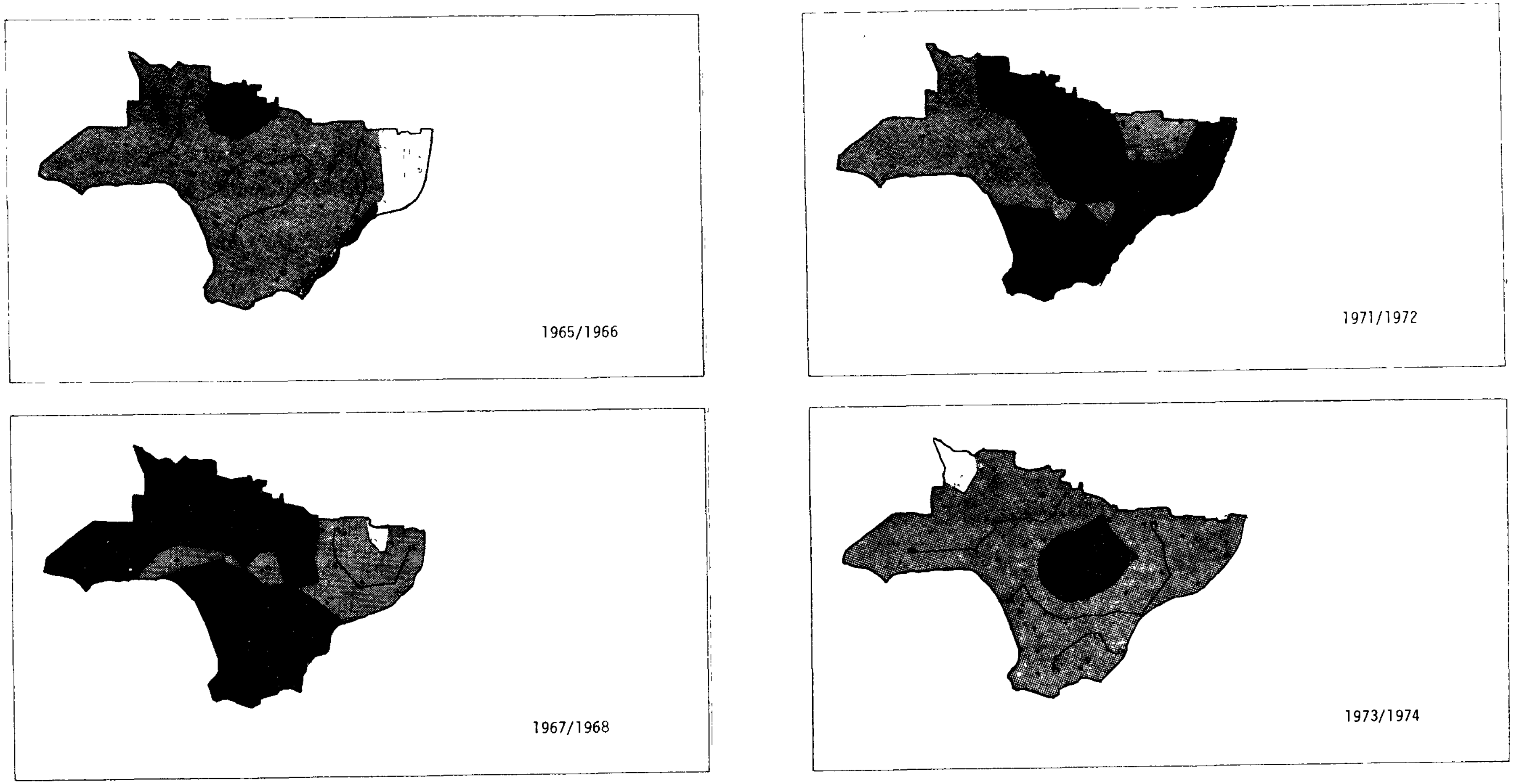


Figure 4.2. PERCENT OF DAYS ON WHICH THE CALIFORNIA 1-HR STANDARD FOR NO_2 WAS EXCEEDED DURING FIVE 2-YEAR PERIODS.





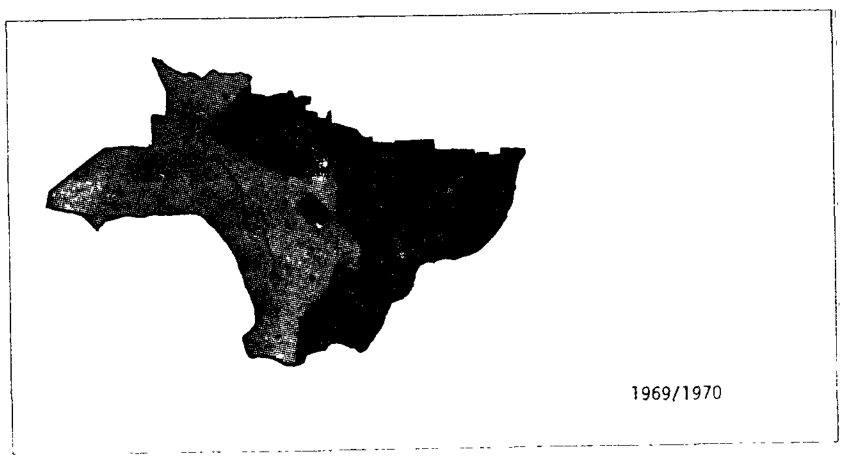
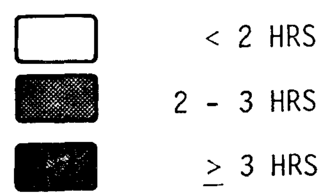


Figure 4.3. AVERAGE DURATION (HOURS) ON DAYS WHEN THE CALIFORNIA 1-HR STANDARD WAS EXCEEDED DURING FIVE 2-YEAR PERIODS.



shrank to the Los Angeles downtown area in 1973/74. A more detailed isopleth map of percentage of days exceeded during each of the five 2-year periods is presented in Figure D3, Appendix D while in Figure D4, an isopleth map of mean duration is shown.

Figure 4.2 and Figure D3 show that NO_2 air quality deteriorated significantly during the middle year period 1967/68-1971/72 throughout the study area, i.e., Southern half of Los Angeles County. NO_2 air quality during the first and last two year periods, i.e., 1965/66 and 1973/74 was considerably better than that during the middle year period. A comparison between NO_2 air quality in 1965/66 and that in 1973/74 shows that the latter is distributed more uniformly over the study area than the former. On the other hand, Figure 4.3 and Figure D4, which show mean duration of the excess NO_2 concentration above the California standard per day, do not show such a marked difference in mean duration between 1965/66 and 1973/74. In terms of mean duration, NO_2 air quality in 1973/74 has a measurable spatial gradient.

Although it is not the purpose of this study to find causes of the air quality changes, the increases in NO_2 air pollution during the middle year period 1967/68-1971/72 were probably due to the air pollution control strategy rather than the meteorology during that period. According to an EQL report,[9] although hydrocarbon emissions decreased by 24% in Los Angeles county during the period 1965-1974, emissions of oxides of nitrogen increased by 25% during the same period. Table 2.2 shows that the population in the NO_2 study area increased from 6.43 million in 1965 to 6.91 million in 1970 and then declined to 6.87 million in 1975. Considering the population trend above and the fact that the NO_x emission standard for new cars became effective in 1971, we can expect that most of the 25% increase in NO_x emissions occurred during the period 1965 to 1970 or to 1971. This increased NO_x emission is the most likely cause of the increases in NO_2 air pollution during the middle year period 1967/68-1971/72.

As to the sudden improvement of NO_2 air quality in 1973/74, there is no satisfactory explanation. However, a part of the cause may be found in the facts that NO_x emission standard for new cars became effective after 1971 and that the population in Los Angeles County declined slightly from 6.91 million people in 1970 to 6.87 million people in 1975. Meteorology may also be an important factor during this period.

4.2 REGIONWIDE TREND IN POPULATION EXPOSURE TO SHORT TERM NO_2

The implications of the air quality changes with time and space on population exposure to NO_2 are summarized in Fig. 4.4 by the percentages of the population exposed to NO_2 above the California standard at various percents of time. The NO_2 air quality deterioration during the middle years 1967/68 to 1971/72 shown in Figs. 4.2 and 4.3 resulted in an increase of the population exposed more frequently than 12% of days and in a decrease of the population exposed less frequently than 6% of days during the same period. These increases in NO_2 air pollution and in

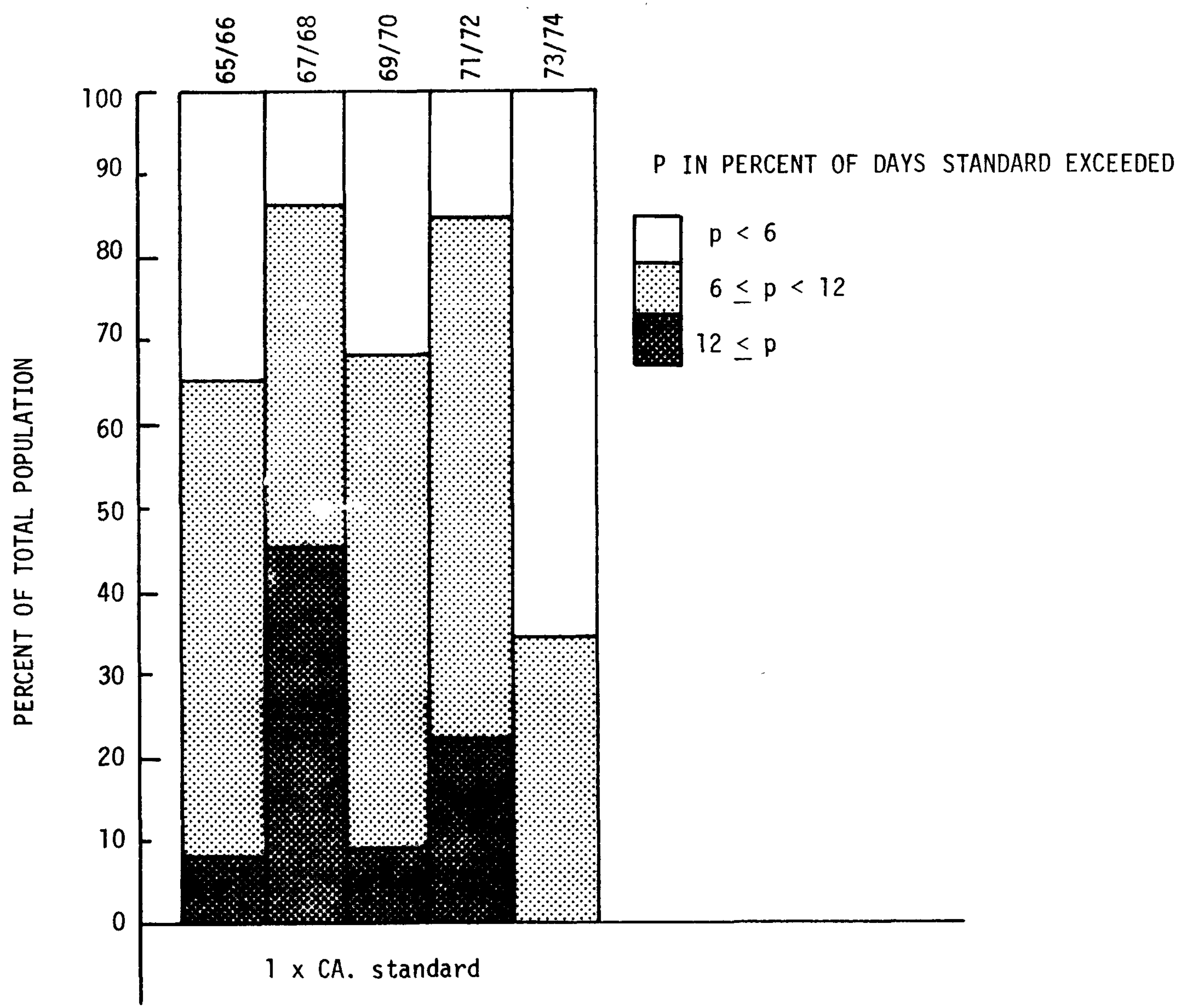


Figure 4.4. CHANGES IN POPULATION EXPOSURE TO NO_2 DURING FIVE 2-YEAR PERIODS.

population exposure to NO_2 during the middle years 1967/68 to 1971/72 are quite a contrast with the continuous decreases in O_x air pollution and in population exposure to O_x which have been observed in the O_x trend analysis.

Population-at-risk distributions for NO_2 during the five two-year periods are shown in Fig. 4.5. The high population exposure to NO_2 during the middle years, 1967/68, 69/70, and 71/72 is depicted by the crowded curves 2, 3, and 4 at the upper right corner of the figure. The difference in population exposure during the two lowest pollution periods 1965/66 and 1973/74 is seen clearly from the population-at-risk distributions of those two periods. Note that the slope of a curve at a given risk frequency indicates the probability density of the population exposed at that risk frequency. We thus know from the two distributions, that the great majority of the population was exposed over a narrow range of risk frequency, say, 3% to 7.5% in 1973/74 while in 1965/66 over a wide range of risk frequency, say, 1% to 15%. The population was also exposed over a wide range of risk frequency during the middle year periods. Therefore, it can be said that the population exposure to NO_2 in 1973/74 is unique and quite different from those in the other periods. This peculiarity might be explained by the year-to-year variation of meteorology. An emission control strategy that tends to suppress the peak concentration of NO_2 might also be responsible for this change in population exposure distribution.[15]

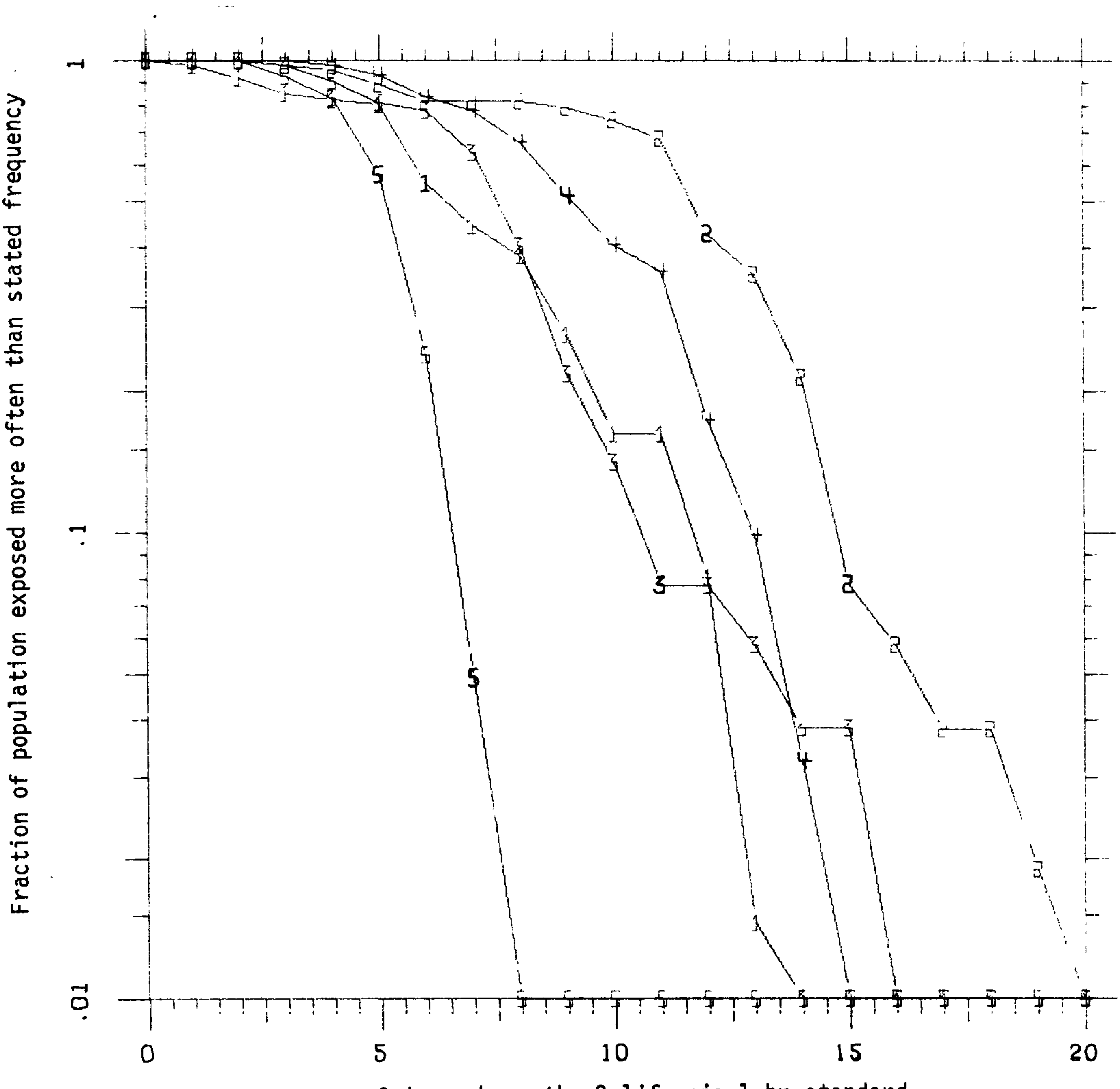


Figure 4.5 POPULATION EXPOSED TO NO_2 DAILY MAXIMUM HOURLY CONCENTRATION ABOVE THE CALIFORNIA 1-hr STANDARD MORE OFTEN THAN STATED FREQUENCY DURING THE FIVE 2-YEAR PERIODS (1 FOR 65/66, 2 FOR 67/68, 3 FOR 69/70, 4 FOR 71/72, AND 5 FOR 73/74).

Population-at-risk distributions for three subpopulations, school-age (2), elderly (3), and non-white (4) as well as total population (1) are shown in Figs. 4.6 and 4.7. As seen from Figure 4.6, during the two 2-year periods, 1965/66, and 73/74, the school-age population was exposed to the least NO_2. The non-white population was exposed most among the four populations during the same two 2-year periods. However, as seen from Figure 4.7, these relations were reversed during the middle year period, 1969/70. The non-white population is more concentrated in the urban core areas than the surrounding areas. It is difficult to explain the reasons for the peculiar behavior of the population exposure of the non-white population, which was less exposed than the other populations when NO_2 air pollution got worse and was more exposed when NO_2 air pollution improved.

The regionwide trend of NO_2 air quality is shown in Fig. 4.8 by using three different indices; population weighted average concentration, area weighted average concentration, and station average concentration. Although there is no obvious trend at any percentile, there seems to exist a somewhat downward trend at the 99th percentile concentration while at the 50th percentile concentration a slightly upward trend. Figure 4.8 also shows that the population weighted average concentration is persistently higher than the area weighted average concentration at each of the three different percentiles. This indicates that NO_2 concentration levels are positively correlated with population density. This interpretation is partly verified by comparing the population density map (Fig. 2.5) to

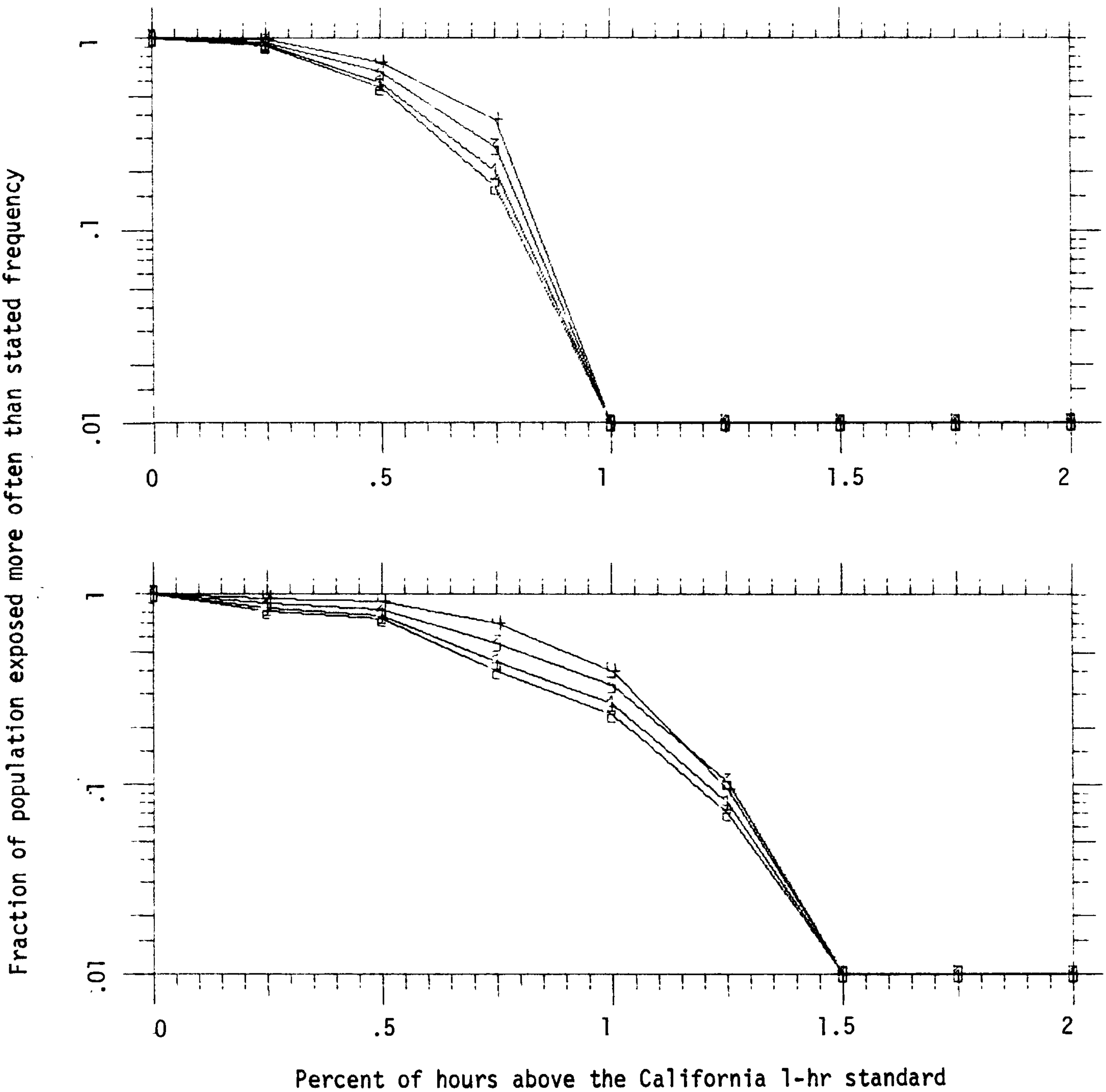


Figure 4.6 POPULATION-AT-RISK DISTRIBUTION FOR NO_2 DURING 1965/66 AND 1973/74 FOR TOTAL (1), SCHOOL-AGE (2), ELDERLY (3), AND NON-WHITE (4) POPULATION.

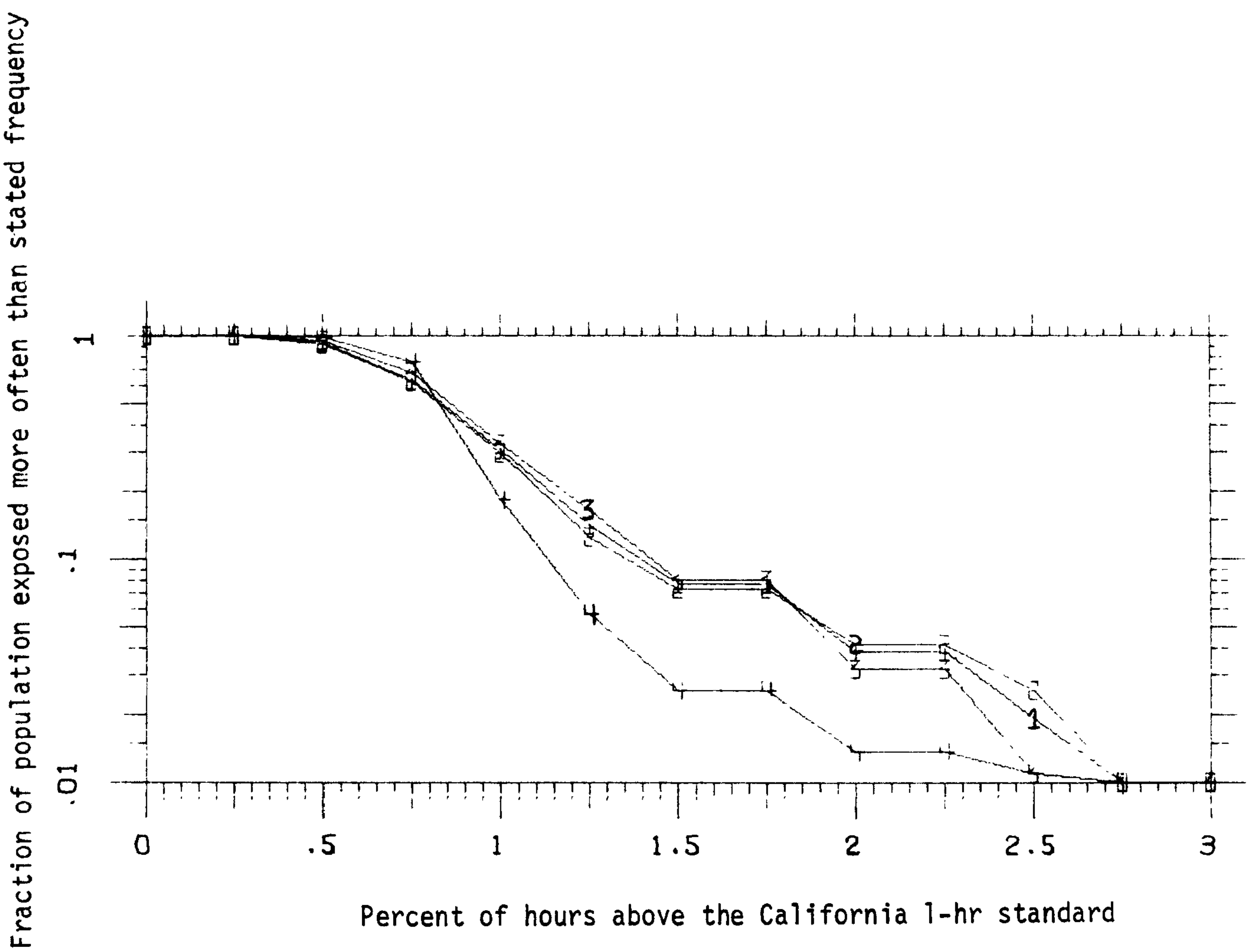


Figure 4.7 POPULATION-AT-RISK DISTRIBUTION FOR NO_2 DURING 1969/70 FOR TOTAL (1), SCHOOL-AGE (2), ELDERLY (3), AND NON-WHITE (4) POPULATION.

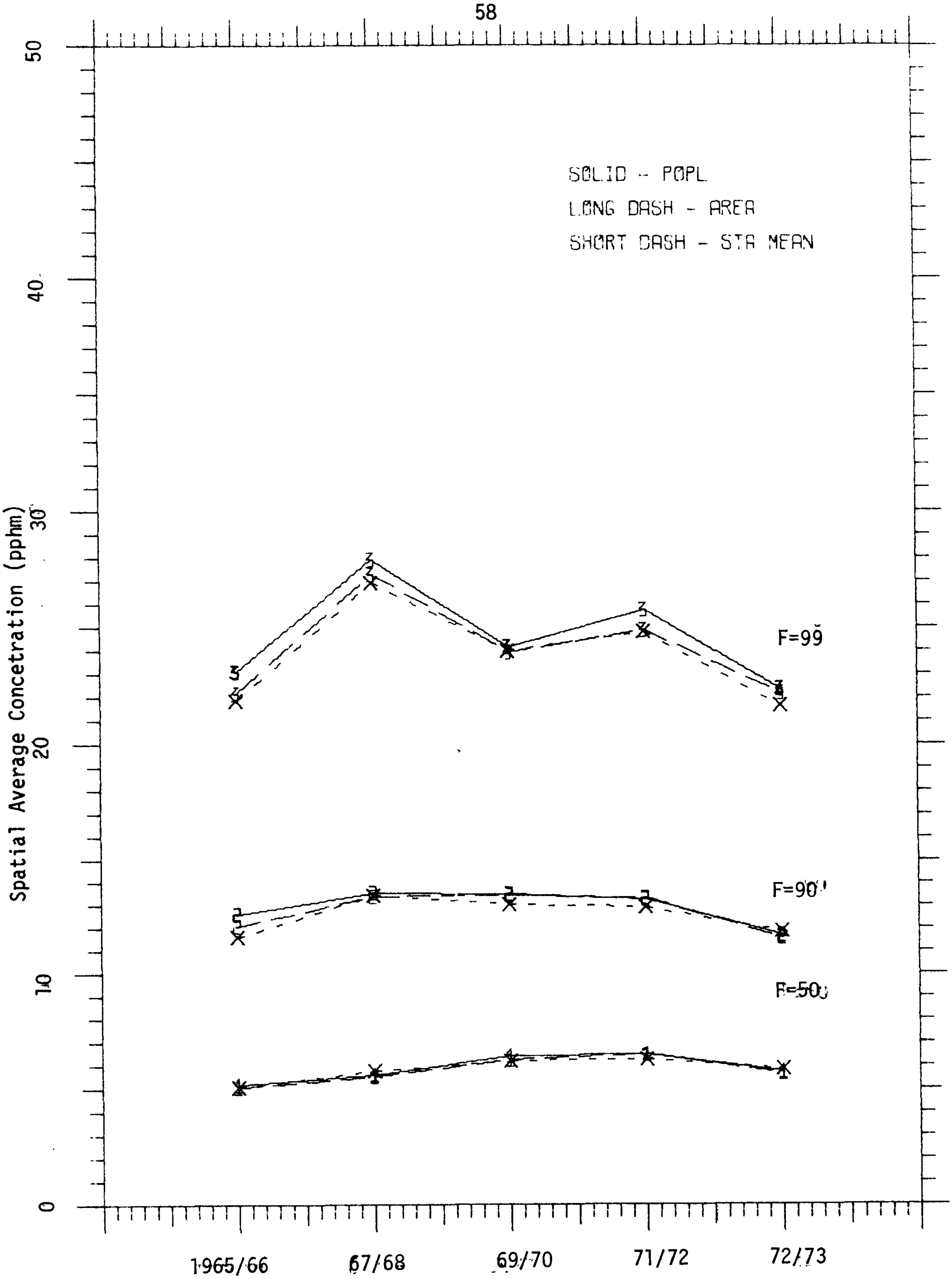


Figure 4.8 NO_2 TRENDS AT THE 50th, 90th, AND 99th PERCENTILE IN THREE AVERAGE CONCENTRATIONS (POPULATION WEIGHTED, AREA WEIGHTED, AND STATION AVERAGE).

the NO_2 risk frequency map (Fig. 4.2). Knowing that levels of primary pollutants such as particulates, SO_2, and CO are strongly (positively) correlated with population density in urban air pollution, the spatial variation pattern of NO_2 behaves similarly to those of primary pollutants in spite of the fact that the ambient NO_2 concentration is mostly due to oxidation of the primary pollutant NO. It should also be noted that the station average concentration gives slightly lower values at higher percentiles than the population weighted average concentration whose value would be most representative for the air environment of an average person.

The regionwide trend in population exposure to NO_2 is shown in Figure 4.9 by the average hourly risk frequency that has been computed by using the concentration threshold equal to the California standard for hourly average NO_2 concentration. There is a slightly downward trend in the average hourly risk frequency although the higher values during the middle-year periods obscure any trend in the population exposure index. The regionwide trend in population exposure to NO_2 is also summarized in Table 4.1 by using the average daily risk frequency and the average mean duration of California standard violations in hours per day. An average person in the study area was exposed to hourly NO_2 concentration above the California standard on 25 days in 1965/66, 27 days in 1969/70, and 18 days in 1973/74. The average duration of such high exposure changed from 2.6 hours per day in 1965/66 to 3.0 hours per day in 1969/70, and to 2.5 hours per day in 1973/74.

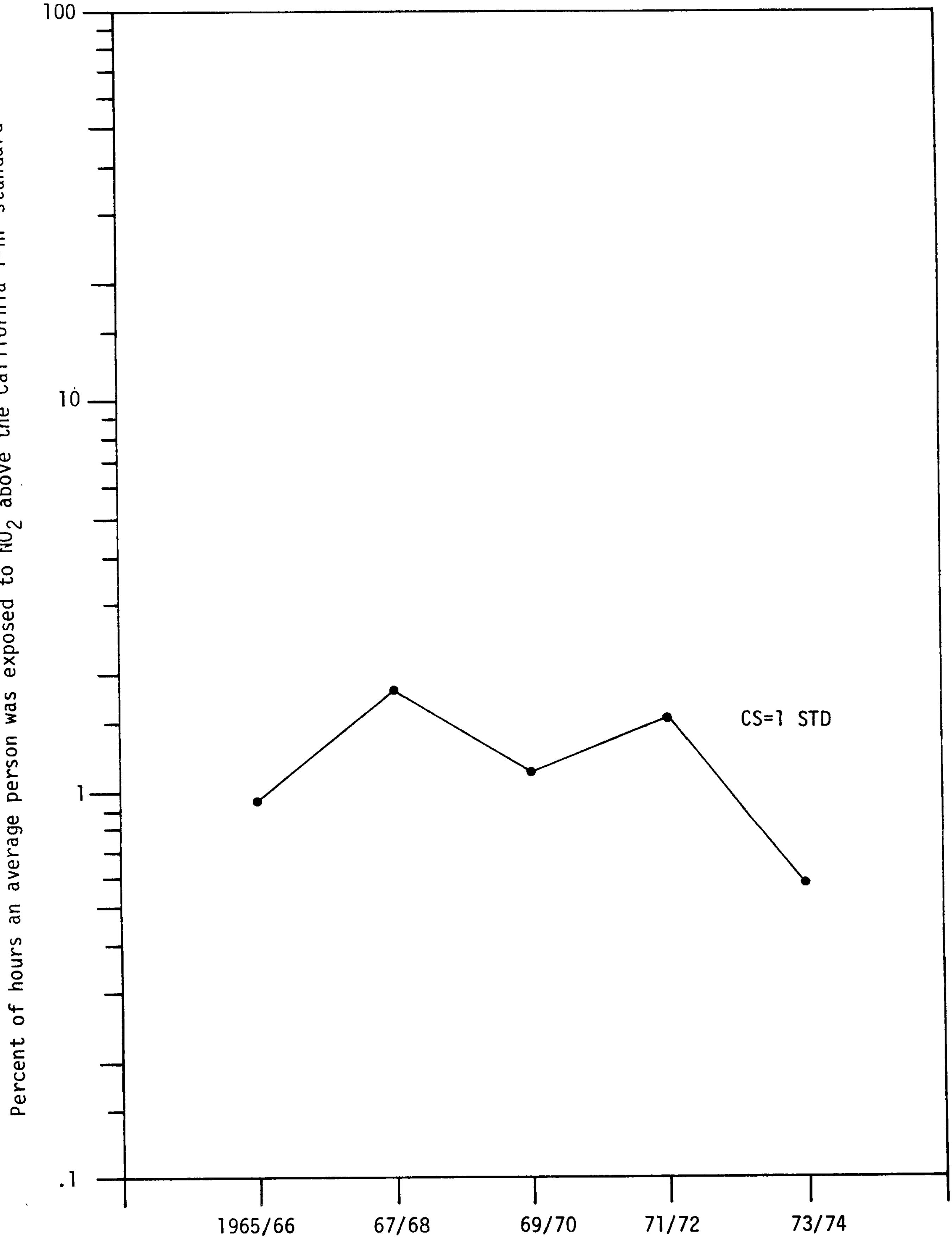


Figure 4.9 NO_2 TREND IN POPULATION EXPOSURE INDEX WITH THE THRESHOLD EQUAL TO THE CALIFORNIA 1-hr STANDARD.

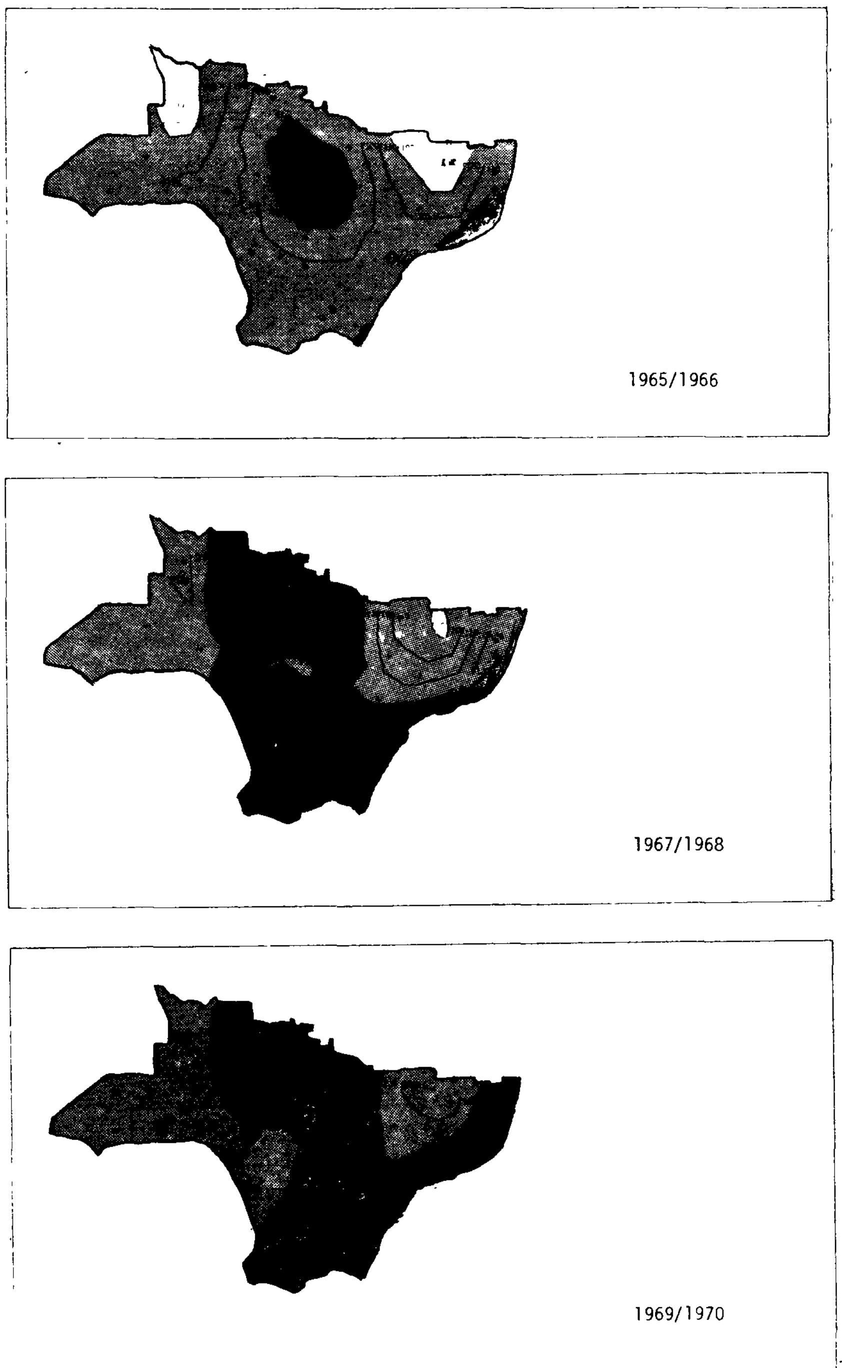
Table 4.1 Regionwide Trend in # Days the California One-Hour Standard for NO_2 was Exceeded and the mean Duration in Hours

Threshold	Index	1965/66	1967/68	1969/70	1917/72	1973/74
1 X STD	# Days Exceeded per Year	25	40	27	33	18
470 μg/m						
(25 pphm)	Mean Duration--Hours	2.6	3.3	3.0	3.0	2.5

4.3 TREND IN NO_2 ANNUAL MEAN CONCENTRATION

This section compares ambient NO_2 levels to the annual arithmetic mean National Ambient Air Quality Standard (100 $\mu g/m^3$ or approximately 5 pphm) for NO_2. Figure 4.10 depicts the spatial and temporal variations of NO_2 annual mean concentration. We see that almost the entire study area exceeded the NO_2 standard during the ten-year period, 1965 to 1974. However, notice that the small area around Azusa met the NAAQS for oxidant during the early years (1965/66 and 67/68) even though in the later years this area had the highest oxidant air pollution readings. In the later years 1969/70, 71/72, and 73/74, the entire study area exceeded the NAAQS.

A more detailed isopleth map of NO_2 annual mean concentration is presented in Appendix D, Figure D5. A closer look at Figures 4.10 and D5 reveals that the spatial gradient of NO_2 annual mean concentration diminishes with time. A similar reduction in the spatial gradient was also found in NO_2 daily risk frequency iscpleth maps (Figs. 4.2 and D3). A possible explanation of the decrease in the NO_2 spatial gradient with time may be the more uniform distribution of NO_x emissions over the Los Angeles Basin in recent years. As discussed in Section 2.1, considerable population growth took place in the suburban areas surrounding downtown Los Angeles during the 10 year period, 1965 to 1974, while almost no population growth in the downtown area itself. The population shift toward the surrounding areas certainly would have brought the spread of automobile traffic that, in turn, resulted in more uniform NO_x emissions through the basin.



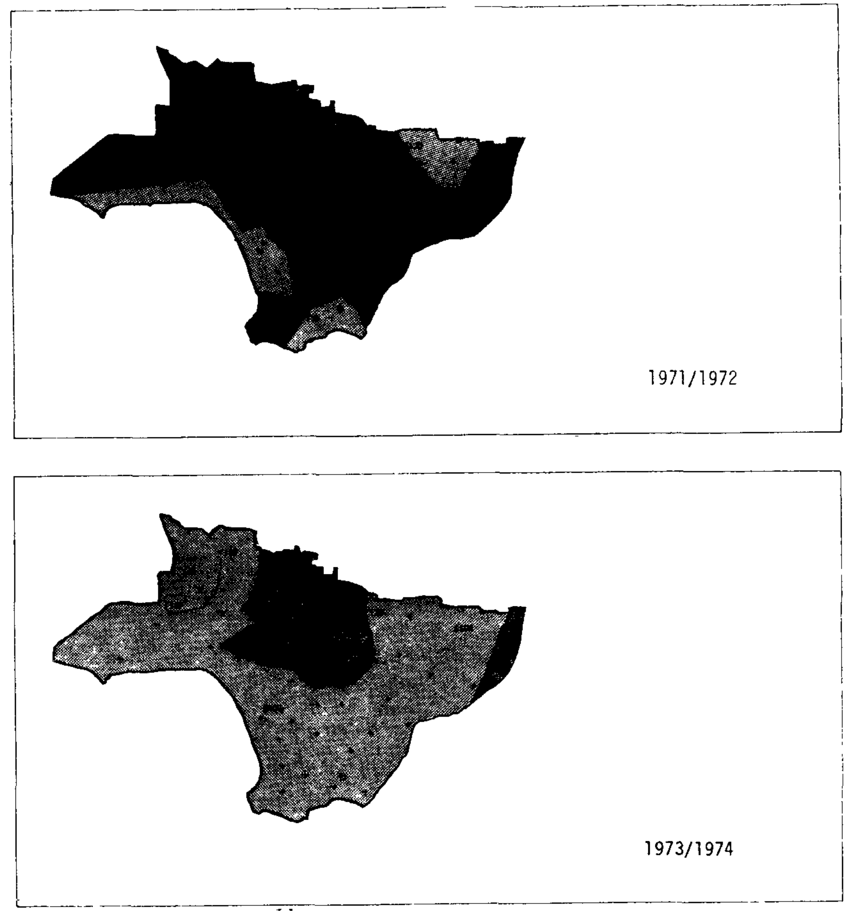


Figure 4.10. NO_2 ANNUAL MEAN CONCENTRATION ($\mu g/m^3$) FOR FIVE 2-YEAR PERIODS.

The population exposure to NO_2 annual mean concentration was determined by computing the population dosage distribution which describes the fraction of the population exposed to a concentration above the stated value. Figure 4.11 was obtained from the computed population dosage distribution to illustrate the distribution of the population at three annual NO_2 dose levels; less than 100 $\mu g/m^3$, between 100 and 130, and greater than 130 $\mu g/m^3$ in annual mean concentration. These are comparable with the shaded areas in the maps of Figure 4.10. In 1965/66, there were about 10% of the population who lived in areas where the NO_2 air quality was better than the NAAQS. Since 1969/70 even this small percentage has disappeared completely.

Regionwide trends in NO_2 annual mean concentrations are shown in Fig. 4.12 by the three different indices; population weight average concentration (3), area weighted average concentration (2), and station average concentration (1). All the indices show that there is an apparent upward trend in NO_2 annual mean concentration until 1973. These curves are in agreement with the 50th percentile of the hourly concentrations displayed in Figure 4.8.

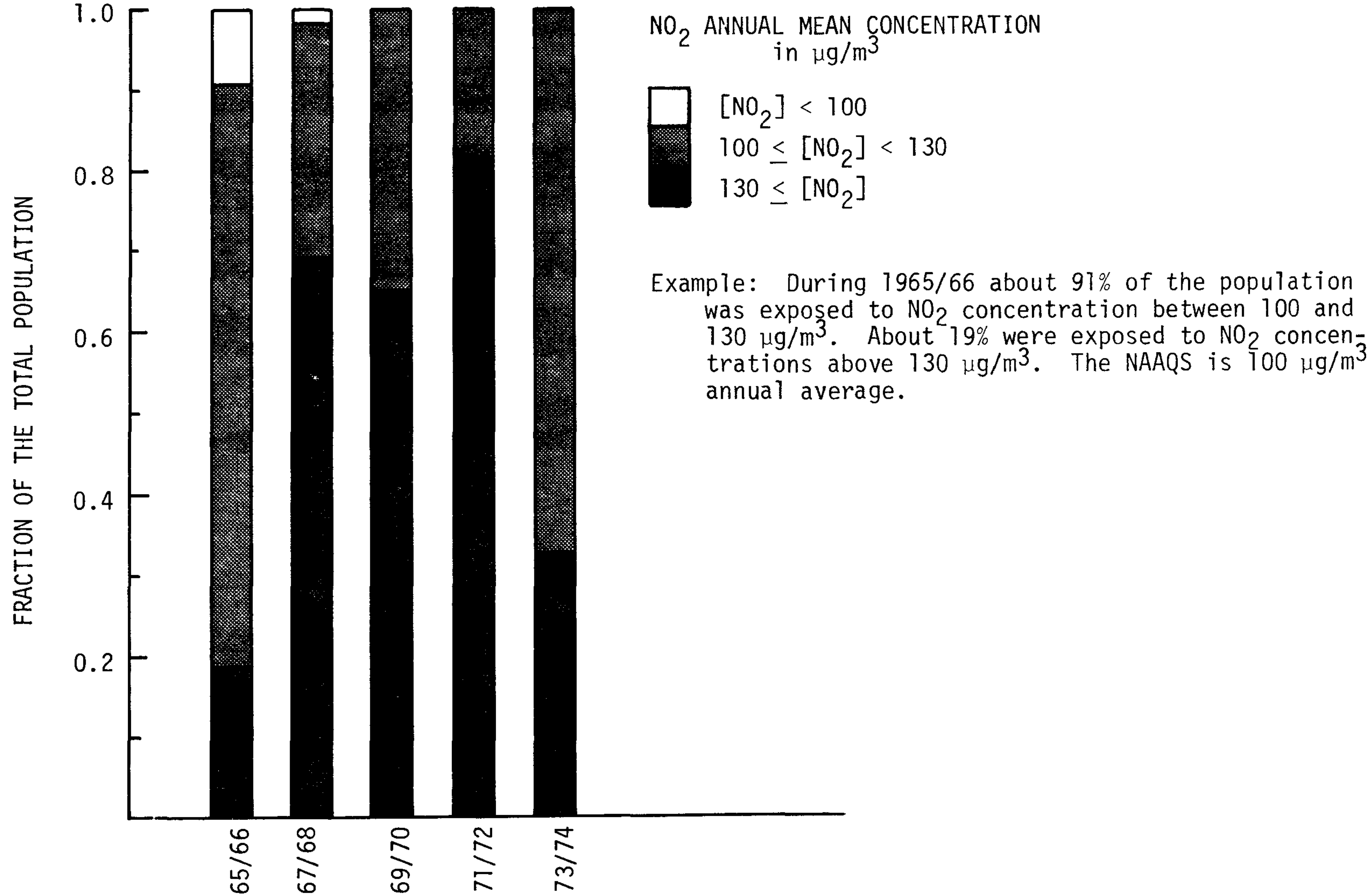


Figure 4.11. CHANGES IN THE TOTAL POPULATION EXPOSURE TO NO_2 DURING FIVE 2-YEAR PERIODS.

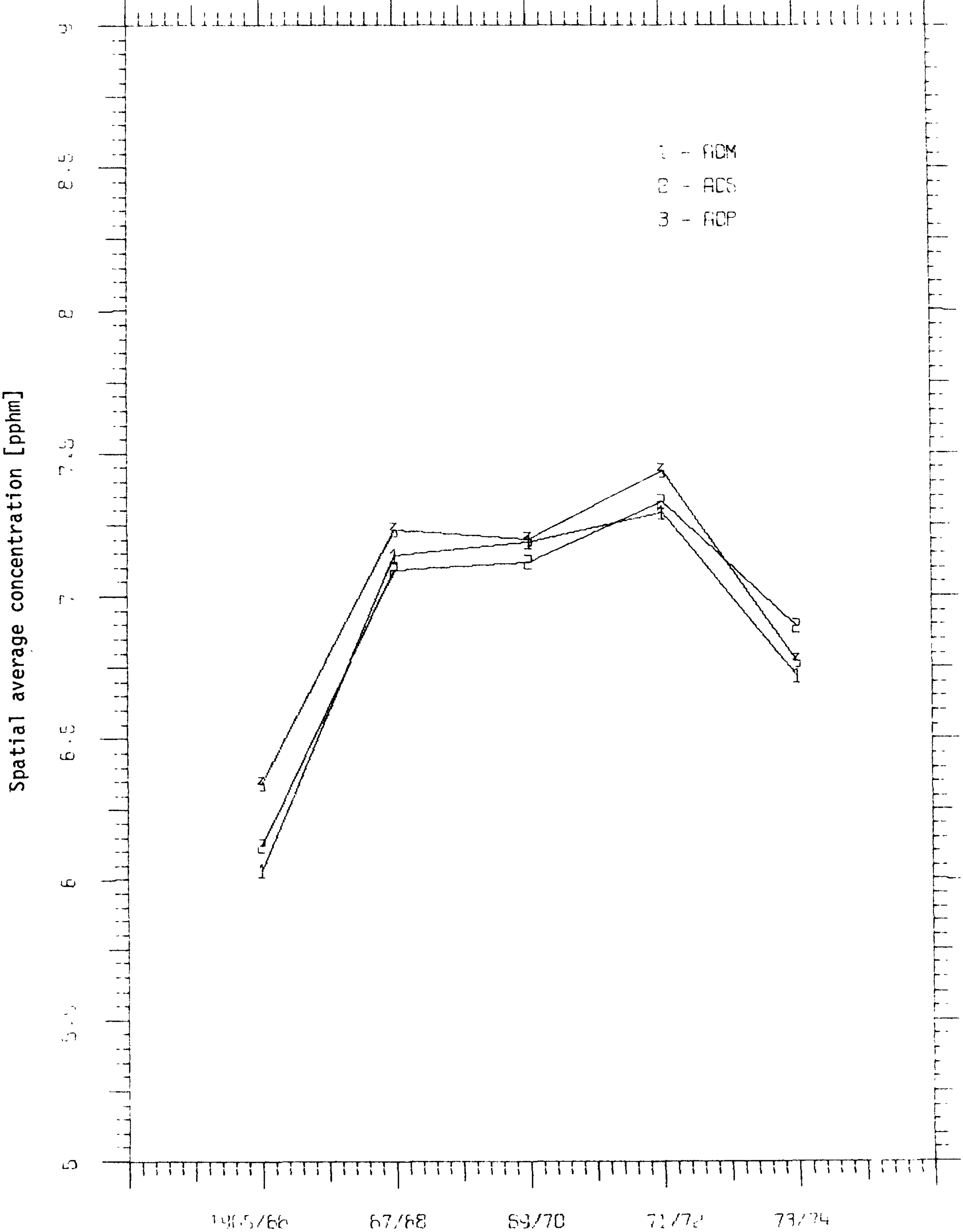


Figure 4.12. NO_2 TREND IN THREE SPACE AVERAGES OF ANNUAL ARITHMETIC MEAN CONCENTRATION (POPULATION WEIGHTED, AREA WEIGHTED, AND STATION AVERAGE).

5. CONCLUDING REMARKS

Population exposure methodology was applied to analyze the 10-year trends in two photochemical pollutants, O_x and NO_2 in the Los Angeles Basin. The following paragraphs summarize the findings and conclusions reached in this report.

Trends in O_x Air Quality and Population Exposure to O_x

- There has been a regionwide downward trend in both O_x air pollution and population exposure to O_x above the NAAQS during the 10-year study period.
- There were two stages in the O_x air quality improvement over that period. The earlier stage (1965 to 1969) is characterized by a sharp improvement in O_x air pollution in the coastal areas around the city of Long Beach. The later stage (1970 to 1974) is characterized by the O_x air quality improvement in the inland areas.
- The reduction in population exposure to O_x air pollution is greatest at high exposure levels. The percentage of the population exposed more than 50% of the time dropped from 53% in 1965/66 to a mere 5% in 1973/74. The percentage of the population exposed less than 20% of the time was zero percent in 1965/67 but increased to 35% in 1973/74.

<u>Trends in NO_2 Air Quality and Population Exposure to NO_2</u>

- During the 10-year study period, practically the entire population in the study area, the southern half of Los Angeles county, has been exposed to NO_2 annual mean concentration above the NAAQS.
- There is no clear trend in either NO_2 air quality or population exposure to NO_2. However, there seems to exist somewhat a downward trend at the 99th percentile concentration while at the 50th percentile concentration and/or in annual mean concentration, a slightly upward trend is observed.
- The NO_2 air quality deterioration and the accompanied increase of population exposure to NO_2 during the middle years from 1967/68 to 1971/72 appear to correspond to the increased NO_x emissions during that period.
- There is a marked shift in the spatial distributions of NO_2 air pollution and population exposure to NO_2 during the 10-year period. NO_2 air pollution and population exposure to NO_2 appear to be spread more uniformly in recent years (1973/1974) than in earlier years (1965/1966). In 1973/1974 the population was

exposed to NO_2 above the California standard over a small range of daily risk frequency from 3% to 7.5% while in 1965/66 over a wide range of daily risk frequency from 1% to 15%.

- For NO_2, the station average concentration gives lower values at higher percentile concentrations than the population weighted average concentrations whose value would be most representative for the air environment of an average person in the study area. Therefore, the station average concentration of NO_2 and probably those of the primary pollutants should be used with caution because the station average may tend to underestimate the regional average concentration to which an average person is exposed.

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APPENDIX A

POPULATION DATA FOR LOS ANGELES AQCR

Table A1. SCAG estimate of total population.

Table A2. 1970 Census data of various subpopulations.

Table A1. SCAG estimate of total population.

RSA No.	RSA Name	1960	1970	1975
	Ventura Co.			
1	LOSPADS	329	375	347
2	VENTURA	78,443	112,165	115,854
3	OXNARD	90,658	136,430	155,400
4	SIMI	11,012	67,756	77,291
5	THSOAKS	9,941	51,542	72,602
6	FILLMOR	8,755	10,229	10,913
	COUNTY TOTAL	199,138	378,497	432,407
	Los Angeles Co.			
7	CALABAS	5,410	18,935	27,898
8	NEWHALL	14,987	48,078	60,035
9	LANCAST	41,979	51,446	55,762
10	PALMDAL	23,579	31,429	33,541
11	S G MTS	2,612	2,013	1,806
12	S W SFV	391,057	539,935	564,005
13	BURBANK	249,337	264,922	256,791
14	N E SFV	205,990	267,158	269,745
15	MALIBU	6,486	11,709	15,478
16	SMONICA	275,921	304,380	313,121
17	WCENTRL	866,053	934,831	908,068
18	SO BAY	471,185	531,318	515,515
19	PALVRDS	276,350	413,506	429,159
20	L BEACH	423,023	435,416	415,387
21	E CENTRAL	808,521	828,311	774,927
22	NOR-WHI	508,130	592,502	615,645
23	LA CBD	96,854	90,416	83,102
24	GLENDAL	376,581	412,626	404,766
25	WSANGAB	594,212	669,136	655,161
26	ESANGAB	303,966	441,043	470,628
27	POMONA	98,572	149,654	150,232
	COUNTY TOTAL	6,040,805	7,038,764	7,020,772
	San Bernardino Co.			
28	WESTEND	159,735	233,386	251,316
29	EASTEND	250,086	312,097	299,019
30	SB MTS	9,454	20,374	23,693
31	BAKER	8,177	9,700	6,696
32	BARSTOW	54,192	76,701	81,502
33	TWPALMS	15,691	24,103	27,931
34	NEEDLES	6,256	5,872	5,907
	COUNTY TOTAL	503,591	682,233	696,064

Table A1. SCAG estimate of total population (Continued).

RSA No.	RSA Name	1960	1970	1975
	Orange Co.			
35	J-BUPK	68,193	160,903	172,496
36	A-FULTN	101,673	170,787	185,292
37	H-ANAHM	225,637	307,729	324,251
38	I-W CST	54,574	240,377	285,100
39	F-C CST	80,353	161,253	199,710
40	D-C CST	15,443	38,834	60,570
41	B-CANYN	7,462	34,390	55,386
42	G-S ANA	140,505	266,278	299,836
43	C-TRABU	1,897	18,306	29,389
44	E-TORO	8,188	21,529	33,046
	COUNTY TOTAL	703,925	1,420,386	1,655,076
	Riverside Co.			
45	JURUPA	25,357	37,095	40,251
46	RVSIDE	154,049	219,750	247,929
47	PERRIS	9,783	22,564	28,300
48	HEMET	17,352	34,368	44,541
49	MURRIET	7,969	12,001	14,356
50	BANNING	20,764	26,852	27,999
51	IDYWILD	1,842	3,048	3,903
52	PALM SP	26,723	48,588	65,903
53	COACHEL	27,265	38,411	41,969
54	CHUCKAW	15,087	16,397	16,528
	COUNTY TOTAL	306,191	459,074	531,679
	Imperial Co.			
55	IMPERL	72,105	74,492	83,250
	REGION	7,825,755	10,053,446	10,419,248

Table A2. 1970 Census data of various subpopulations.

RSA No.	Location	Total Population Number	School Age (5-17 years) Number	School Age (5-17 years) Percent*	Elderly (=>65) Number	Elderly (=>65) Percent*	Nonwhite Number	Nonwhite Percent*
	VENTURA COUNTY							
1	LOSPADS	375	80	21.3	40	10.7	9	2.4
2	VENTURA	110690	28423	25.7	12386	11.2	2128	1.9
3	OXNARD	136545	40122	29.4	7170	5.3	11098	8.1
4	SIMI	66588	23987	36.0	1945	2.9	868	1.3
5	THOUSAND OAKS	52003	17115	32.9	2027	3.9	741	1.4
6	FILLMORE	10229	2797	27.3	979	9.6	225	2.2
	COUNTY TOTAL	376430	112533	29.9	24547	6.5	15069	4.0
	LOS ANGELES COUNTY							
7	CALABASAS	18935	5863	31.0	732	3.9	273	1.4
8	NEWHALL	47241	13918	29.5	2224	4.7	1328	2.8
9	LANCASTER	48035	13756	28.6	3725	7.8	2304	4.8
10	PALMDALE	32723	9779	29.9	2509	7.7	1691	5.2
11	S G MTS	2015	380	18.9	175	8.7	122	6.1
12	VAN NUYS	539935	139506	25.8	34289	6.4	8332	1.5
13	BURBANK	254922	51236	19.3	26891	10.2	5342	2.0
14	NE SFV	267294	83714	31.3	14076	5.3	22724	8.5
15	MALIBU	11709	2911	24.9	634	5.4	206	1.8
16	SANTA MONICA	309278	53773	17.4	34203	11.1	26476	8.6
17	CULVER CITY	923817	154867	17.2	134335	14.5	365531	39.6
18	INGLEWOOD	531138	120752	22.7	36845	6.9	74967	14.1
19	SAN PEDRO	413510	114717	27.7	22933	5.5	35800	8.7
20	LONG BEACH	437186	83967	19.2	54631	12.5	31368	7.2
21	SOUTH GATE	835683	227786	27.3	69859	8.4	304852	36.4
22	DOWNEY	592297	166719	28.1	34006	5.7	11922	2.0
23	CBD	90416	9884	10.9	14843	16.4	15145	16.8
24	GLENDALE	417901	84611	20.2	54149	13.0	28466	6.8
25	PASADENA	657320	148176	22.5	79017	12.0	60445	9.2
26	COVINA	458691	152320	33.2	19706	4.3	16410	3.6
27	POMONA	132029	36124	27.4	12615	9.6	11872	9.0
	COUNTY TOTAL	7032075	1674759	23.8	652397	9.3	25576	14.6

*Percent of total population

Table A3. 1970 Census data of various subpopulations (Continued).

RSA No.	Location	Total Population Number	School Age (5-17 years) Number	School Age (5-17 years) Percent*	Elderly (=>65) Number	Elderly (=>65) Percent*	Nonwhite Number	Nonwhite Percent*
	SAN BERNARDINO CO							
28	ONTARIO	233386	67582	29.0	16754	7.2	8481	3.6
29	SAN BERNARDINO	311654	62965	26.6	34922	11.2	25213	8.1
30	SB MTS	20374	5303	26.0	2055	10.1	209	1.0
31	BAKER	11982	2563	21.4	358	3.0	1177	9.8
32	BARSTOW	76701	21811	28.4	5681	7.4	6032	7.9
33	TWPALMS	24103	4201	17.4	4861	20.2	1006	4.2
34	NEEDLES	5872	1521	25.9	669	11.4	473	8.1
	COUNTY TOTAL	684072	185946	27.2	65301	9.5	42591	6.2
	ORANGE COUNTY							
35	J-BUPK	161866	53629	33.1	5445	3.4	4057	2.5
36	FULLERTON	170784	48475	28.4	9986	5.8	4098	2.4
37	ANAHEIM	307729	87517	28.4	17406	5.7	6969	2.3
38	HUNTINGTON BEACH	240357	70093	29.2	16949	7.1	5879	2.4
39	LAGUNA BEACH	160319	34835	21.7	21127	13.2	2745	1.7
40	SAN CLEMENTE	38834	8828	22.7	5437	14.0	947	2.4
41	B-CANYN	34390	11539	33.6	1116	3.2	602	1.8
42	SANTA ANA	266272	72331	27.2	18370	6.9	11704	4.4
43	C-TRABU	18306	5755	31.4	444	2.4	275	1.5
44	EL TORO	21529	4328	20.1	2151	10.0	1369	6.4
	COUNTY TOTAL	1420386	397330	28.0	98431	6.9	38644	2.7
	RIVERSIDE COUNTY							
[illegible]	JURUPA	37095	10500	28.3	3343	9.0	3299	8.9
[illegible]	RIVERSIDE	221619	62079	28.0	16578	7.5	14247	6.4
[illegible]	[illegible] S VALLEY	22414	4531	20.2	6720	30.0	2486	11.1
[illegible]	[illegible]	34368	6026	17.5	11016	32.1	750	2.2
[illegible]	[illegible]	10282	2282	22.2	2466	24.0	832	8.1

*Percent of total population

Table A3. 1970 Census data of various subpopulations (Continued).

RSA No.	Location	Total Population Number	School Age (5-17 years) Number	School Age (5-17 years) Percent*	Elderly (=>65) Number	Elderly (=>65) Percent*	Nonwhite Number	Nonwhite Percent*
	RIVERSIDE COUNTY							
50	SAN GORGONIO PASS	26852	6303	23.5	5959	22.2	2499	9.3
51	IDYLLWILD	3048	644	21.1	530	17.4	74	2.4
52	PALM SPRINGS	48588	8410	17.3	10746	22.1	2471	5.1
53	COACHELLA	38411	11967	31.2	2101	5.5	3317	8.6
54	CHUCKAWALLA	16397	4885	29.8	1124	6.9	1574	9.6
	COUNTY TOTAL	459074	117627	25.6	60583	13.2	31549	6.9
	IMPERIAL COUNTY							
55	IMPERIAL COUNTY TOTAL	74492	23885	32.1	5575	7.5	4570	6.1
	REGION TOTAL	10046529	2512080	25.0	906834	9.0	1157999	11.5

*Percent of total population

APPENDIX B

AIR QUALITY DATA FOR O_X AND NO_2 IN LOS ANGELES AQCR

Table B1. Corrected O_x daily maximum hourly average concentrations in 1965 to 1974.

Table B2. Corrected O_x hourly average concentrations in 1965 to 1974.

Table B3. NO_2 daily maximum hourly average concentrations in 1965 to 1974.

Table B4. NO_2 hourly average concentrations in 1965 to 1974.

Table B1. Corrected Ox daily maximum hourly average concentrations in 1965 to 1974. (all values in pphm)

No.	Station	Obs.	Max.	1%	3%	5%	10%	25%	50%	75%
				PERCENTILE						
1	Anaheim									
	1965/66	351/356	36.0	28.8	25.2	21.2	17.2	11.2	6.8	4.0
	1967/68	356/360	29.2	24.8	20.0	17.2	16.8	10.0	6.0	3.6
	1969/70	345/325	29.2	20.8	17.2	15.2	12.8	8.0	5.2	3.2
	1971/72	349/359	30.8	19.2	15.2	12.8	10.0	6.4	3.6	2.0
	1973/74	361/363	25.2	18.0	16.0	14.0	10.0	6.4	4.0	2.4
2	Azusa									
	1965/66	365/365	53.5	41.0	36.5	33.5	31.0	24.0	14.5	6.0
	1967/68	365/365	54.5	44.0	36.5	34.0	30.0	23.0	13.0	6.0
	1969/70	363/365	56.0	47.0	41.0	37.0	32.5	23.5	13.0	6.0
	1971/72	365/362	48.5	37.5	32.5	29.5	25.5	18.5	10.5	5.0
	1973/74	365/365	42.0	34.5	29.0	27.5	24.5	17.5	9.0	4.0
3	Burbank									
	1965/66	365/365	36.0	31.5	27.7	26.0	24.0	17.5	10.5	4.5
	1967/68	364/365	44.5	39.5	34.5	32.5	26.5	19.5	11.5	5.0
	1969/70	365/365	36.5	32.5	28.5	25.5	21.5	16.5	10.0	4.5
	1971/72	365/363	29.5	26.5	23.5	21.0	19.0	13.0	7.5	4.0
	1973/74	365/365	32.0	26.0	22.0	20.0	17.0	12.5	7.0	3.5
4	Lennox									
	1965/66	324/365	34.5	24.5	18.0	15.0	12.0	8.0	5.0	3.5
	1967/68	364/366	28.3	21.0	16.5	14.0	11.5	7.5	4.5	3.0
	1969/70	359/363	24.0	19.0	14.0	12.0	9.5	7.5	5.0	3.0
	1971/72	358/366	19.0	16.0	11.5	10.5	8.0	5.0	3.5	2.5
	1973/74	365/364	19.5	12.0	9.0	8.0	6.0	5.0	3.0	2.5
5	Long Beach									
	1965/66	362/364	30.5	24.5	18.5	16.0	11.5	7.0	4.5	2.5
	1967/68	364/365	27.0	15.5	13.5	11.0	9.0	6.5	3.5	2.0
	1969/70	359/362	20.0	15.0	12.0	10.0	8.0	6.0	4.0	3.0
	1971/72	365/366	22.0	15.5	10.5	9.0	8.0	5.5	3.5	2.5
	1973/74	364/361	18.5	14.0	9.5	8.5	7.0	5.0	3.0	2.0
6	L.A. Downtown									
	1965/66	365/365	54.0	38.0	31.5	26.0	22.5	16.5	10.5	5.0
	1967/68	364/365	41.0	30.5	26.5	24.0	19.5	14.0	8.5	4.5
	1969/70	365/357	31.5	25.5	20.5	19.0	16.0	12.0	7.5	3.5
	1971/72	365/363	24.5	22.6	19.5	17.5	14.0	9.5	6.5	3.0
	1973/74	365/361	38.5	27.0	20.0	18.0	15.0	11.0	6.5	3.0
7	Pomona									
	1965/66	192*/365	44.0	38.0	35.0	30.0	28.0	21.0	12.0	5.0
	1967/68	365/366	46.0	39.5	35.1	32.0	28.0	20.5	11.5	5.0
	1969/70	365/365	46.5	40.5	35.0	32.5	28.0	20.0	10.0	5.0
	1971/72	364/366	36.0	29.0	25.0	24.0	20.0	14.0	7.5	3.5
	1973/74	364/365	31.5	30.5	25.5	24.0	20.5	14.5	7.0	3.0

Table B1.(Continued).

No.	Station	Obs.	Max.	1%	3%	5%	10%	25%	50%	75%
				PERCENTILE						
8	Reseda									
	1965/66	291/365	45.5	34.0	29.0	26.5	24.5	19.0	12.5	5.0
	1967/68	365/365	37.5	34.5	30.5	28.5	24.0	18.0	10.0	4.5
	1969/70	363/365	38.0	31.5	26.5	24.5	22.0	17.0	9.5	5.0
	1971/72	360/366	30.5	25.5	20.5	19.5	17.0	12.5	7.5	4.0
	1973/74	365/365	28.3	23.6	22.0	19.5	17.0	13.0	7.0	3.5
9	San Bernardino									
	1965/66	360/355	30.8	25.2	22.4	21.2	17.6	12.4	6.8	2.8
	1967/68	365/362	30.4	24.0	22.4	20.0	17.2	12.4	6.4	3.2
	1969/70	363/363	30.8	28.4	25.2	23.2	19.6	14.0	6.0	2.8
	1971/72	364/363	29.6	26.6	20.4	18.8	16.4	11.2	5.2	2.5
	1973/74	353/193*	33.6	28.8	25.6	23.2	19.2	15.2	5.6	2.4
10	West L.A.									
	1965/66	365/365	34.0	29.0	23.0	20.5	16.5	12.0	8.0	5.0
	1967/68	365/366	40.0	26.0	21.5	19.5	16.5	12.5	8.5	5.0
	1969/70	365/365	27.0	22.5	18.0	16.0	14.0	10.5	7.0	4.0
	1971/72	365/365	22.5	18.0	14.5	13.0	10.5	8.0	5.5	3.0
	1973/74	364/365	29.0	18.5	14.0	12.5	10.5	8.0	5.5	3.5

*A year has less than 75 percent of the possible observations.

Table B2. Corrected Ox hourly average concentrations in 1965 to 1974.
(all values in pphm)

No.	Station	Obs.	Max.	1%	3%	5%	10%	25%	50%	75%
				PERCENTILE						
1	Anaheim									
	1965/66	7645/7684	36.0	18.0	12.5	10.0	7.2	3.6	1.6	0.8
	1967/68	7737/8115	29.2	14.8	10.4	8.4	6.0	3.2	1.6	0.8
	1969/70	7678/7285	29.2	13.2	9.6	7.6	5.2	2.8	0.8	0.0
	1971/72	7714/8040	30.8	10.0	6.8	5.6	3.6	2.0	0.4	0.0
	1973/74	8173/8077	25.2	10.8	7.2	6.0	4.0	2.4	0.8	0.0
2	Azusa									
	1965/66	8206/8270	53.5	30.5	24.0	21.0	15.0	6.3	2.0	1.0
	1967/68	8040/8212	54.5	30.0	23.5	20.0	14.0	5.5	2.0	1.0
	1969/70	8195/8313	56.0	32.0	24.0	20.5	14.0	5.5	2.0	1.0
	1971/72	8260/8187	48.5	25.0	19.0	16.0	11.5	4.5	2.0	1.0
	1973/74	8162/8278	42.0	24.0	18.5	15.5	10.5	4.0	2.0	1.0
3	Burbank									
	1965/66	8180/8257	36.0	23.0	17.5	15.0	11.0	4.5	1.5	1.0
	1967/68	8015/8151	44.5	27.0	20.5	17.5	12.0	4.5	2.0	1.0
	1969/70	8193/8842	36.5	22.5	17.5	14.5	10.5	4.0	2.0	1.0
	1971/72	8218/8214	29.5	18.5	14.0	11.5	8.0	3.0	1.0	1.0
	1973/74	8315/8319	32.0	17.0	19.0	11.0	8.0	3.5	1.0	1.0
4	Lennox									
	1965/66	7191/8279	34.5	13.0	9.9	6.5	5.0	3.0	1.0	1.0
	1967/68	8220/8237	28.0	12.0	8.0	6.5	5.0	3.0	1.0	1.0
	1969/70	8072/8094	24.0	10.0	7.5	6.5	5.0	3.0	1.5	1.0
	1971/72	8072/8281	19.0	8.0	5.5	5.0	3.5	2.5	1.0	1.0
	1973/74	8316/8272	19.5	7.0	5.0	4.0	3.0	2.0	1.0	1.0
5	Long Beach									
	1965/66	8101/8224	30.5	12.5	8.0	6.0	4.0	2.0	1.0	1.0
	1967/68	8214/8120	27.0	9.0	6.5	5.0	3.5	2.0	1.0	1.0
	1969/70	7852/8025	20.0	7.5	5.5	5.0	3.5	2.0	1.0	1.0
	1971/72	8303/8254	27.9	7.5	5.5	4.5	3.5	2.0	1.0	1.0
	1973/74	8201/8146	18.5	7.0	5.0	4.0	3.0	2.0	1.0	1.0
6	LA Downtown									
	1965/66	8221/8262	54.0	22.0	16.5	14.0	10.0	4.5	2.0	1.0
	1967/68	8202/8155	41.0	19.5	14.5	12.0	8.6	4.0	1.5	1.0
	1969/70	8224/7865	31.5	16.5	13.0	10.5	7.5	3.4	1.5	1.0
	1971/72	8230/8426	24.5	14.4	10.5	8.5	6.5	3.0	1.0	1.0
	1973/74	8357/8003	38.5	16.0	12.0	10.0	6.5	3.5	1.0	1.0
7	Pomona									
	1965/66	4282/8195*	44.0	27.0	21.0	18.0	12.0	5.0	2.0	1.0
	1967/68	8305/8325	49.2	28.0	21.5	18.0	12.5	5.0	2.0	1.0
	1969/70	8201/8266	45.8	28.0	21.0	17.5	12.0	4.5	2.0	1.0
	1971/72	8171/8343	36.0	20.0	14.5	12.0	8.0	3.5	1.5	1.0
	1973/74	8253/8330	31.5	21.0	15.5	13.0	8.5	3.0	1.0	1.0

Table B2 (Continued).

No.	Station	Obs.	Max.	1%	3%	5%	10%	25%	50%	75%
				PERCENTILE						
8	Reseda	*								
	1965/66	6530/8232	44.0	23.0	19.0	17.0	13.0	6.0	2.0	1.0
	1967/68	8291/8055	37.5	25.0	19.5	16.5	12.0	5.0	2.0	1.0
	1969/70	8221/8097	38.0	22.5	18.5	15.5	11.0	5.0	2.0	1.0
	1971/72	8241/8383	30.5	17.0	13.0	11.5	8.5	4.0	2.0	1.0
	1973/74	8350/8347	28.0	17.5	14.0	12.2	9.0	4.0	2.0	1.0
9	San Bernardino									
	1965/66	8058/7955	30.8	18.0	13.6	12.0	8.4	3.6	0.8	0.0
	1967/68	8320/8229	30.4	17.6	13.6	12.0	8.4	3.6	0.8	0.0
	1969/70	7909/7845	30.8	20.0	15.2	12.8	9.6	3.6	0.8	0.0
	1971/72	7882/7904	29.6	16.4	12.8	10.4	7.6	2.8	0.8	0.0
	1973/74	7682/4139	30.0	19.2	14.8	12.4	8.8	3.6	1.2	0.0
10	West L.A.									
	1965/66	8203/8121	34.0	17.5	12.5	10.5	8.0	4.5	2.0	1.0
	1967/68	8255/8204	40.0	17.0	12.5	11.0	8.5	4.5	2.0	1.0
	1969/70	8160/8246	27.0	14.0	11.0	9.5	7.5	4.0	2.0	1.0
	1971/72	8118/8337	22.5	10.5	8.0	6.5	5.0	3.3	1.0	1.0
	1973/74	8222/8193	29.0	10.5	8.5	7.0	6.0	3.5	1.5	1.0

*A year has less than 75 percent of the possible observations.

Table B3. NO_2 daily maximum hourly average concentrations in 1965 to 1974. (all values in pphm)

No.	Station	Obs.	Max.	1%	3%	5%	10%	25%	50%	75%
				PERCENTILE						
1	Anaheim									
	1965/66	226*/257*								
	1967/68	314/337	30.5	28.0	23.5	21.5	18.5	12.0	8.0	5.5
	1969/70	360/335	34.5	26.0	20.5	18.5	15.0	11.0	8.0	6.0
	1971/72	359/358	43.5	35.5	22.5	21.0	16.5	10.5	7.5	5.0
	1973/74	329/360	43.0	33.5	26.0	22.5	17.5	11.5	8.0	6.0
2	Azusa									
	1965/66	300/363	30.5	24.0	19.0	17.5	14.5	11.0	7.5	5.5
	1967/68	364/362	33.0	29.0	23.5	21.0	17.0	12.5	8.0	5.0
	1969/70	365/354	39.0	31.0	23.0	21.5	17.5	13.5	9.0	6.0
	1971/72	364/361	40.5	32.0	26.5	23.5	19.0	14.0	10.0	7.5
	1973/74	361/364	38.5	30.5	26.5	23.0	19.0	14.0	10.0	7.5
3	Burbank									
	1965/66	365/365	43.5	36.5	29.5	27.0	23.5	17.0	11.0	7.5
	1967/68	363/363	55.0	45.5	39.5	35.5	31.0	23.5	15.5	10.0
	1969/70	364/362	49.0	45.0	36.0	34.0	29.0	22.0	14.5	9.5
	1971/72	362/364	51.0	37.5	34.0	30.0	26.0	20.5	14.0	9.5
	1973/74	364/363	36.5	34.0	29.5	26.0	22.5	16.5	11.5	7.5
4	Lennox									
	1965/66	324/360	41.5	34.0	29.0	25.0	21.5	15.5	10.0	7.0
	1967/68	364/358	62.0	54.5	43.0	37.0	29.0	19.0	12.5	8.0
	1969/70	365/364	40.0	32.5	28.0	25.5	22.0	15.5	11.5	7.5
	1971/72	359/366	41.0	35.0	30.0	26.0	22.5	15.5	10.5	7.5
	1973/74	363/361	41.0	34.0	29.0	23.0	19.0	14.0	10.0	7.0
5	Long Beach									
	1965/66	361/362	44.0	34.5	28.5	25.0	20.0	14.5	9.5	6.5
	1967/68	365/355	58.0	42.5	38.0	34.0	29.0	19.0	13.0	8.0
	1969/70	360/365	52.5	40.5	35.0	31.0	25.5	18.5	12.5	9.0
	1971/72	364/362	50.5	40.0	32.5	27.5	24.0	15.5	10.0	7.5
	1973/74	361/358	36.0	32.0	29.0	26.0	20.0	14.5	10.0	7.0
6	L.A. Downtown									
	1965/66	365/365	75.0	45.5	35.5	32.0	27.5	20.0	12.5	8.5
	1967/68	365/358	50.5	42.0	36.5	31.5	26.0	15.5	11.0	7.5
	1969/70	355/361	75.5	43.0	33.5	28.0	23.0	16.0	10.5	7.5
	1971/72	359/361	56.5	46.5	39.5	34.5	28.5	20.0	13.5	9.5
	1973/74	353/363	61.0	39.0	30.5	26.0	22.5	16.0	10.5	7.5
7	Pomona									
	1965/66	187*/363	29.0	26.0	22.0	21.0	17.0	14.0	10.0	7.0
	1967/68	363/365	39.5	33.0	28.5	24.5	20.5	15.5	11.5	8.5
	1969/70	365/365	44.0	33.0	27.5	24.5	21.5	17.0	12.5	9.5
	1971/72	365/363	41.5	32.5	27.0	23.0	20.5	15.5	11.0	8.0
	1973/74	365/364	35.0	27.0	24.0	21.0	19.0	14.5	10.0	8.0

Table B3 (Continued).

No.	Station	Obs.	Max.	1%	3%	5%	10%	25%	50%	75%
				PERCENTILE						
8	Reseda									
	1965/66	292/365	34.0	28.5	23.5	21.5	17.0	12.5	9.0	5.5
	1967/68	363/361	45.0	36.5	28.5	25.5	20.5	15.0	10.0	6.5
	1969/70	362/364	37.0	29.5	25.0	23.5	20.5	15.5	11.0	7.0
	1971/72	359/364	40.0	34.5	28.5	25.5	21.5	16.5	12.0	8.0
	1973/74	365/364	33.5	30.0	24.0	22.0	18.5	14.5	10.5	7.0
9	San Bernardino									
	1965/66	110*/303	25.0	21.0	18.0	16.0	12.0	9.0	7.0	5.0
	1967/68	313/292	23.5	20.5	17.5	15.5	13.0	10.0	7.0	4.5
	1969/70	169*/203*								
	1971/72	321/341	28.0	22.0	19.0	16.5	14.5	11.0	8.0	6.0
	1973/74	356/351	32.0	18.5	16.0	14.5	13.0	11.0	7.5	5.0
10	West L.A.									
	1965/66	358/365	50.0	42.5	32.5	29.5	24.0	16.5	10.0	7.0
	1967/68	364/362	48.5	40.5	33.5	30.0	25.0	16.5	11.0	8.0
	1969/70	364/365	50.0	37. 5	29.5	27.5	22.5	16.0	10.5	7.5
	1971/72	362/357	51.0	42.0	33.5	30.0	25.0	17.0	11.5	7.5
	1973/74	358/363	61.5	38.5	32.5	29.0	23.5	16.5	11.5	8.0

*A year has less than 75 percent of the possible observations.

Table B4. NO_2 hourly average concentrations in 1965 to 1974.
All values in pphm.

No.	Station	Obs.	Max	1%	3%	5%	10%	25%	50%	75%
				PERCENTILE						
1	Anaheim									
	1965/66	4758*/5381*								
	1967/68	6749/7356	30.5	19.0	15.0	13.0	10.0	6.0	4.0	2.5
	1969/70	7985/7429	34.5	17.0	13.0	11.0	9.0	6.0	4.0	3.0
	1971/72	7875/8004	43.5	19.5	14.0	12.0	9.0	6.0	4.0	3.0
	1973/74	7340/7993	43.0	21.0	15.5	13.0	9.5	6.5	4.5	3.0
2	Azusa									
	1965/66	6119*/7736	31.0	16.0	12.0	11.0	9.0	6.0	4.0	2.0
	1967/68	7690/7622	33.0	19.5	19.5	12.5	10.0	6.5	3.5	1.5
	1969/70	7853/7311	39.0	20.0	15.5	13.5	11.0	7.5	4.5	2.5
	1971/72	7998/8081	40.5	21.5	16.5	14.0	11.0	8.0	5.5	3.0
	1973/74	8096/8269	38.5	20.5	16.0	14.0	11.5	8.0	5.5	3.5
3	Burbank									
	1965/66	7674/7736	43.5	25.5	20.5	17.0	13.0	9.0	6.0	3.5
	1967/68	7682/7583	55.0	33.5	27.0	23.0	18.5	12.0	8.0	5.5
	1969/70	7753/7683	49.0	30.5	24.5	21.5	17.0	12.0	8.0	5.5
	1971/72	7833/8467	51.0	27.0	22.0	19.5	15.5	11.0	7.5	5.0
	1973/74	8462/8280	36.5	23.0	18.5	16.0	13.0	9.0	6.0	4.0
4	Lennox									
	1965/66	6452*/7397	40.0	22.0	17.0	15.0	12.0	7.0	5.0	3.0
	1967/68	7521/7351	62.0	34.0	23.5	19.5	14.5	9.0	6.0	4.0
	1969/70	7676/8065	40.0	22.5	17.5	15.5	12.0	8.5	6.0	4.0
	1971/72	8030/8338	41.0	24.0	17.5	15.0	11.5	8.0	5.5	4.0
	1973/74	8294/8254	41.0	20.5	16.0	13.5	11.0	8.0	5.5	4.0
5	Long Beach									
	1965/66	7914/7306	44.0	22.5	17.0	14.5	11.5	7.5	4.5	3.0
	1967/68	7505/7992	58.0	29.5	22.5	19.5	15.0	10.0	6.0	4.0
	1969/70	7827/8073	52.5	27.0	21.0	18.0	14.0	9.5	6.5	4.0
	1971/72	8087/8183	50.5	25.5	19.0	16.0	12.0	8.5	5.5	4.0
	1973/74	8108/7890	36.0	22.0	16.5	14.5	12.0	8.0	6.0	4.0
6	L.A. Downtown									
	1965/66	7616/7817	75.0	26.5	21.5	18.0	14.0	9.5	6.0	4.0
	1967/68	7781/7623	50.5	26.5	19.5	16.5	12.5	8.5	5.5	4.5
	1969/70	7399/7902	75.5	24.5	18.5	16.0	12.5	8.5	6.0	4.0
	1971/72	8017/8215	56.5	29.0	22.5	19.0	14.5	10.5	7.5	5.5
	1973/74	7717/7959	61.0	23.5	18.5	15.5	12.0	8.5	6.0	4.0
7	Pomona									
	1965/66	3813*/7634	29.0	18.0	15.0	13.0	11.0	8.0	6.0	4.0
	1967/68	7685/7848	39.5	23.0	17.0	15.0	12.5	9.5	6.5	4.5
	1969/70	7936/7930	44.0	23.0	19.0	16.5	13.5	10.5	7.5	5.0
	1971/72	8120/8231	41.5	22.5	17.5	15.5	13.0	10.0	7.0	5.0
	1973/74	8353/8270	35.0	19.5	15.5	14.5	11.5	9.0	6.0	4.5

Table B4 (Continued).

No.	Station	Obs.	Max	1%	3%	5%	10%	25%	50%	75%
				PERCENTILE						
8	Reseda									
	1965/66	5939*/7729	35.0	19.0	14.0	12.0	10.0	7.0	4.0	3.0
	1967/68	7565/7558	45.0	24.0	17.5	15.0	12.0	8.0	5.0	3.0
	1969/70	7683/7764	37.0	21.5	17.5	15.5	12.5	8.5	5.5	3.0
	1971/72	7881/8318	40.0	23.5	18.0	16.0	13.0	9.0	6.0	3.5
	1973/74	8506/8390	33.5	20.0	15.5	13.5	11.0	7.5	5.5	3.5
9	San Bernardino									
	1965/66	2117*/5913*								
	1967/68	6173*/5808*								
	1969/70	3105*/3820*								
	1971/72	6575/6891	28.0	15.5	12.0	11.0	8.5	6.0	4.0	3.0
	1973/74	7408/8058	32.0	13.0	11.0	9.5	7.5	5.5	4.0	2.0
10	West L.A.									
	1965/66	7282/7779	50.0	25.0	18.5	15.5	12.0	7.5	5.0	3.0
	1967/68	7632/7798	48.5	25.0	19.0	16.5	12.5	8.0	5.5	3.5
	1969/70	8103/8008	50.0	22.5	17.0	15.0	11.5	8.0	5.5	4.5
	1971/72	7918/8042	51.0	25.0	19.0	16.0	12.5	8.5	5.5	3.5
	1973/74	8207/8184	61.5	23.5	18.5	15.5	12.5	8.5	6.0	4.0

*: A year has less than 75 percent of the possible observations.

APPENDIX C

MONITORING STATIONS AND RECEPTOR POINTS

Table C1. Locations and Addresses of Air Monitoring Stations

	UTM	X-Y Coord.
1. Anaheim #050230001I01 (30176) 1010 S. Harbor Blvd., Anaheim, Orange County	N = 3,742,467 E = 415,477	Y = 1340 X = 1824
2. Azusa #050500002I01 (70060) 803 Loren Ave., Azusa, Los Angeles County	N = 3,777,371 E = 414,892	Y = 1634 X = 1819
3. Burbank #050900002I01 (70069) 228 W. Palm, Burbank, Los Angeles County	N = 3,782,904 E = 379,355	Y = 1681 X = 1520
4. Lennox #053900001I01 (70076) 11408 La Cienega Blvd., Lennox, LA County	N = 3,755,070 E = 373,477	Y = 1446 X = 1470
5. Long Beach #054100002I01 (70072) 3648 N. Long Beach Blvd., Long Beach, LA Cty.	N = 3,743,190 E= 390,007	Y = 1346 X = 1610
6. L.A. Downtown #054180001I01 (70001) 434 S. San Pedro St., Los Angeles County	N = 3,767,650 E = 385,310	Y = 1552 X = 1570
7. Pomona #056040001I01 (70075) 924 N. Garey Ave., Pomona, Los Angeles County	N = 3,767,844 E = 430,882	Y = 1554 X = 1900
8. Reseda #054200001I01 (70074) 18330 Gault St., Reseda, Los Angeles County	N = 3,785,129 E = 358,851	Y = 1699 X = 1347
9. San Bernardino #056680001I01 (36151) 172 W. 3rd St., San Bernardino, S.B. Cty.	N = 3,773,634 E = 473,637	Y = 1602 X = 2315
10. West L.A. #054180002I01 (70071) 2351 Westwood Blvd., Los Angeles County	N = 3,767,403 E = 368,178	Y = 1550 X = 1426

Table C2. Receptor Points Assigned to the Los Angeles AQCR

No.	County	RSA #	Code #	X-Coord.	Y-Coord.
1	Los Angeles	7	2071	1285	1610
2	Los Angeles	12	2121	1361	1670
3	"	12	2122	1351	1720
4	"	12	2123	1400	1630
5	Los Angeles	13	2131	1485	1645
6	"	13	2132	1521	1650
7	Los Angeles	14	2141	1421	1730
8	"	14	2142	1510	1710
9	Los Angeles	15	2151	1221	1550
10	Los Angeles	16	2161	1380	1570
11	"	16	2162	1430	1465
12	Los Angeles	17	2171	1521	1510
13	"	17	2172	1521	1550
14	"	17	2173	1521	1590
15	"	17	2174	1480	1530
16	"	17	2175	1480	1580
17	Los Angeles	18	2181	1521	1440
18	"	18	2182	1475	1460
19	"	18	2183	1500	1410
20	Los Angeles	19	2191	1505	1320
21	"	19	2192	1505	1365
22	Los Angeles	19	2193	1545	1350
23	Los Angeles	20	2201	1595	1330
24	"	20	2202	1650	1320
25	"	20	2203	1625	1390
26	Los Angeles	21	2211	1565	1420
27	"	21	2212	1565	1470
28	"	21	2213	1565	1520
29	"	21	2214	1610	1520
30	"	21	2215	1610	1470

Table C2 (Continued).

No.	County	RSA #	Code #	X-Coord.	Y-Coord.
31	Los Angeles	22	2221	1660	1420
32	"	22	2222	1690	1480
33	"	22	2223	1725	1435
34	Los Angeles	23	2231	1555	1545
35	Los Angeles	24	2241	1561	1585
36	"	24	2242	1561	1640
37	"	24	2243	1595	1595
38	Los Angeles	25	2251	1641	1625
39	"	25	2252	1660	1560
40	"	25	2253	1710	1555
41	"	25	2254	1730	1620
42	Los Angeles	26	2261	1765	1520
43	Los Angeles	26	2262	1810	1595
44	"	26	2263	1840	1500
45	Los Angeles	27	2271	1900	1580
46	Orange	35	3351	1710	1355
47	Orange	36	3361	1800	1410
48	Orange	37	3371	1765	1320
49	"	37	3372	1785	1355
50	Orange	38	3381	1708	1280
51	"	38	3382	1750	1250
52	Orange	41	3411	1911	1390
53	Orange	42	3421	1825	1285
54	"	42	3422	1840	1335
55	San Bernardino	28	4281	1960	1490
56	"	28	4282	2000	1590
57	San Bernardino	29	4291	2190	1625
58	"	29	4292	2335	1555

APPENDIX D

ISOPLETH MAP OF RISK FREQUENCY, MEAN DURATION, AND ANNUAL MEAN CONCENTRATION

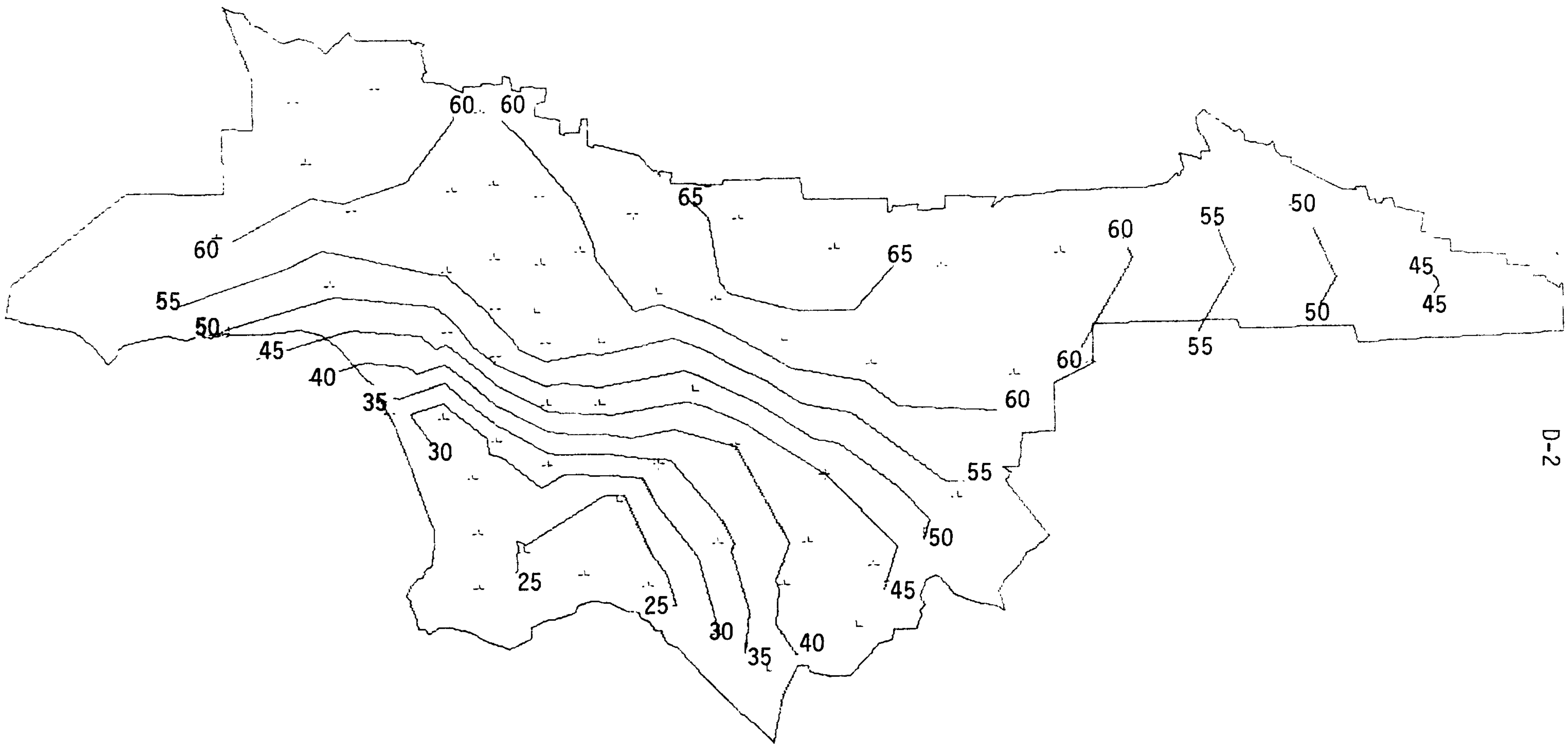

Figure D1-a. Oxidant Air Quality in Percent of Days on Which the NAAQS Was Exceeded During 1965/66

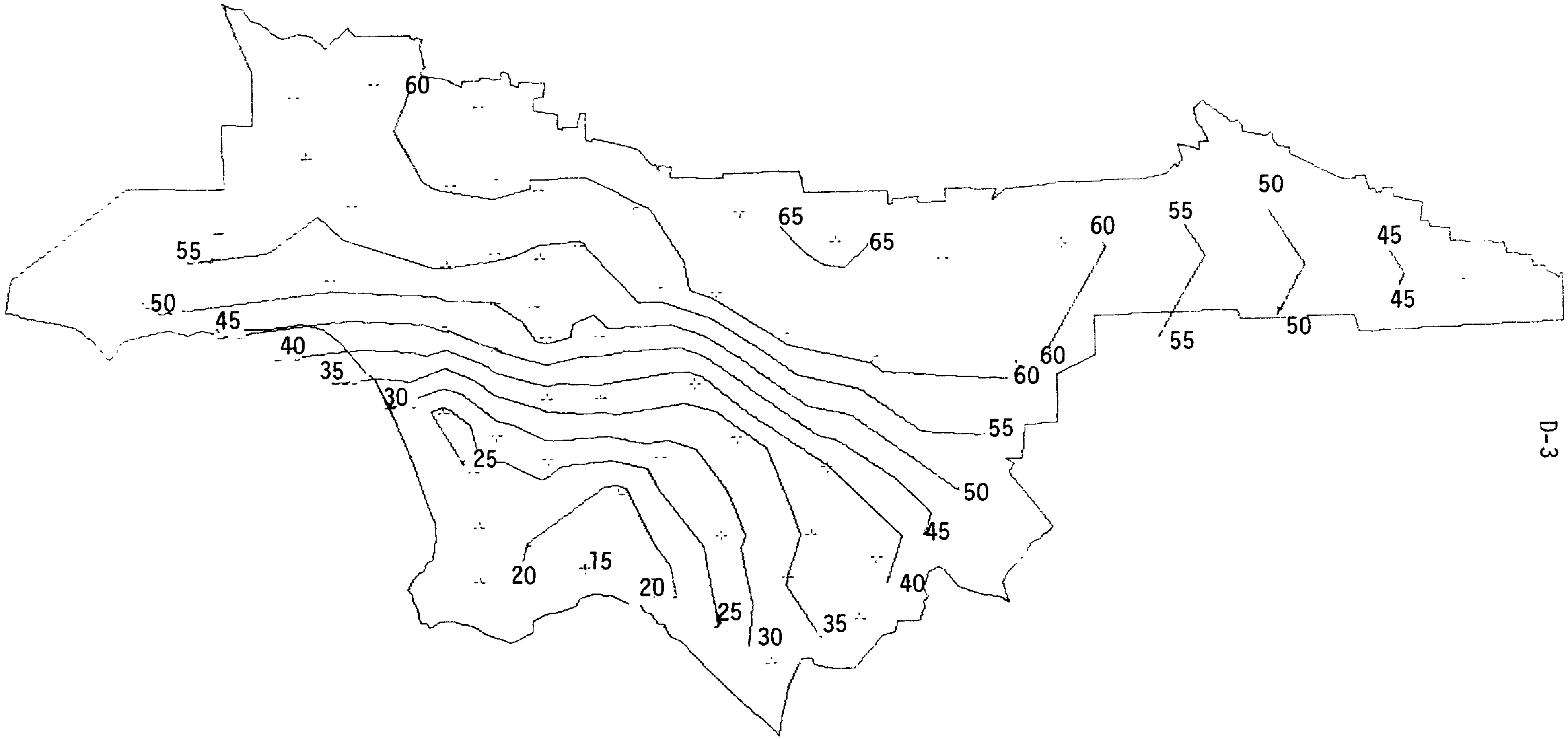

Figure D1-b. Oxidant Air Quality in Percent of Days on Which the NAAQS Was Exceeded During 1967/68

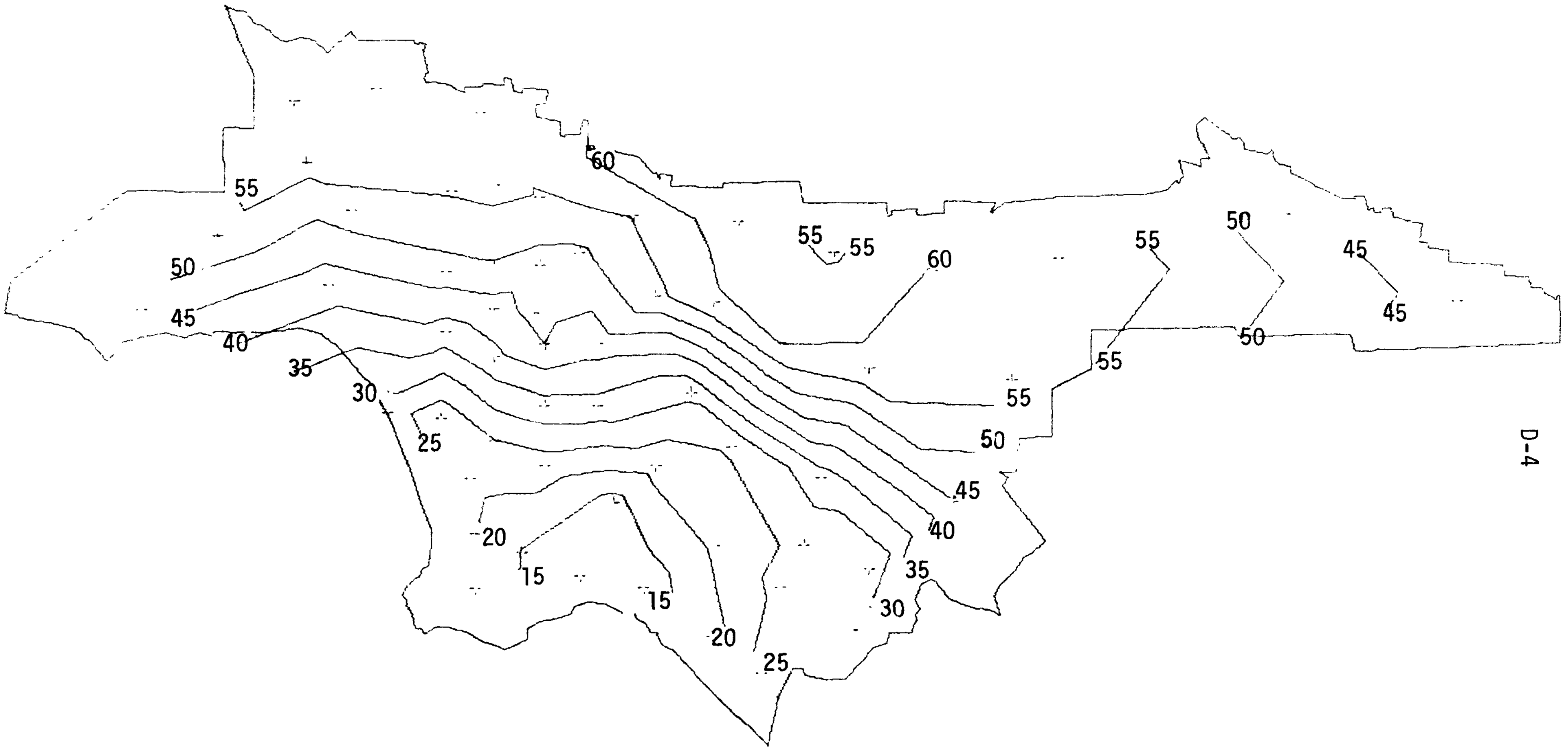

Figure D1-c. Oxidant Air Quality in Percent of Days on Which the NAAQS Was Exceeded During 1969/70

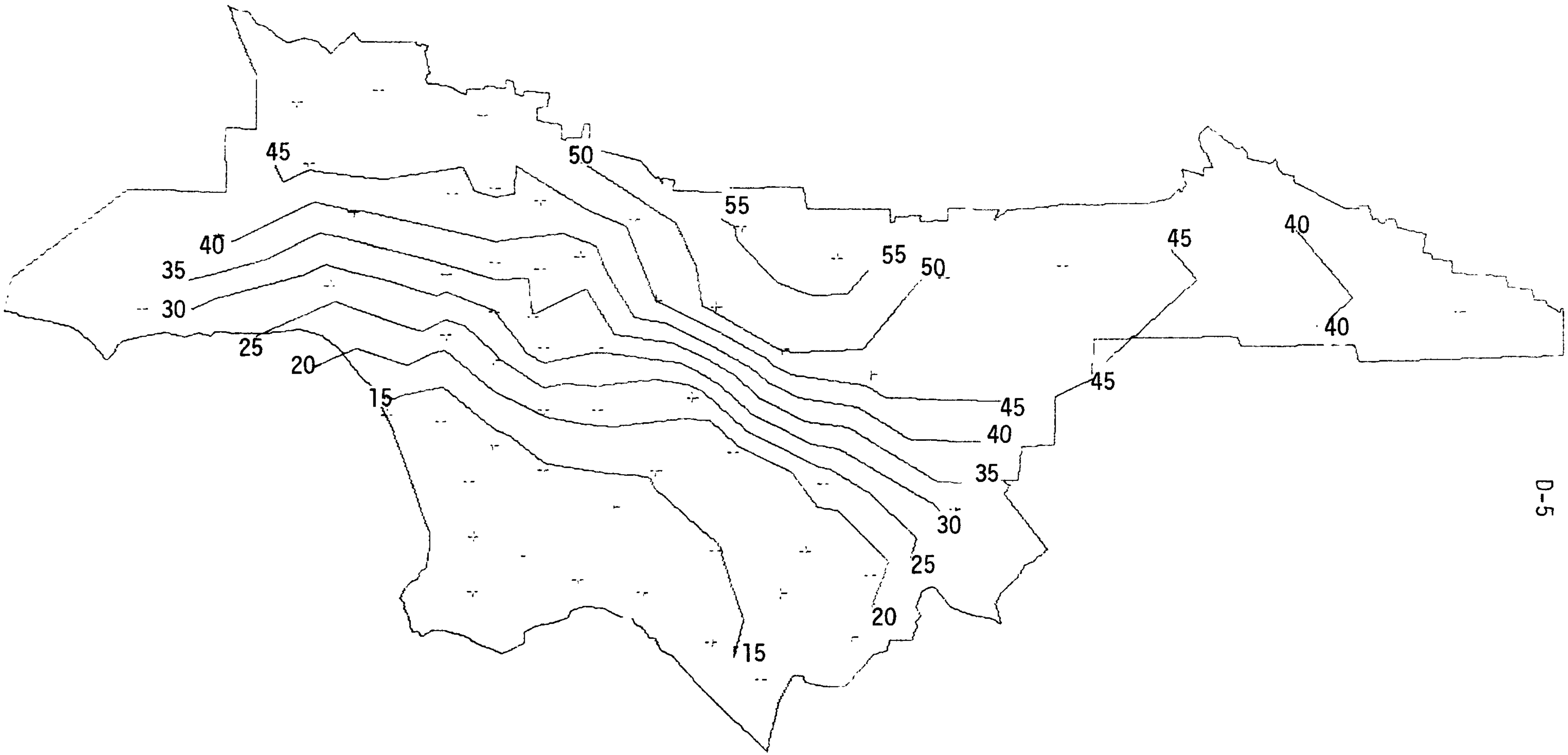

Figure D1-d. Oxidant Air Quality in Percent of Days on Which the NAAQS Was Exceeded During 1971/72

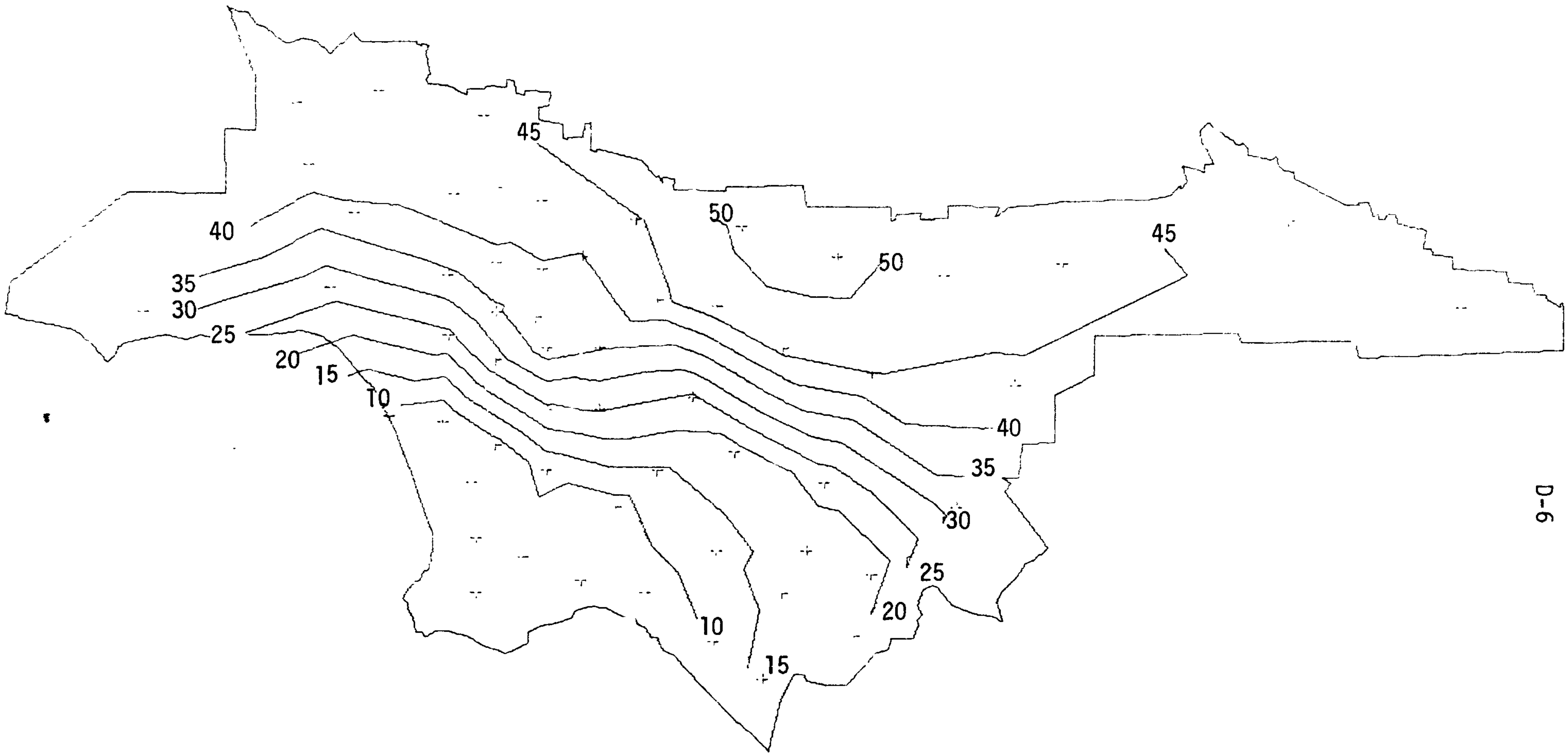

Figure D1-e. Oxidant Air Quality in Percent of Days on Which the NAAQS Was Exceeded During 1973/74

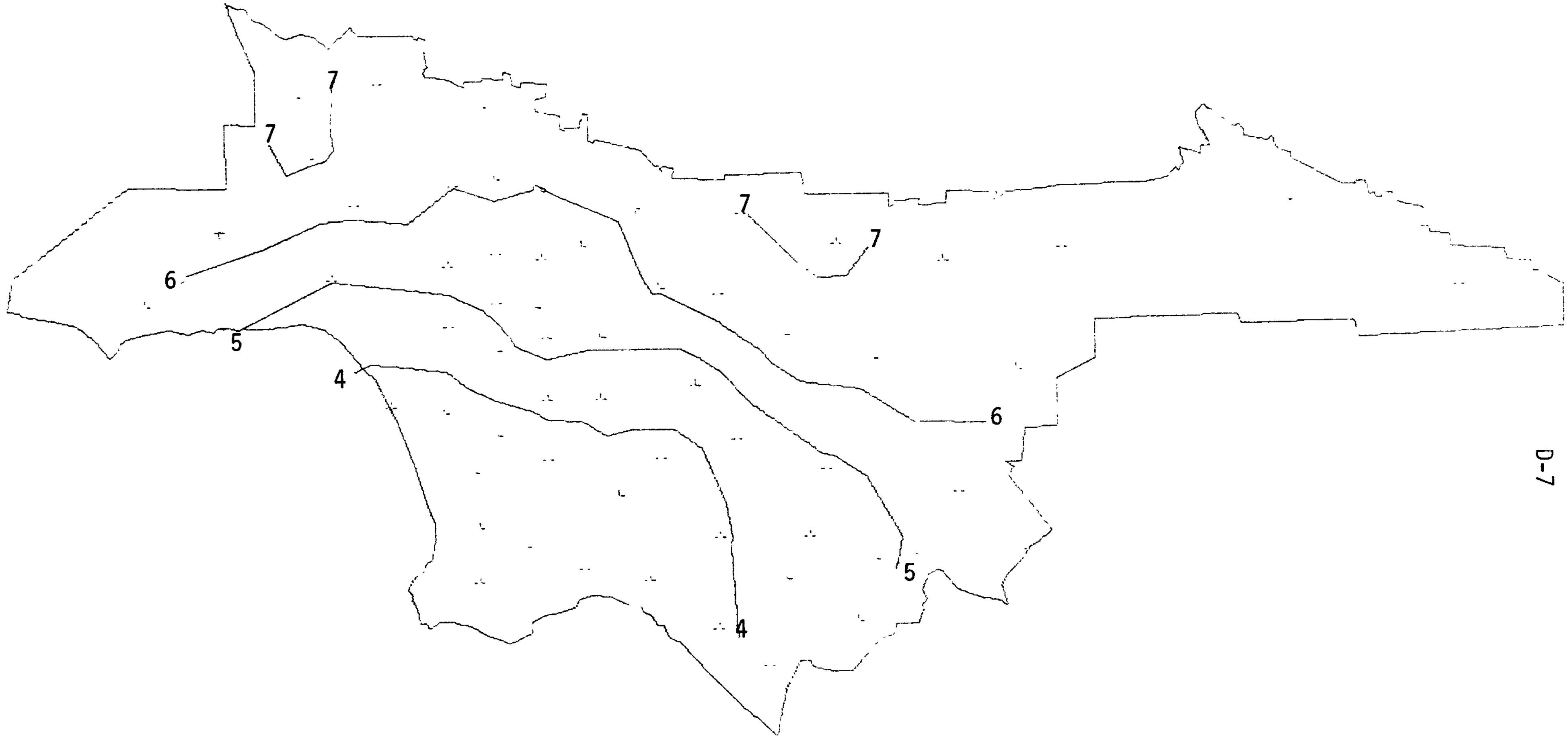

Figure D2-a. Oxidant Air Quality in Mean Duration (Hrs/Day) of NAAQS Violations During 1965/66

Figure D2-b. Oxidant Air Quality in Mean Duration (Hrs/Day) of NAAQS Violations During 1967/68

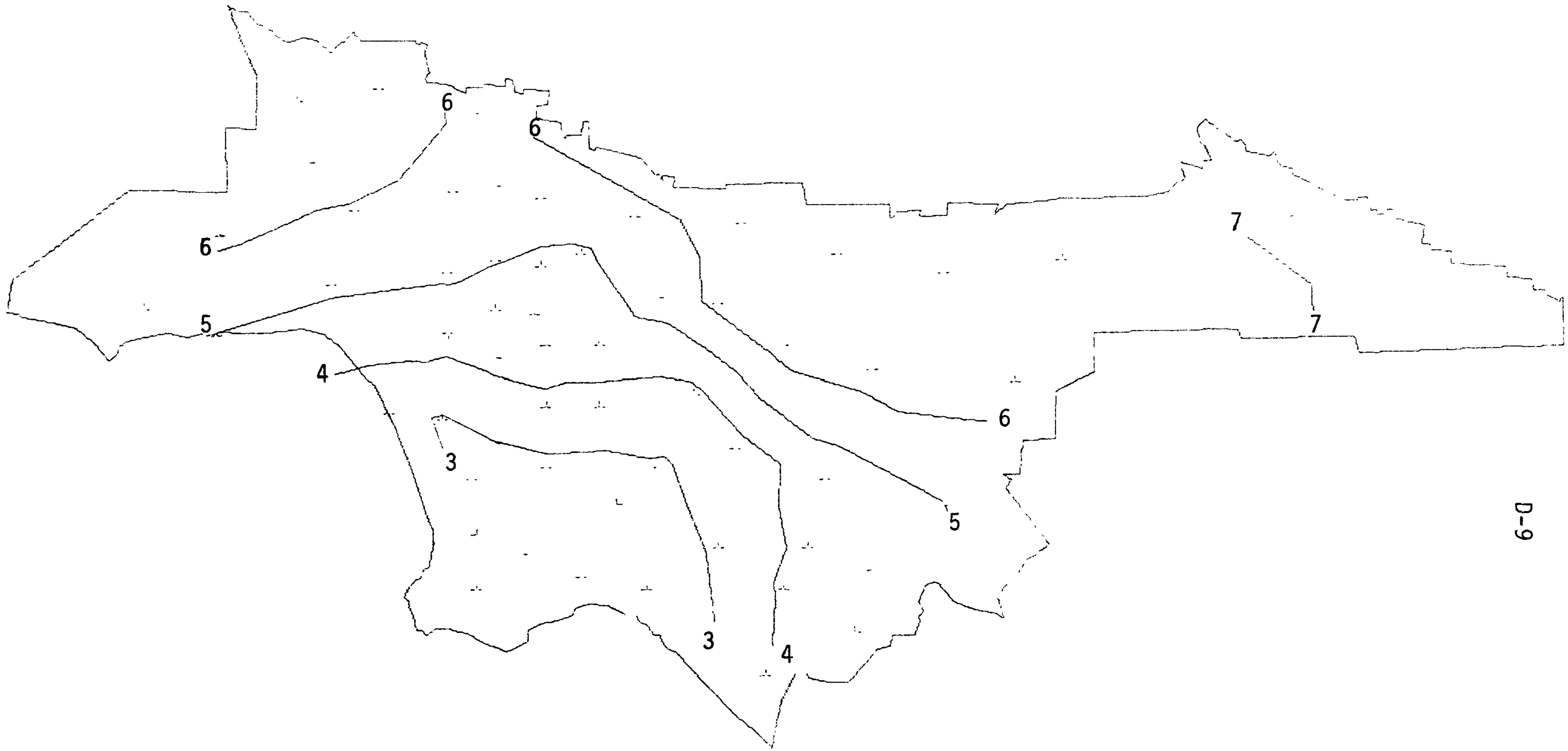

Figure D2-c. Oxidant Air Quality in Mean Duration (Hrs/Day) of NAAQS Violations During 1969/70

Figure D2-d. Oxidant Air Quality in Mean Duration (Hrs/Day) of NAAQS Violations During 1971/72

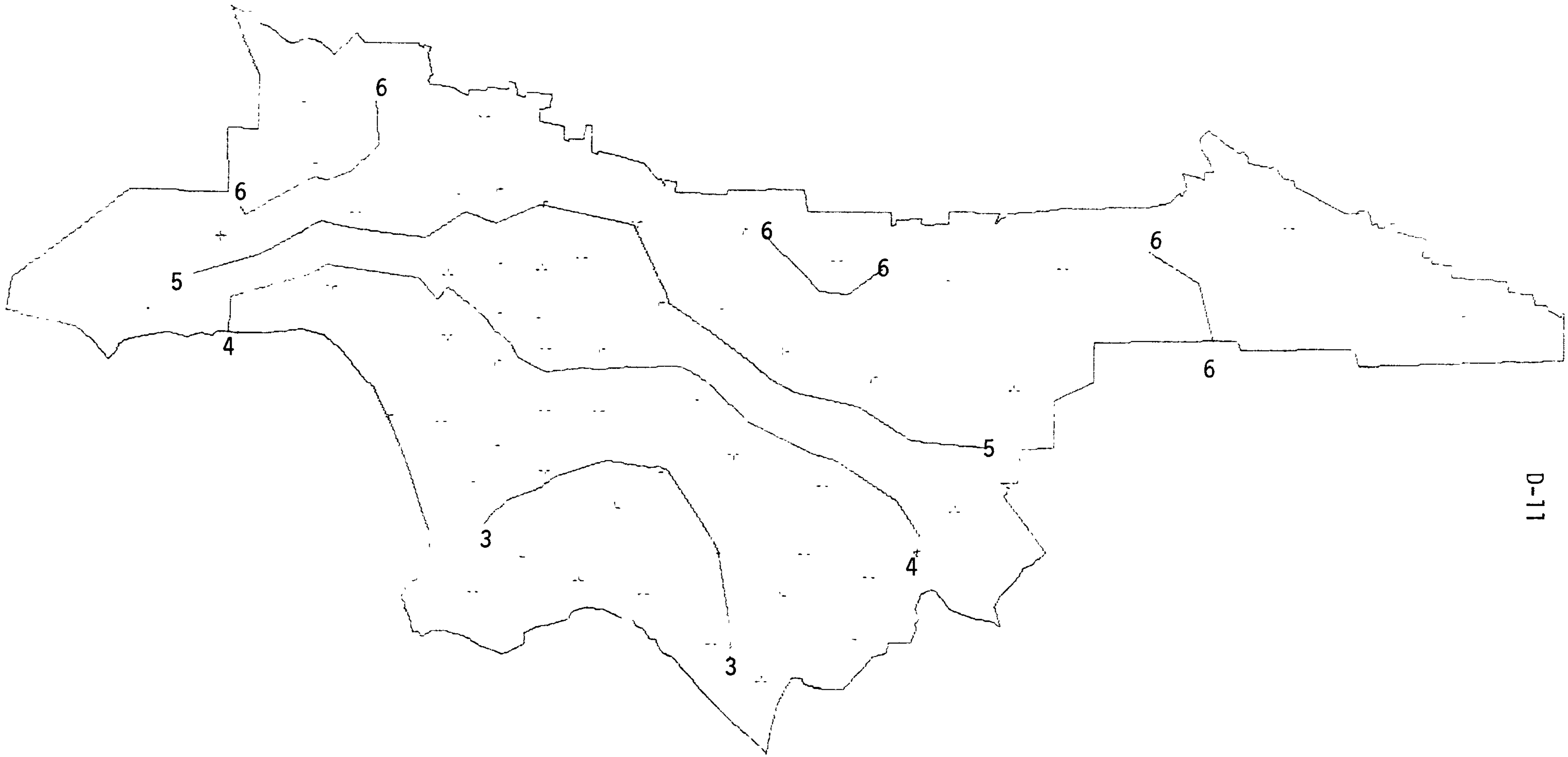

Figure D2-e. Oxidant Air Quality in Mean Duration (Hrs/Day) of NAAQS Violations During 1973/74

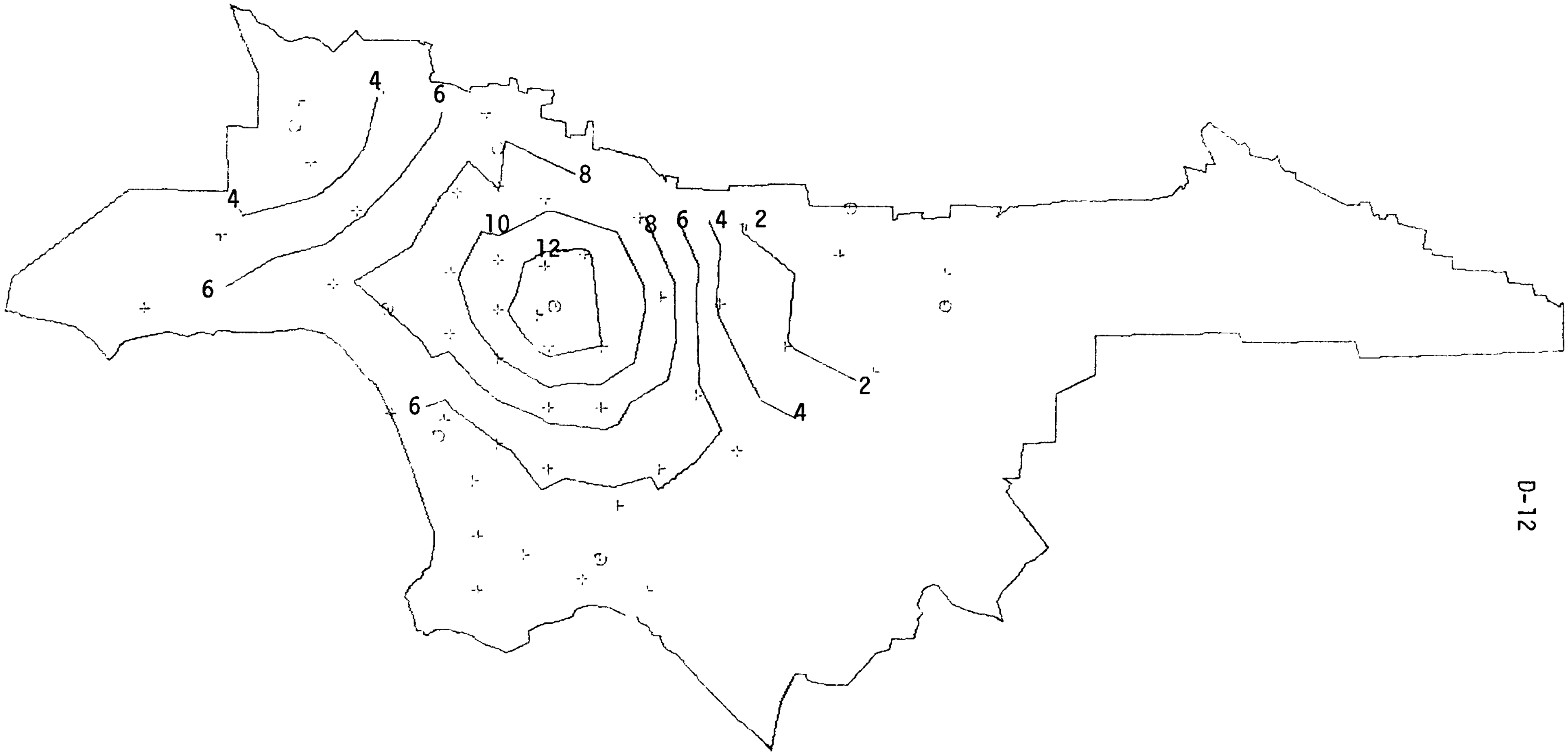

Figure D3-a. NO_2 air quality in percent of days on which the California 1-hr standard was exceeded during 1965/66.

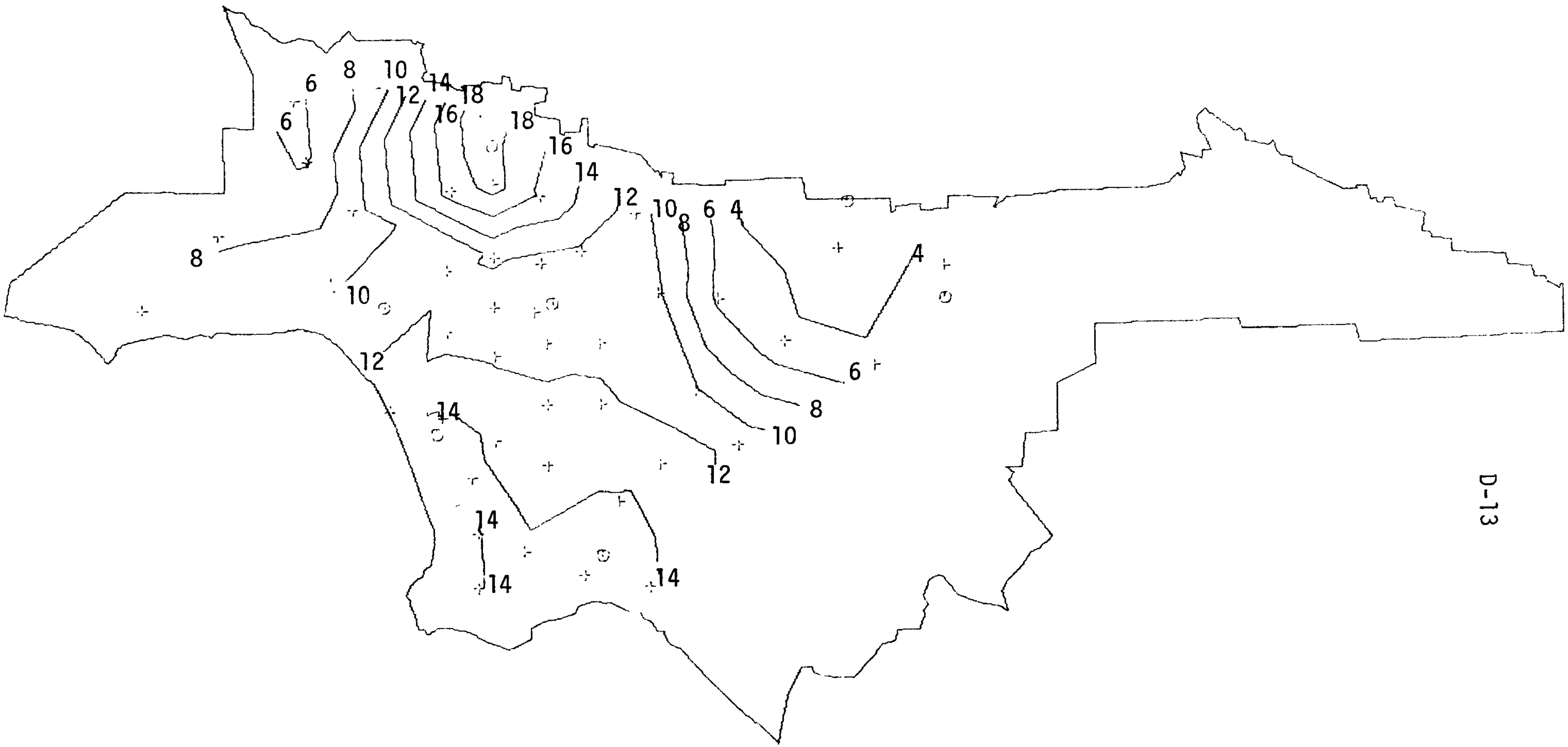

Figure D3-b. NO_2 air quality in percent of days on which the California 1-hr standard was exceeded during 1967/68.

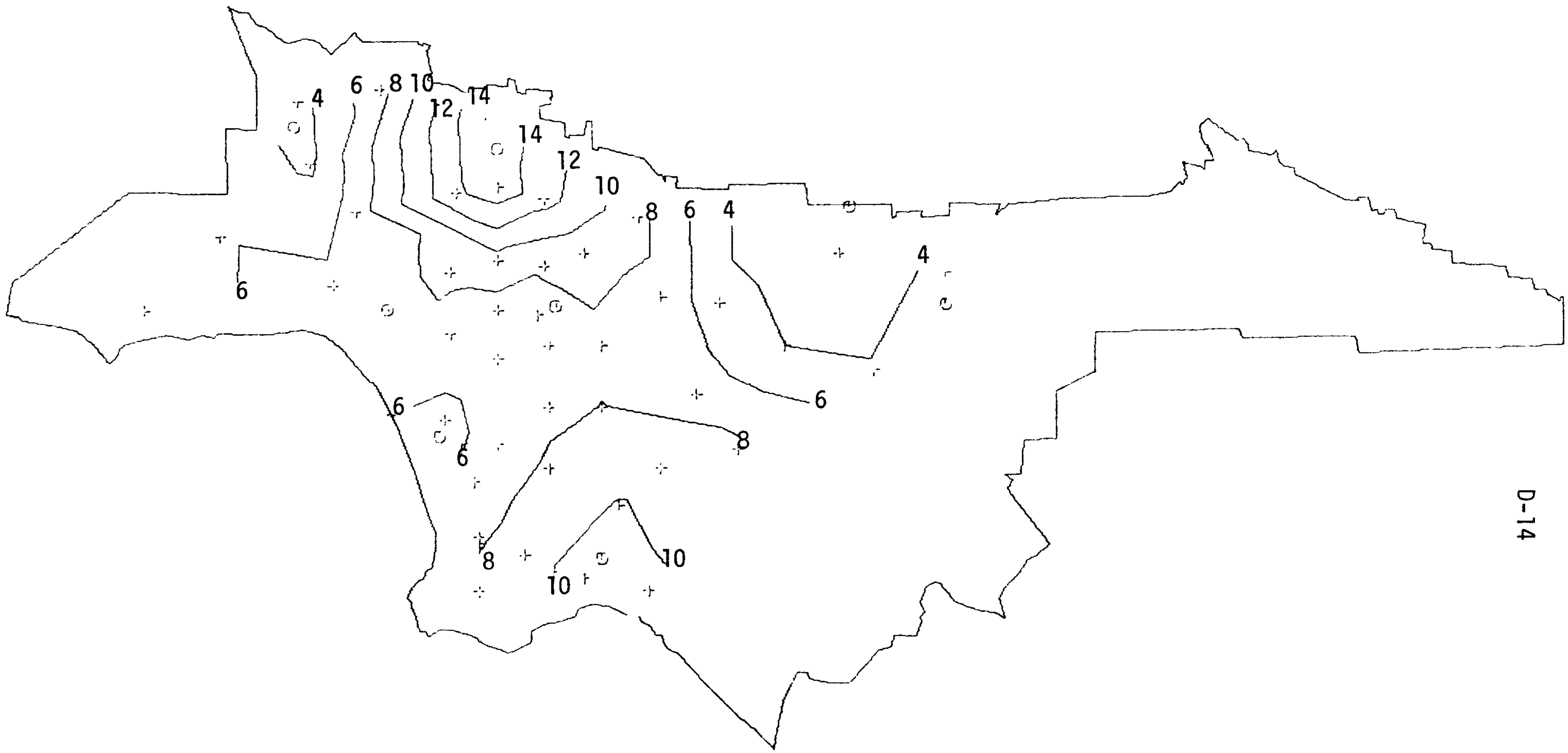

Figure D3-c. NO_2 air quality in percent of days on which the California 1-hr standard was exceeded during 1969/70.

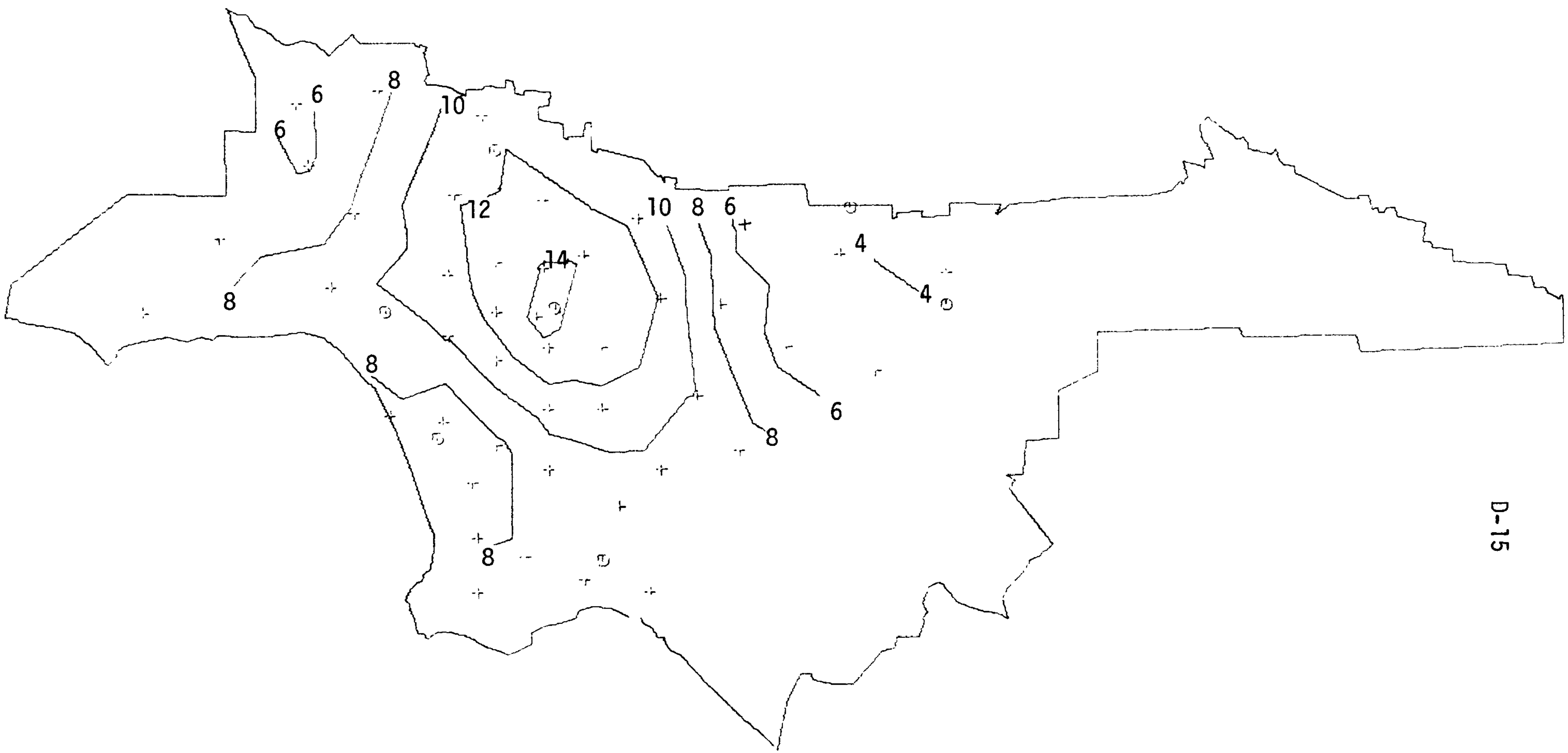

Figure D3-d. NO_2 air quality in percent of days on which the California 1-hr standard was exceeded during 1971/72.

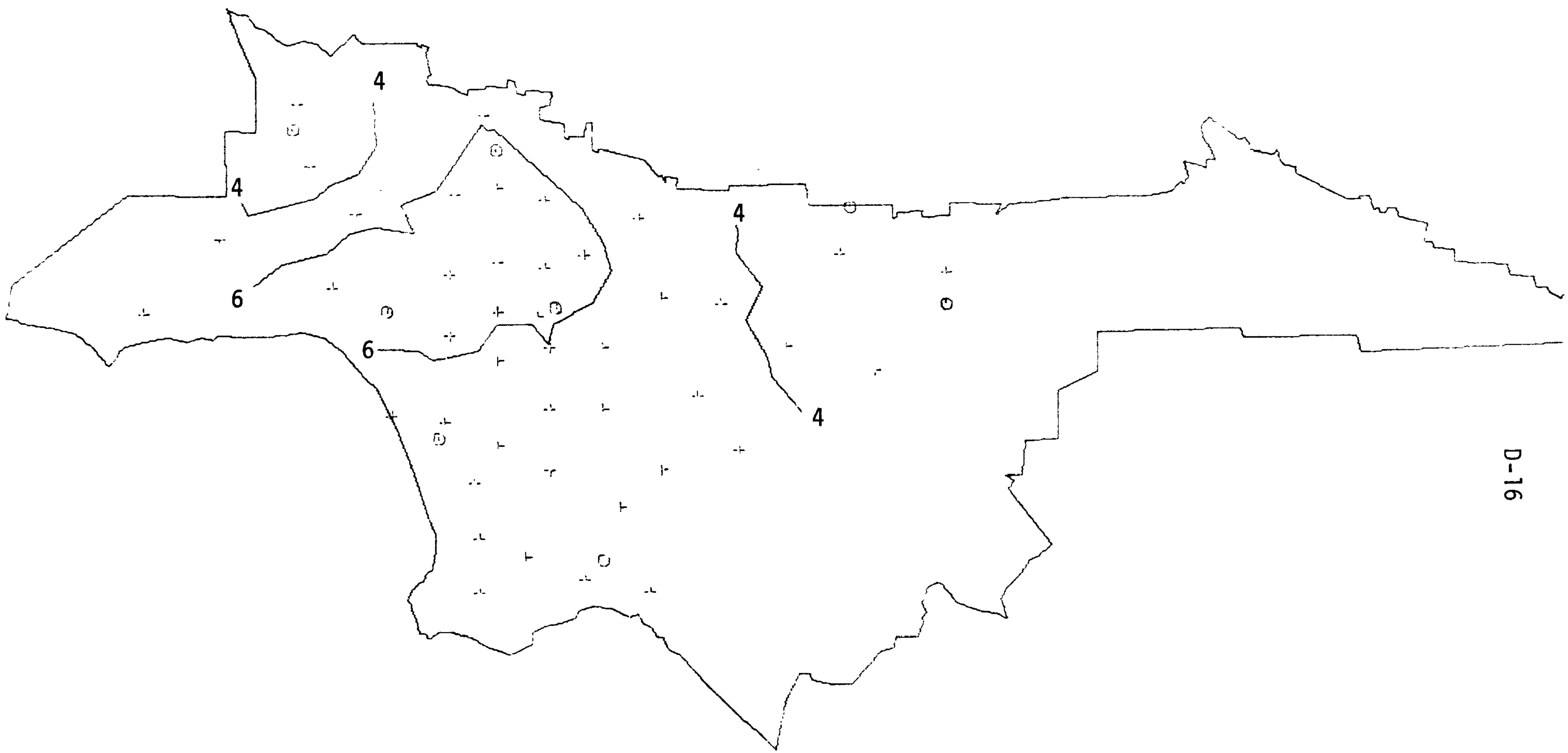

Figure D3-e. NO_2 air quality in percent of days on which the California 1-hr stnadard was exceeded during 1973/74.

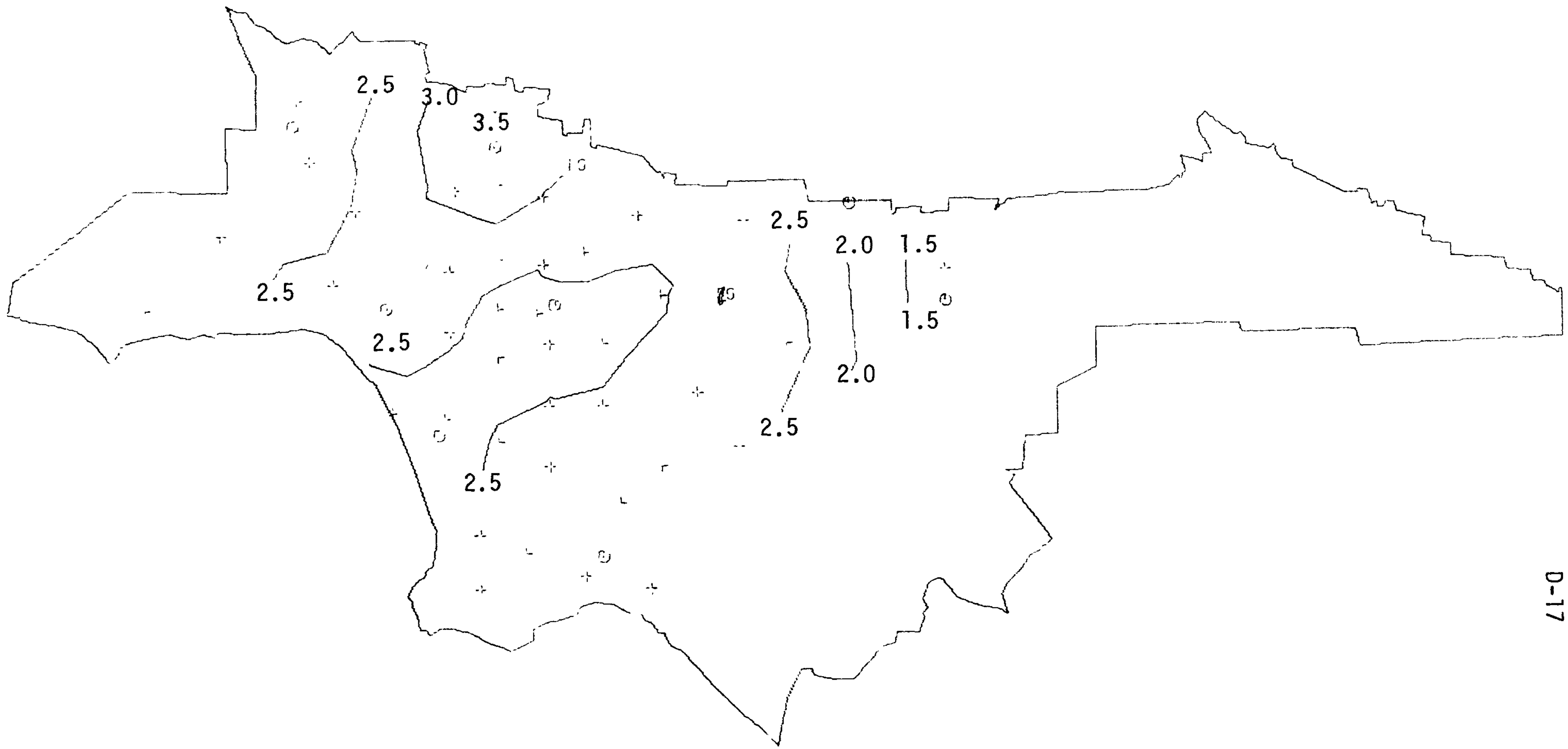

Figure D4-a. NO_2 air quality in mean duration (hrs/day) of California standard violations during 1965/66.

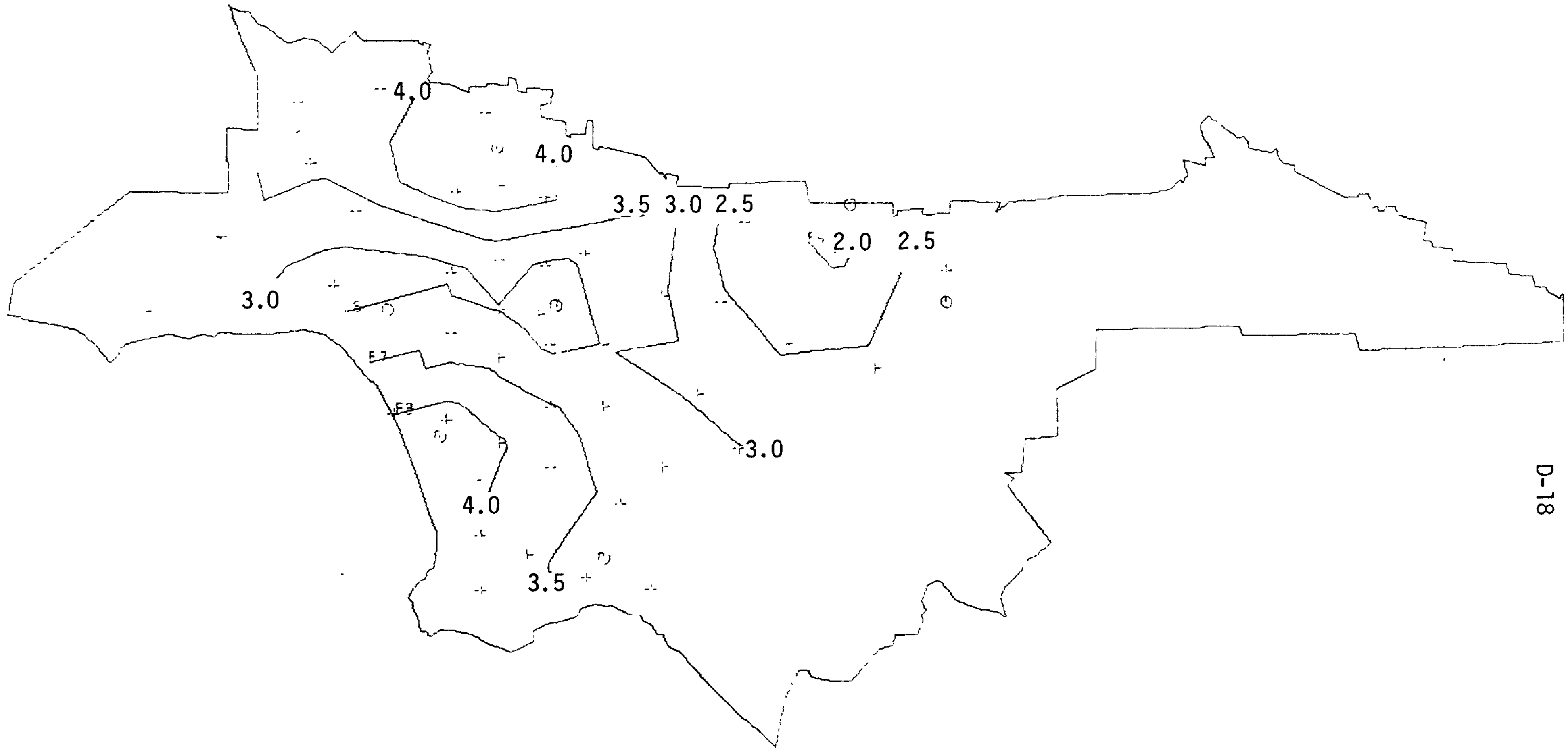

Figure D4-b. NO_2 air quality in mean duration (hrs/day) of California standard violations during 1967/68.

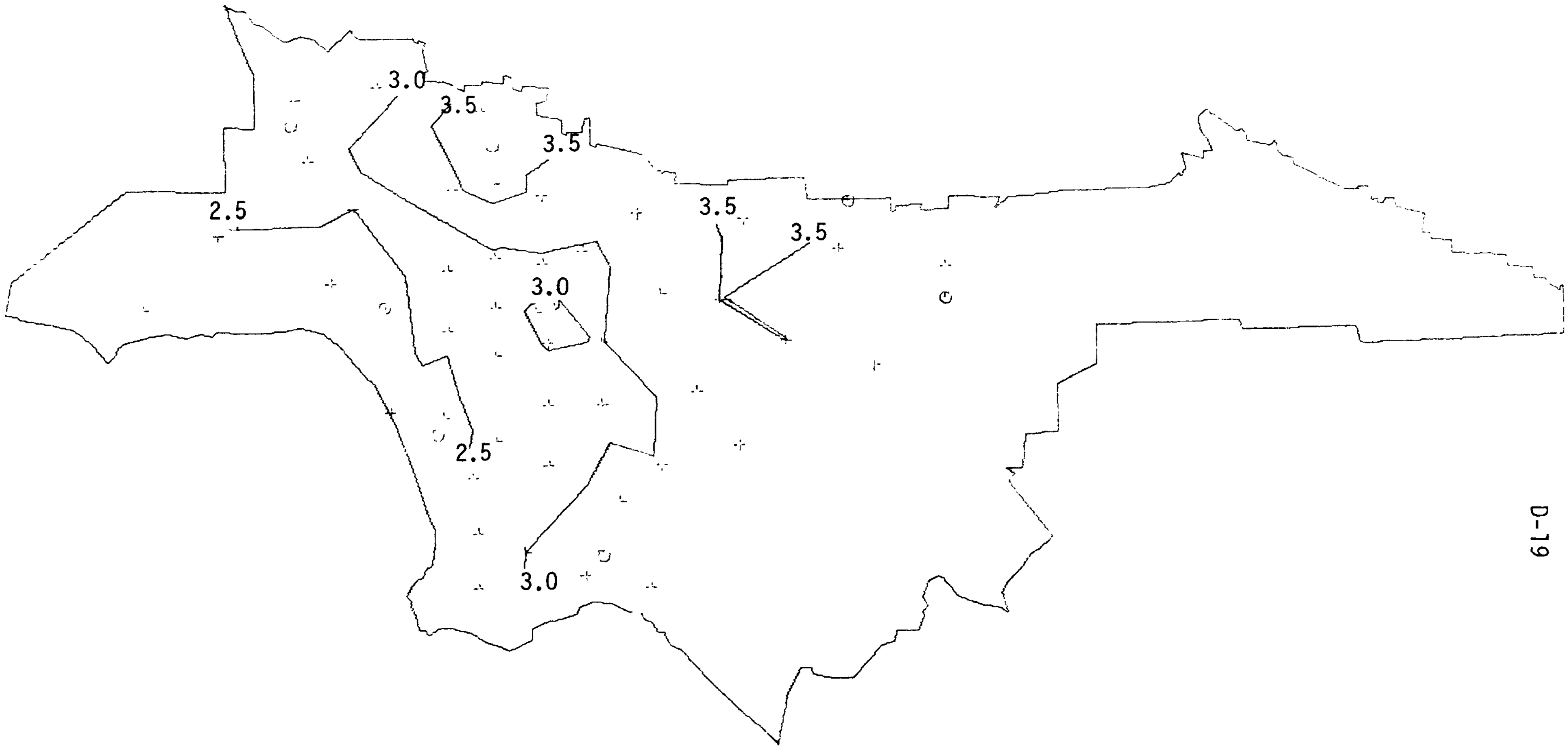

Figure D4-c. NO_2 air quality in mean duration (hrs/day) of California standard violations during 1969/70.

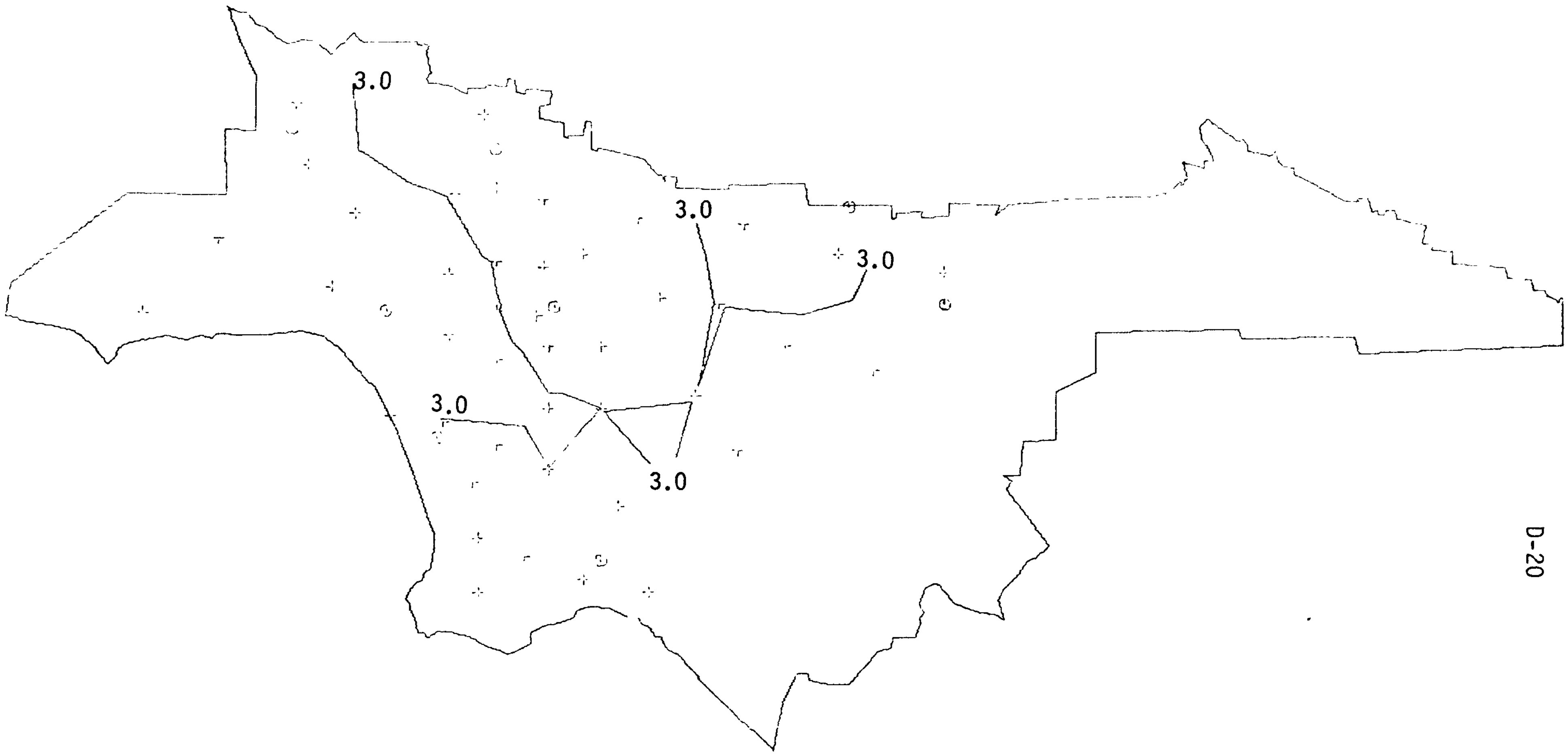

Figure D4-d. NO_2 air quality in mean duration (hrs/day) of California standard violations during 1971/72.

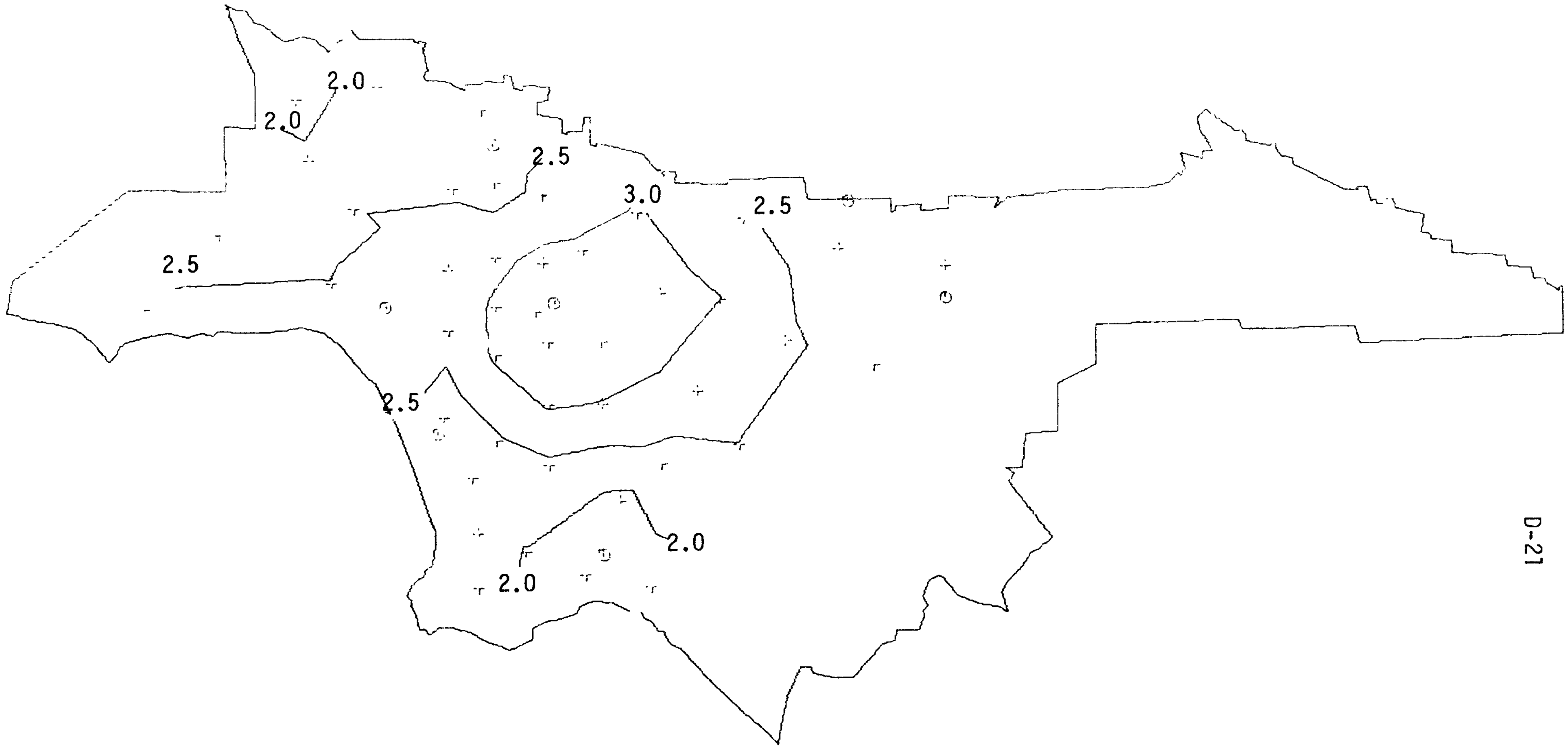

Figure D4-e. NO_2 air quality in mean duration (hrs/day) of California standard violations during 1973/74.

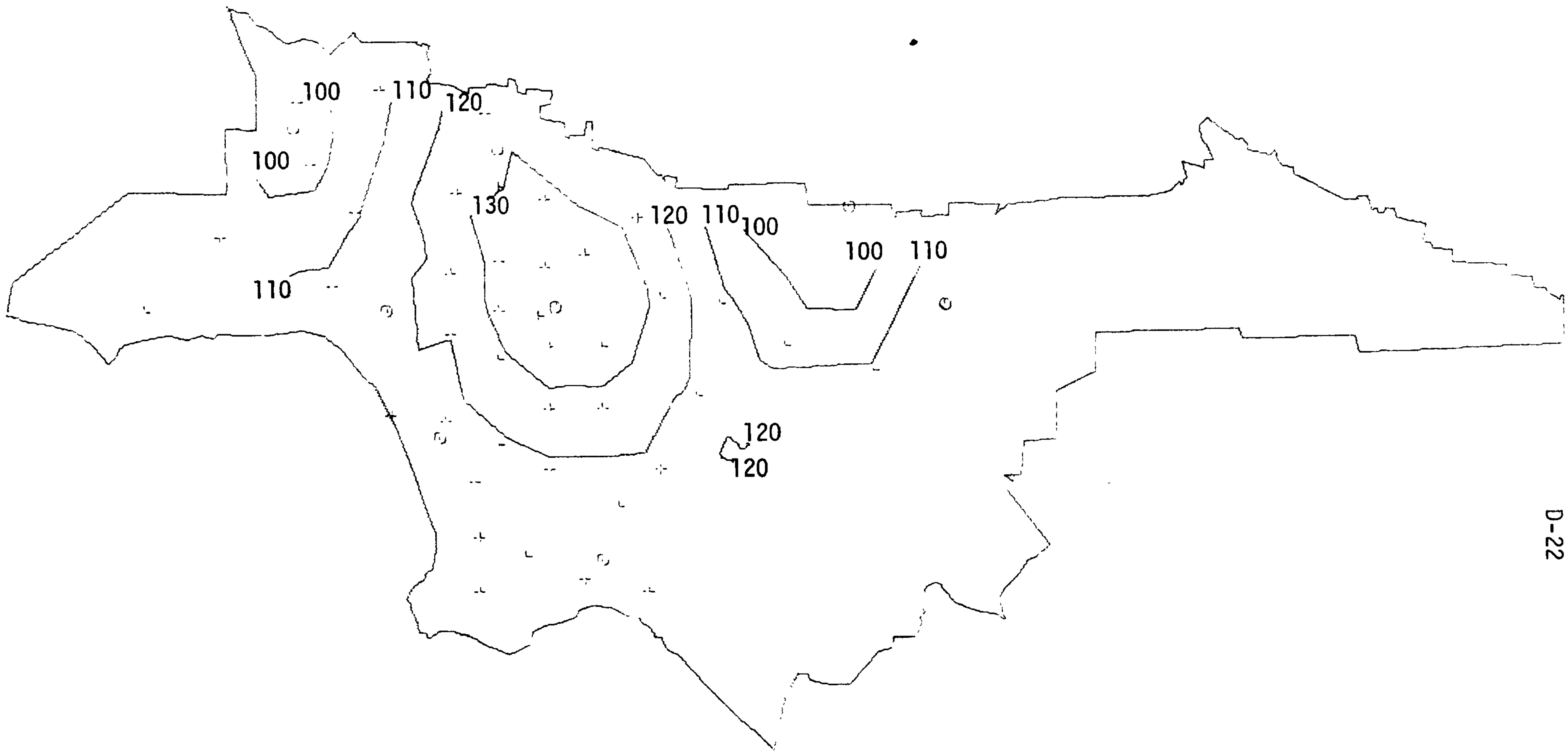

Figure D5-a. NO_2 Annual Arithmetic Mean Concentration (μg/m^3) During 1965/66.

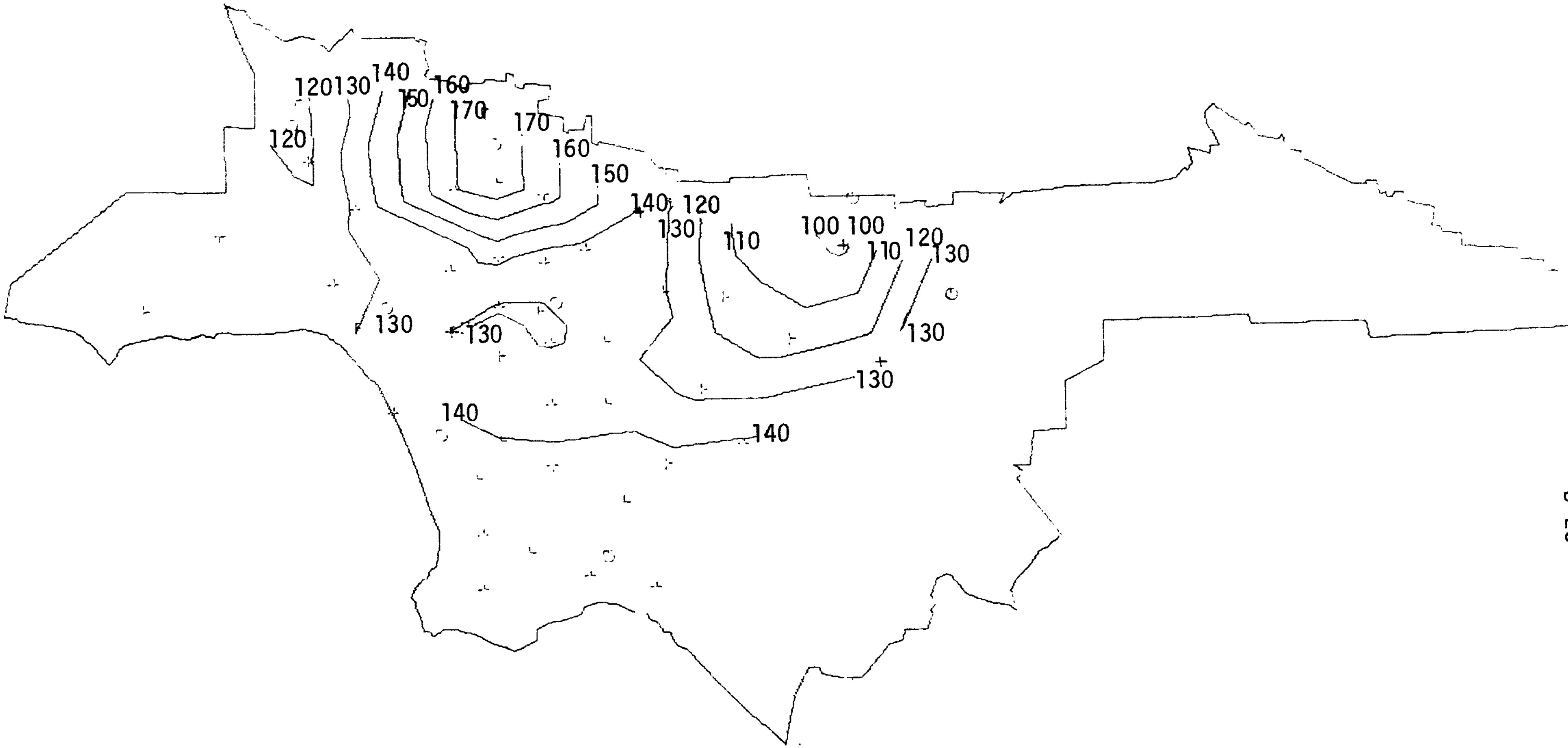

Figure D5-b. NO_2 Annual Arithmetic Mean Concentration ($\mu g/m^3$) During 1967/68.

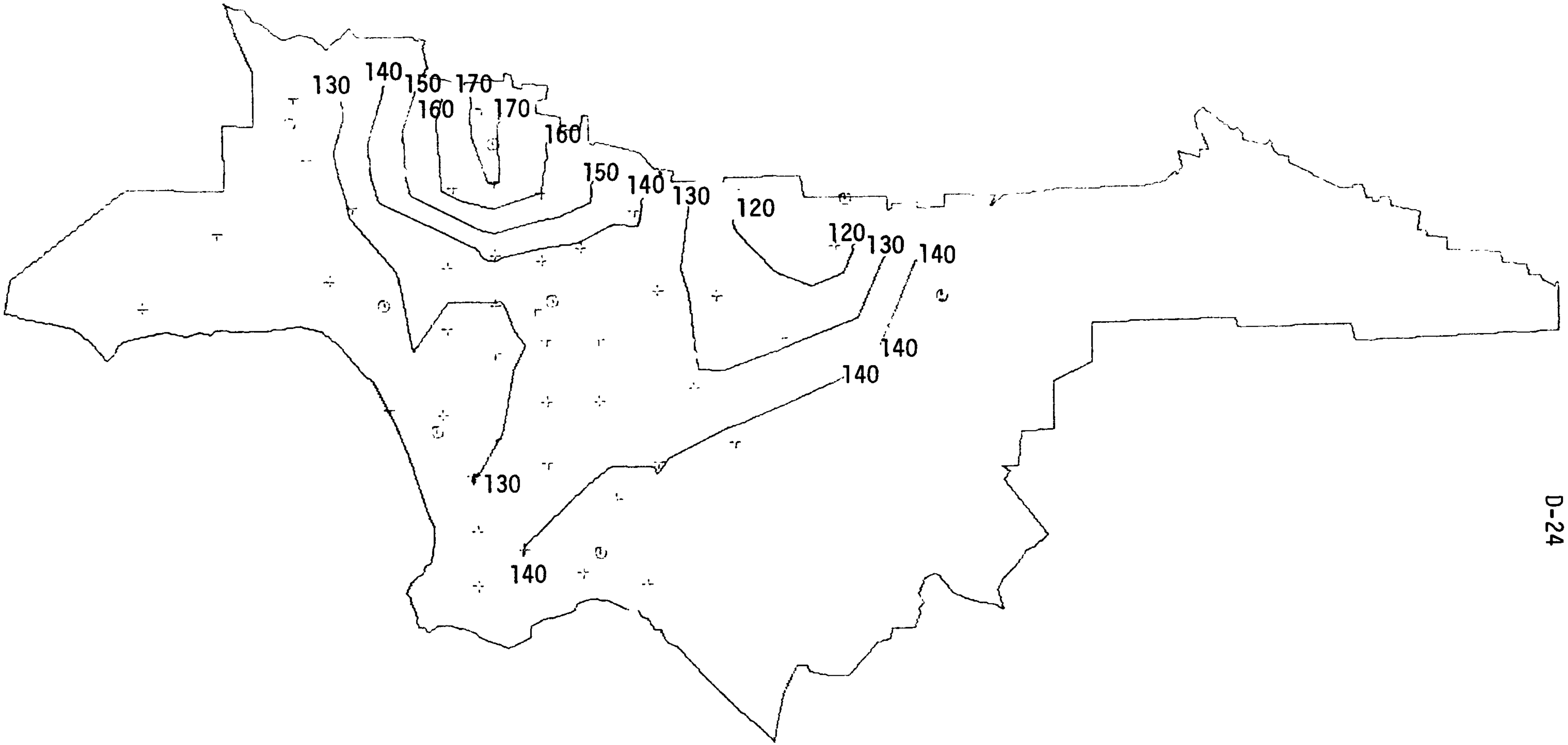

Figure D5-c. NO_2 Annual Arithmetic Mean Concentration ($\mu g/m^3$) During 1969/70.

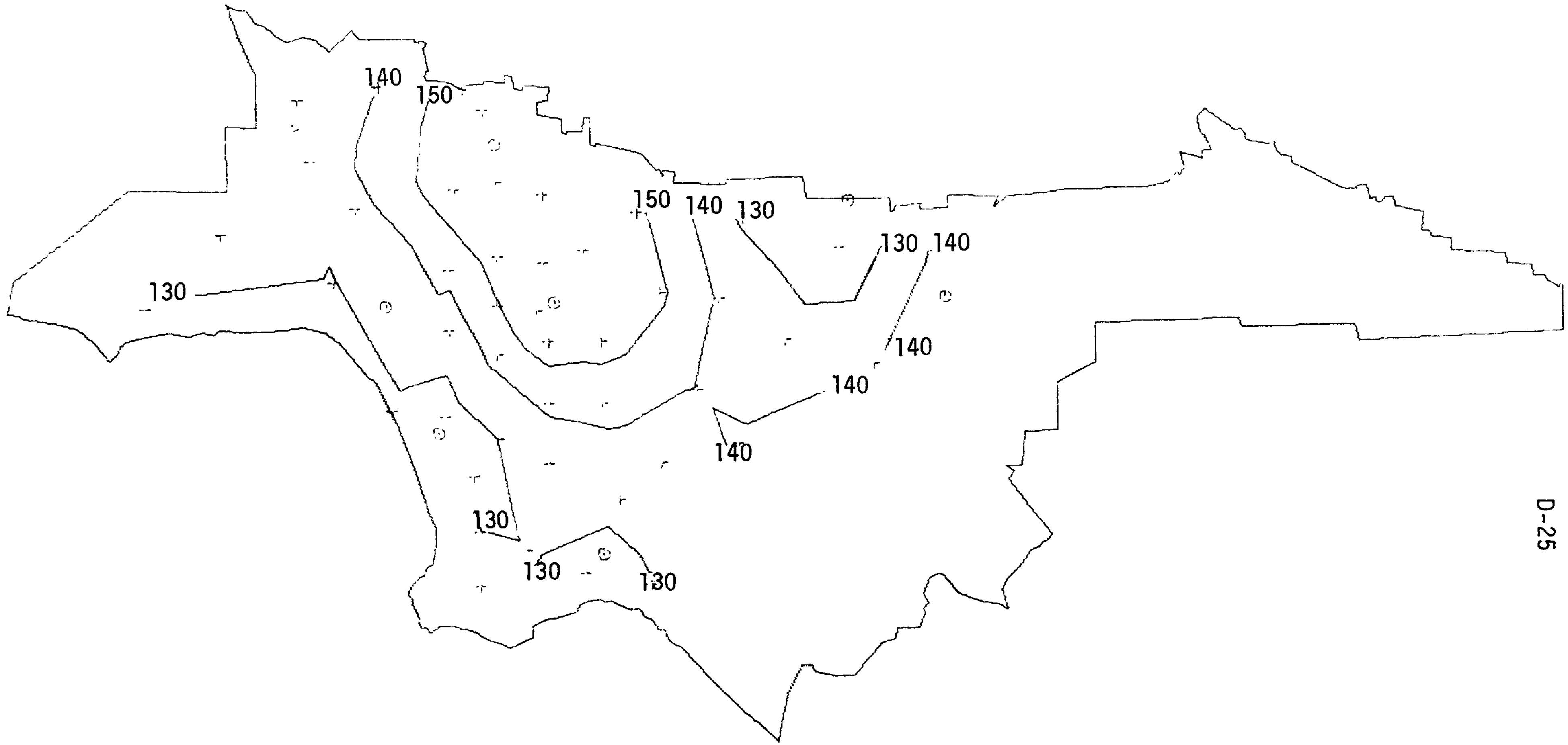

Figure D5-d. NO_2 Annual Arithmetic Mean Concentration ($\mu g/m^3$) During 1971/72.

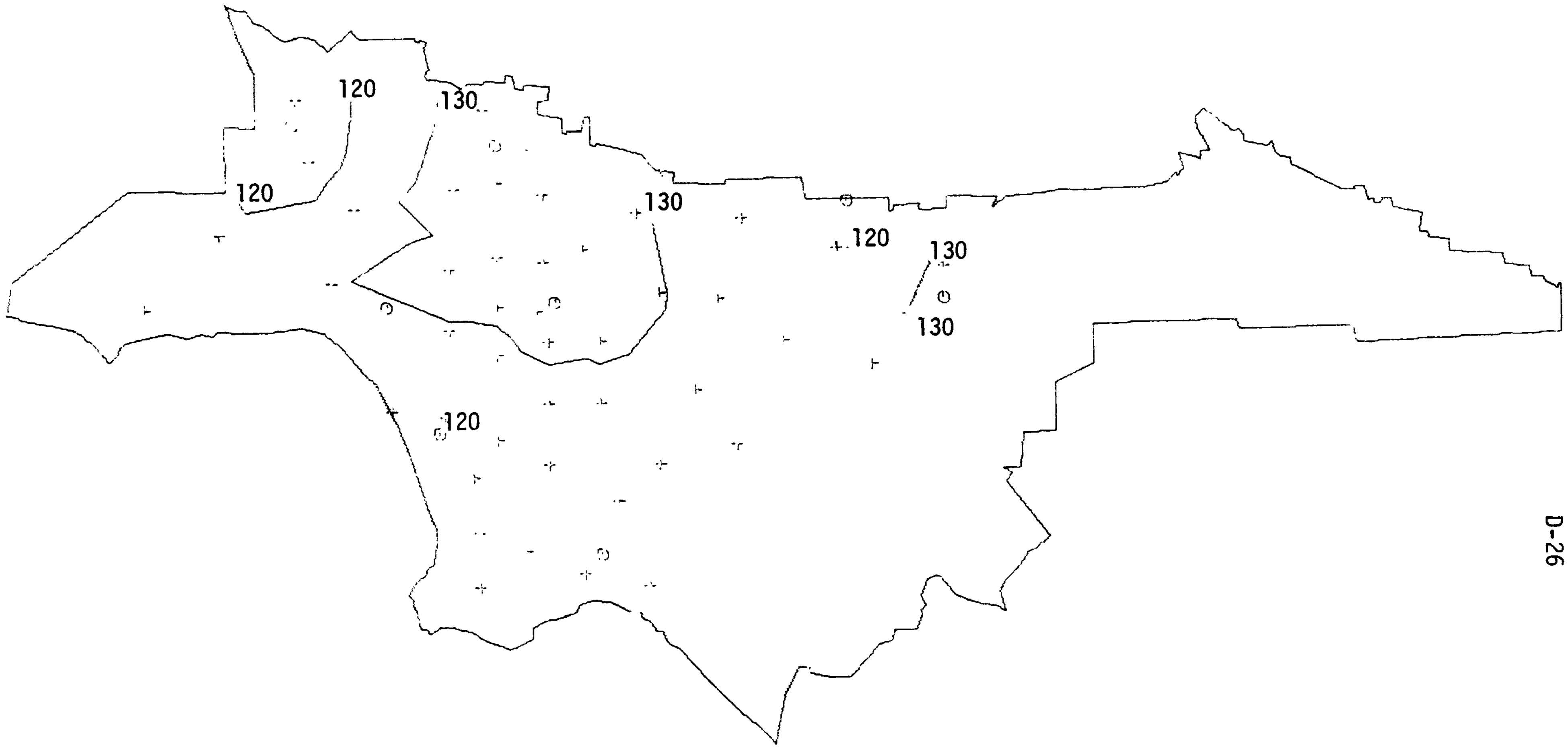

Figure D5-e. NO_2 Annual Arithmetic Mean Concentration ($\mu g/m^3$) During 1973/74.

APPENDIX E

METHODOLOGY TO CHARACTERIZE POPULATION EXPOSURE

FORMULATION OF POPULATION EXPOSURE PARAMETERS

Suppose a person stays at a place where the air quality is continously monitored. Then, the pollution "dose" of that person over a time period T can be given by[1]

$$\text{DOSE} = \int_0^T C(t)\, dt \qquad \text{(E-1)}$$

where C(t) is the concentration reading at time t. A pollutant concentration is usually measured at a constant time interval, say, every hour. Monitored concentrations are often sorted in ascending order and summarized to percentile concentration statistics. In this case, Eq. (E-1) reduces to

$$\text{DOSE} = T\int_0^1 C(f)\, df \qquad \text{(E-2)}$$

where C(f) is the concentration at the f^{th} percentile.

From the quantities in Eq. (E-2) we will derive the three exposure parameters: "dose rate," "risk frequency," and "mean duration". The dose rate is the average concentration with respect to a subject person and is given, for the above example, as

$$D = \int_0^1 C(f)\, df \qquad \text{(E-3)}$$

Namely, the dose rate is equal to the artihmetic mean concentration averaged over the time period T, i.e., a year in this study. The risk frequency is the percentage of time that a subject person is exposed to a concentration above a given concentration threshold C_S.[2]

$$R(C_S) = 1 - f_s \tag{E-4}$$

where f_s is the percentile given by a solution to $C(f) = C_S$. The mean duration can be determined when the percentile concentration statistics are available for both hourly average concentrations and daily maximum hourly average concentrations. It is given by

$$\tau(C_S) = 24\ R_{hour}/R_{day} \tag{E-5}$$

where R_{hour} is the risk frequency for hourly average concentrations (hourly risk frequency) and R_{day} the risk frequency for daily maximum hourly average concentrations (daily risk frequency).

Using an indicator step function U(x) that assumes the value one for positive arguments and zero elsewhere, the distribution function for each of the three population exposure parameters D, $R(C_S)$, and $\tau(C_S)$ is given as[3]:

$$S(D^*) = \sum_i P_i\ U(D_i - D^*)/P_o \tag{E-6}$$

$$S(R^*) = \sum_i P_i\ U[R_i(C_S) - R^*]/P_o \tag{E-7}$$

$$S(\tau^*) = \sum_i P_i\ U[\tau_i(C_S) - \tau^*]/P_o \tag{E-8}$$

where P_i is the size of the local population at the i-th receptor point, P_o the total number of people of the population, and D^*, R^*, and τ^* are, respectively, the threshold values of D, $R(C_S)$ and $\tau(C_S)$.

Once the distribution function is determined for a parameter D, R, or τ, the mean value of that parameter over the entire population is given by the integral of the distribution function with respect to the threshold of that parameter[4]. The average dose rate $\overline{D}$, the average risk frequency $\overline{R}(C_S)$ and the average mean duration $\overline{\tau}(C_S)$ over the entire population are given as

$$\overline{D} = \int_0^\infty S(D^*)\ dD^* \qquad \text{(E-9)}$$

$$\overline{R}(C_S) = \int_0^\infty S(R^*)\ dR^* \qquad \text{(E-10)}$$

$$\overline{\tau}(C_S) = \int_0^\infty S(\tau^*)\ d\tau^* \qquad \text{(E-11)}$$

The actual computation of $\overline{D}$, $\overline{R}(C_S)$ and $\overline{\tau}(C_S)$ was done by numerically integrating the distribution functions $S(D^*)$, $S(R^*)$, and $S(\tau^*)$, respectively.

REFERENCES TO APPENDIX E

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16. ABSTRACT

A population exposure methodology was applied to trend analyses of photochemical air pollution and population exposure to O_x and NO_2 in the Los Angeles Basin. The analyses were made on the air quality and population data during the five 2-year periods from 1965/66 to 1973/74 to determine the 10-year trends in air quality and in population exposure to the two pollutants.

Oxidant air quality improved throughout the region during the 10-year period. The improvement appeared first in the coastal region and thereafter proceeded toward the inland region. The extent of O_x air quality improvement was greater in the coastal region than in the inland region. As a result, population exposure to O_x above the standard was also diminished. The decrease in population exposure to O_x was pronounced more at higher exposure levels than at lower exposure levels.

There was no obvious trend in NO_2 air quality and population exposure to NO_2. The middle years 1967/68-1971/72 were more polluted than the end years 1965/66 and 1973/74. The spatial gradient of NO_2 air pollution became smaller in recent years and consequently, the population received more uniform exposure to NO_2. The NAAQS for NO_2 annual mean concentration was violated practically everywhere in the region during the entire period.

17. KEY WORDS AND DOCUMENT ANALYSIS

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