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EMISSIONS AND AIR QUALITY TRENDS IN THE SOUTH COAST AIR BASIN

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John C. Trijonis
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ENVIRONMENTAL QUALITY LABORATORY
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ABSTRACT

This paper documents the historical trends of pollutant emissions and ambient air quality for the South Coast Air Basin (SCAB) for the period 1965-1974. Emission trends for nitrogen oxides, reactive hydrocarbons, and carbon monoxide are developed. A detailed appendix describes the methodology and presents the latest test information--in particular the contribution of evaporative emissions from light-duty vehicles. Basin-wide and county trends are presented to characterize the overall changes as well as the spatial distribution of emissions. Ambient concentrations of total nitrogen oxides (NO_x), nitrogen dioxide (NO_2), oxidant (OX), and carbon monoxide (CO) are compared to the emissions changes during the same period. Detailed analyses of air quality indices, including extreme levels, average values, and frequency of standard violation are presented for each pollutant. The final section of the paper discusses current and proposed control strategies and their impact on future air quality.

TABLE OF CONTENTS

		Page
I	Introduction	1
II	Recent Control Policy and Emission Trends	2
	Methodology	4
	Trends in Total Emissions	6
	Graphical Distribution of Emission Trends	11
III	Recent Air Quality Trends	17
	Methodology	17
	Trends in NO_x and NO_2 Air Quality	19
	Trends in Oxidant Air Quality	25
	Trends in Carbon Monoxide Air Quality	31
IV	Conclusions	37
References		41
Appendix A - Basis for Emission Trend Estimates		A-1
1.	Mobile Sources	A-1
	A. Light-Duty Vehicles	A-1
	B. Heavy-Duty Vehicles	A-4
	C. Aircraft	A-5
	D. Ships and Railroads	A-5
	E. Motorcycles and Off-Road Vehicles	A-5
2.	Stationary Sources	A-6
	A. Reactive Hydrocarbon (RHC)	A-6
	B. Carbon Monoxide (CO)	A-7
	C. Oxides of Nitrogen (NO_x)	A-8
References for Appendix A		A-10

LIST OF FIGURES AND TABLES

Page

Figure 1 - Map of South Coast Air Basin 3

Figure 2 - South Coast Air Basin NO_x Emission Trends (1965-1974) 7

Figure 3 - South Coast Air Basin Reactive Hydrocarbon (RHC) Emission Trends. 9

Figure 4 - South Coast Air Basin CO Emission Trends (1965-1974) 11

Figure 5 - Average Yearly VMT and Population Growth Rates, 1965-1974 . . . 13

Figure 6 - Trends in NO_x Emissions, 1965-1974 15

Figure 7 - Trends in RHC Emissions, 1965-1974 16

Figure 8 - Trends in Carbon Monoxide Emissions, 1965-1974 18

Figure 9 - Typical Annual Average NO_2 Concentrations in the Early 1970's . 20

Figure 10 - Trends in NO_x Emissions and Air Quality, 1965-1974 22

Figure 11 - Trends in NO_x Emissions and NO_2 Air Quality, 1965-1974 . . . 24

Figure 12 - Details of Nitrogen Dioxide Air Quality Trends, 1963-1974 . . 26

Figure 13 - Typical Yearly Maximum One Hour Oxidant Concentrations in the Early 1970's 27

Figure 14 - Trends in RHC Emissions and Oxidant Air Quality, 1965-1974 . . 28

Figure 15 - Details of Oxidant Air Quality Trends, 1963-1974 30

Figure 16 - Details of Oxidant Air Quality Trends at Azusa, 1963-1974 . . 32

Figure 17 - Trends in Hours per Year that Oxidant Exceeds Specified Levels, 1963-1974 33

Figure 18 - Typical Max 8-Hour CO Concentration in the Early 1970's . . . 34

Figure 19 - Trends in Carbon Monoxide Emissions and Air Quality, 1965-1974 . 36

Table A-1 - Low Mileage Emission Factors for Light-Duty Motor Vehicles in Los Angeles (Grams/Mile) A-3

EMISSIONS AND AIR QUALITY TRENDS IN THE SOUTH COAST AIR BASIN

I Introduction

In 1972, Lester Lees and several other members of the Environmental Quality Laboratory staff published "Smog: A Report to the People" [1]. That report examined some of the technical, legal, social, and economic aspects of the photochemical smog problem in the South Coast Air Basin (SCAB). As an example, the EQL Smog Report formulated one possible control strategy for air pollution abatement and evaluated the impact of that strategy based on statistical air quality models developed at EQL.

The Smog Report emphasized that pollution control was a dynamic process and recommended that "feedback" be incorporated in the development of control strategies. Progress (or lack of progress) in improving ambient air quality should be continually reviewed. Control strategies should be periodically reexamined and, if necessary, reformulated.

The period 1976-1977 is an excellent time for such a reexamination of air pollution control strategies in the South Coast Air Basin. It has been ten years since the motor vehicle control program started in California, and four years since the major thrust in air quality implementation planning began in response to the requirements of the Federal Clean Air Act Amendments of 1970. As a preliminary to examining future control strategy alternatives, EQL has undertaken a study to review what present control strategies have achieved to date and to assess where these policies are leading the South Coast Air Basin in the future. This paper, which documents historical trends in emissions and ambient air quality, is a progress report on EQL's initial work in the preliminary review study.

Section II of this paper describes trends in control strategies and emissions over the last decade for three pollutants: nitrogen oxides, reactive hydrocarbons, and carbon monoxide. This update of emission

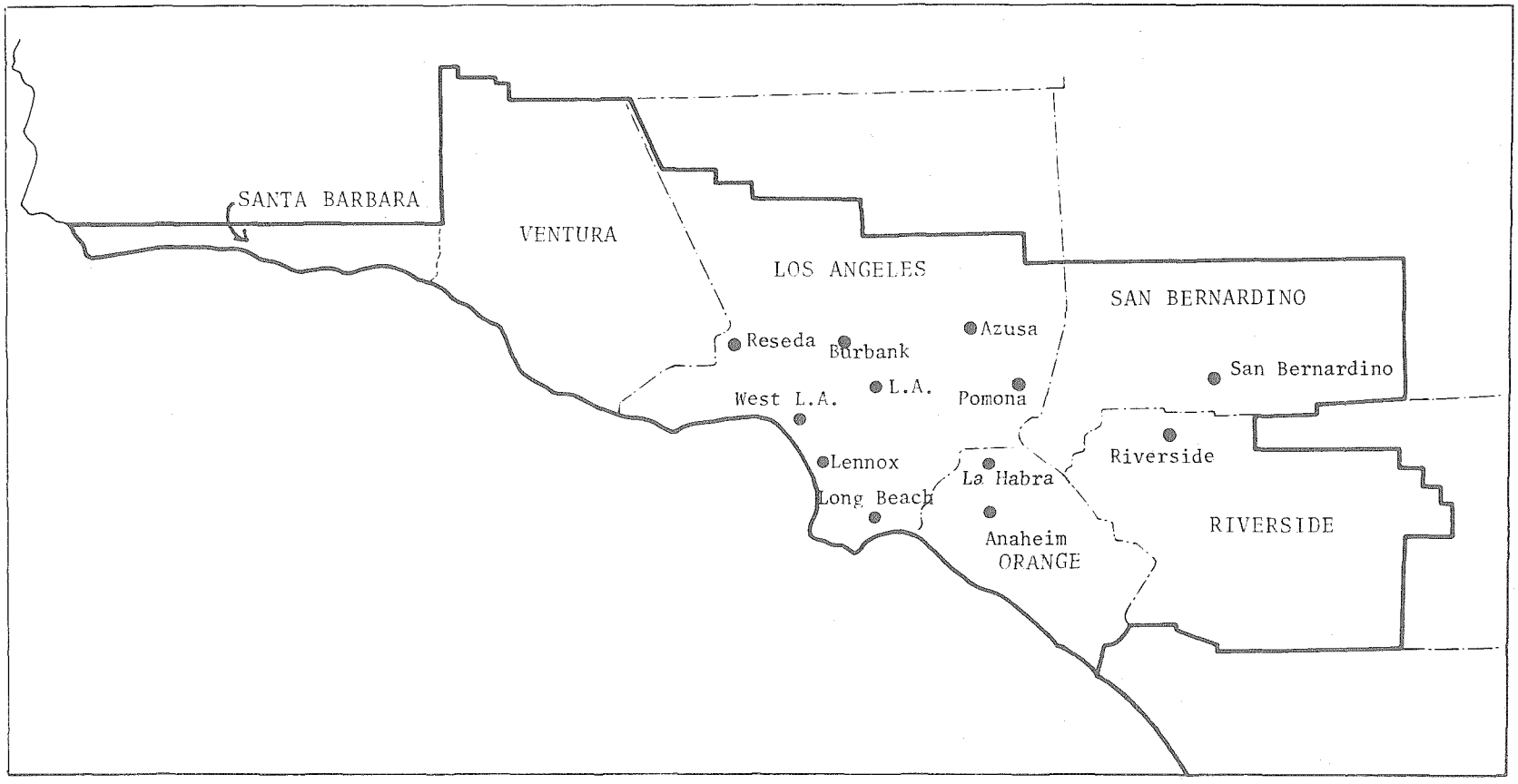
trends includes much of the latest information available on sources, such as new reactivity factors for hydrocarbon emissions, recent test data on auto exhaust emission and deterioration factors, the latest stationary source NO_x inventory, and test data on the unexpectedly large contributions made by evaporative emissions from light-duty vehicles. Basin-wide emissions of each pollutant are documented year by year from 1965 to 1974 in order to characterize overall emission trends and the changing role of various source categories. To illustrate the spatial distribution of emission trends, net percentage changes in emissions over the decade are determined for each of the six counties within (or partially within) the SCAB. Figure 1 shows the area covered by the South Coast Air Basin and the geography of the six county sub-areas.

Section III examines ambient air quality trends over the past decade for four pollutants: total nitrogen oxides, nitrogen dioxide, oxidant, and carbon monoxide. The net changes in ambient pollutant concentrations over the decade are compared to net changes in emissions over the same period. The comparison is performed for sub-areas of the SCAB as well as for the entire Basin. More detailed (year by year) trends in air quality are also examined for several types of air quality indices, including extreme levels, average levels, and frequency of standard violation. Figure 1 illustrates some of the monitoring sites which are used in the analysis of air quality trends.

The final section of thie paper summarizes the main findings. Implications of the results for control strategy formation are also discussed.

II Recent Control Policy and Emission Trends

This section documents total emission trends for the South Coast Air Basin as well as emission trends for the six counties inside the Basin. The purpose of determining total Basin-wide emission trends is to illustrate the changes in emission levels for various source categories. These changes result from emission control actions in competition



MAP OF SOUTH COAST AIR BASIN

FIGURE 1

with the growth of source activities. Since different source categories are associated with different rates of growth and degrees of control, the roles of various source categories in the total emission burden have been changing. The purpose of documenting trends for individual counties is to illustrate the geographical variation of emission trends. Growth rates of population, energy use, and business activity vary substantially from county to county (population increased 3 percent in Los Angeles County but 46 percent in Orange County from 1965-1974), while the extent of emission source controls has been essentially the same for each county. Consequently, emission trends have differed considerably from county to county.

Trends in Basin-wide carbon monoxide, nitrogen oxide, and reactive hydrocarbon emissions will be characterized year by year for the decade 1965-1974. The geographical variation by county, however, will be illustrated by comparing the net percentage changes in emissions for each county over the entire decade.

Methodology

Before presenting the emission trend estimates, it is useful to indicate how these estimates were derived. Appendix A provides a detailed description of the assumptions and data sources used in the emission calculations. A very brief explanation of the methodology is presented below.

Exhaust emissions from motor vehicles were calculated according to procedures suggested by the Environmental Protection Agency (EPA) [2]. The emission factors and deterioration factors for 1966-1974 model year light-duty vehicles were based on a California Air Resources Board (ARB) analysis of test data [3, 4]. Exhaust emission factors for uncontrolled (pre-1966) light-duty vehicles represented an average of test data for Los Angeles [5]. Emission factors for gasoline and diesel powered heavy-duty vehicles were those published by EPA [2]. Speed correction factors and the vehicle age-mileage distribution were obtained from studies by EPA, ARB, and JPL* [2, 6, 7].

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*Caltech Jet Propulsion Laboratory

Data on the level and trends of vehicle miles traveled (VMT) by motor vehicles in the SCAB were based on the Los Angeles Regional Transportation Study (LARTS) for the years 1960, 1967, 1970 and 1974 [8, 9, 10]. The VMT levels and trends were allocated among the counties according to LARTS data for five counties [10], traffic count data for six counties, and county registration data. The distribution of VMT among light-duty, gasoline heavy-duty, and diesel vehicles was based on studies by the ARB and JPL [6, 7].

Evaporative hydrocarbon emission factors for light-duty vehicles represented recent data using the SHED* test [11, 12]. These data indicate that new car evaporative control devices are significantly less effective than anticipated.

Emission estimates for other transportation sources (aircraft, ships/railroads, and motorcycles/off-road vehicles) and stationary sources were based on a variety of reports. Most significant were a Los Angeles Air Pollution Control report [13], recent ARB inventory data, two reports by TRW Environmental Sciences [14, 15], and the stationary source NO_x inventories by KVB Engineering [16]. Trend information on source growth and control effectiveness was determined for individual source categories. The county-by-county distribution of emissions was also based on an analysis of individual source categories.

The task of documenting emission trends for the last decade (1965-1974) was quite an interesting undertaking, because it served as a check on the emission projections made by EQL and other organizations in 1971. Those emission projections used assumptions about future emission factors, growth rates, control effectiveness, control deterioration, and fuel usage patterns. Although these parameters are still not precisely known, much better data are available in retrospect. For instance, instead of assuming emission rates for automobiles, it is now possible to use actual test data on emission rates and deterioration rates for automobiles. As will be evident in the forthcoming discussion of results, the new information on emissions often disagrees with the assumptions made in 1971. The earlier projections generally tended to underestimate

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*Shield House for Evaporative Determination

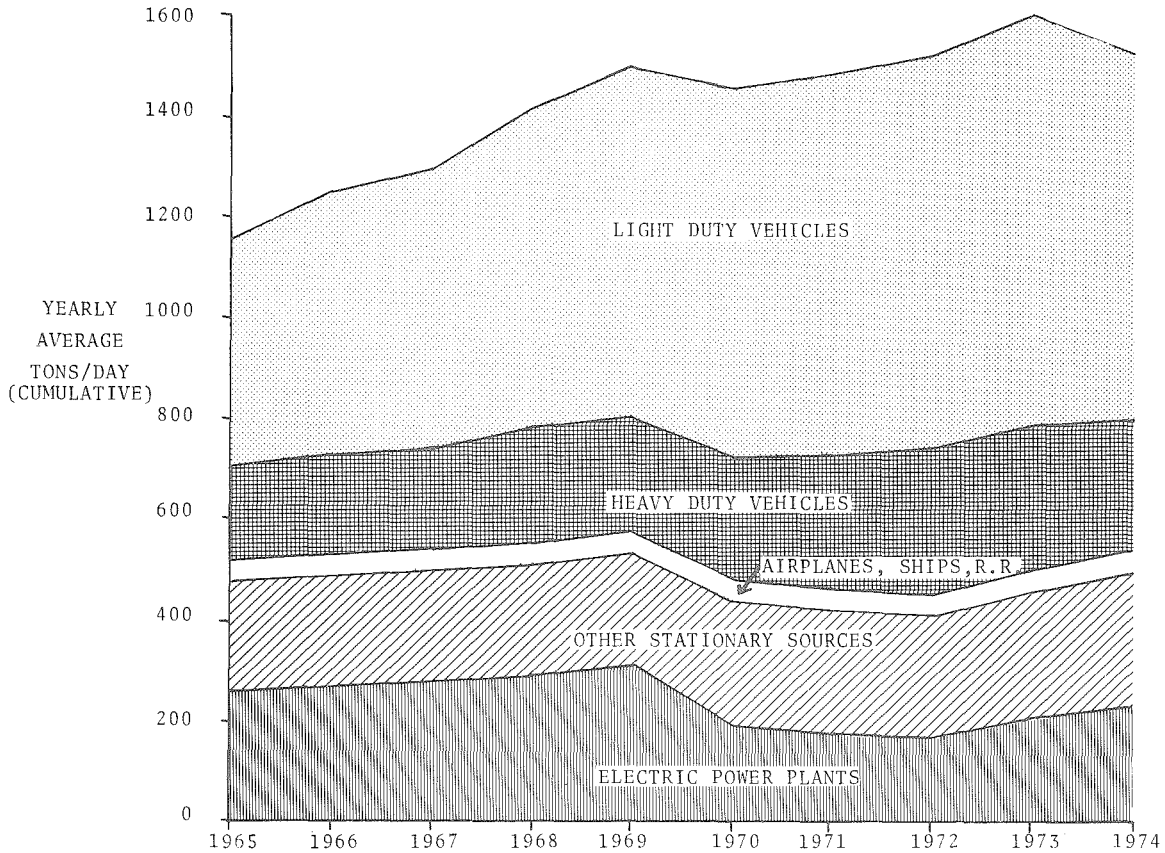
future emission levels, i.e., they were optimistic when compared to emissions trend estimates made in retrospect.

Trends in Total Emissions

It is useful to examine Basin-wide trends in total emissions in order to illustrate the changing roles of various source categories and to help explain trends in average, Basin-wide air quality. Figure 2 presents EQL's estimates of Basin-wide NO_x emission trends over the past decade. The Basin-wide total is represented by the top line, while the distances between the other lines illustrate the contributions of various source categories.

As shown in Figure 2, total NO_x emissions in the South Coast Air Basin increased by about 36 percent from 1965 to 1974. The major contributor to this increase was the rise in NO_x emissions from light-duty vehicles; total NO_x emissions from light-duty vehicles increased by 75 percent over the decade. This was partially due to a 41 percent increase in Basin-wide VMT and partially due to the large increase in NO_x emissions among 1966-1969 model year vehicles. The control techniques used to reduce hydrocarbons and carbon monoxide in 1966-1969 vehicles had the side effects of raising NO_x emissions. New car emission standards for NO_x took effect in 1971, but as yet these standards have not had a great impact on Basin-wide NO_x emissions.

Heavy-duty vehicles were also a growing source category for NO_x over the decade. Basin-wide emissions from heavy-duty vehicles increased by 40 percent, basically due to VMT growth. Although facing a high rate of demand growth, the electric power plants have contained and reduced their NO_x emissions effectively by use of natural gas and substitution of low-sulfur fuel for high-sulfur fuel in the sixties and by the Rule 68 retrofits and the industry's own extensive work which caused significant reductions after 1969. Nevertheless, the years 1972-1974 have already witnessed the growth of power plant NO_x emissions due to shortage of natural gas and increased use of fuel oil. Emissions from other stationary sources of NO_x essentially increased with energy use by those sources.



SOUTH COAST AIR BASIN NO_X EMISSION TRENDS (1965-1974)

FIGURE 2

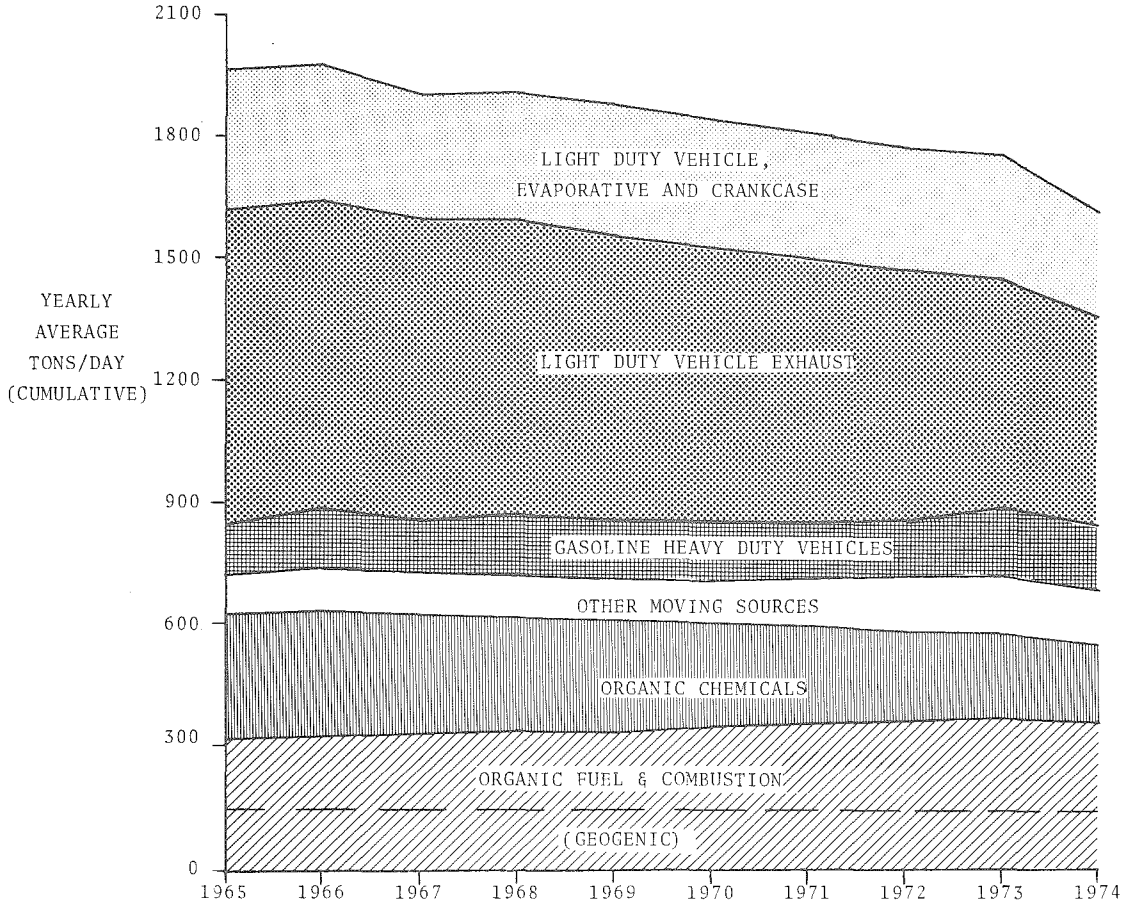
A slight downturn in total NO_x emissions occurred from 1973 to 1974. This downturn is partially due to emission controls on new light-duty vehicles, but mostly reflects the energy crisis and resulting decrease in traffic from 1973 to 1974. The downward trend in total NO_x emissions should continue at an even greater rate after 1975 because of the stringent new car NO_x emission standards which started in 1975.

The NO_x emission trends presented in Figure 2 are more pessimistic than the 1971 EQL projections which indicated that total emissions in 1974 would be nearly the same as in 1965. This discrepancy is partly due to the unforeseen switch from natural gas to fuel oil in power plants. It is also a result of using actual test data for emission factors and deterioration factors for automobiles. The recent test data imply smaller emission reductions than would be attained by assuming that all 1971-1974 model year vehicles met the standards and did not deteriorate.

Figure 3 summarizes Basin-wide trends in reactive hydrocarbon emissions from 1965 to 1974. The top line represents total RHC emissions, and the distances between the lines represent the contributions from various source categories. Here, the definition of reactive hydrocarbon emissions is based on a two-group reactivity scheme proposed by Dimitriades [17] of the Environmental Protection Agency and on reactivity factors calculated in a recent TRW report [14].

The net change in Basin-wide reactive hydrocarbon emissions over the decade was a decrease of 18 percent. Most of this reduction was due to controls on light-duty vehicles. Light-duty vehicle crankcase emissions were reduced in the early and middle 1960's. Slight reductions in evaporative emissions were obtained in the 1970's from the new car evaporative controls. Exhaust emission standards for new automobiles resulted in RHC emissions for the average vehicle over the decade was a 52 percent decrease. In the presence of a 41 percent increase in VMT, the net reduction in total RHC emissions from light-duty vehicles was only 32 percent.

Gasoline-powered, heavy-duty vehicles experienced a 23 percent reduction of per-mile RHC emissions over nine years, most of the reduction



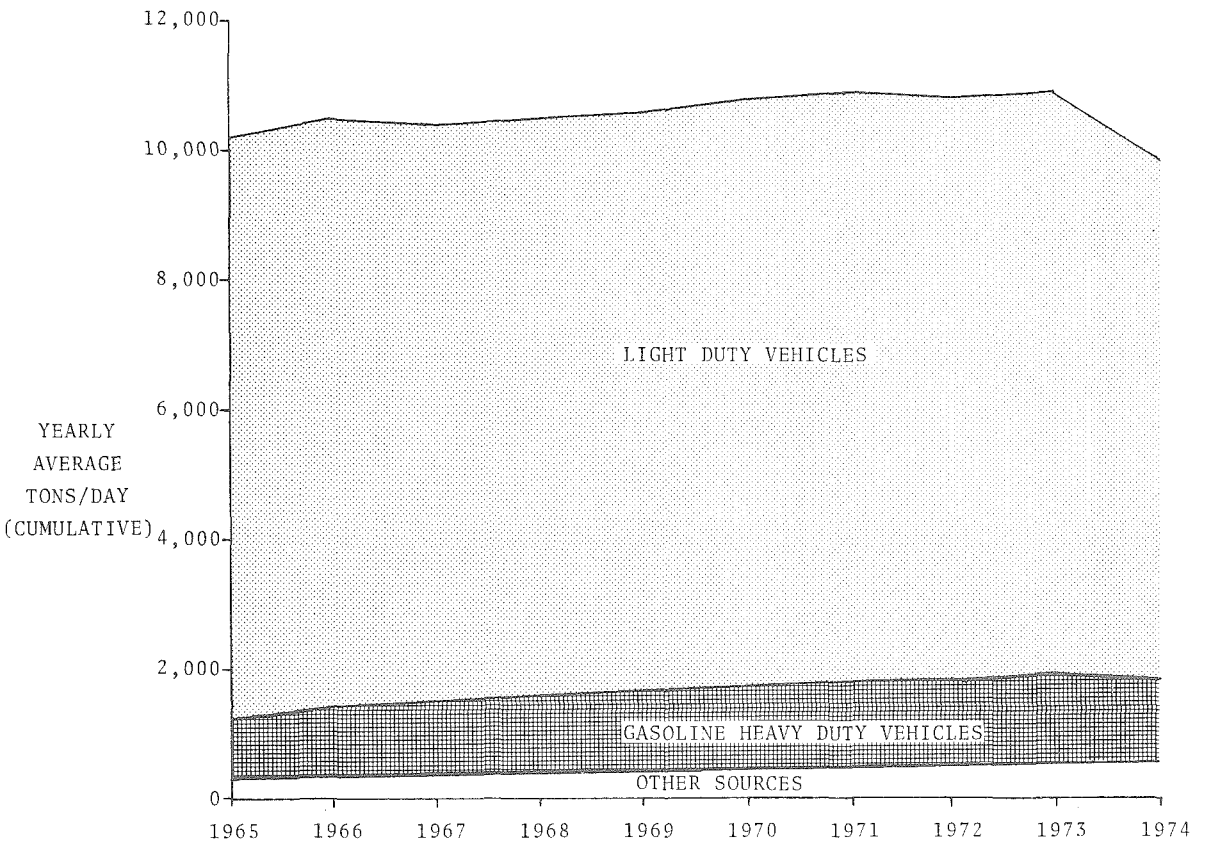
SOUTH COAST AIR BASIN REACTIVE HYDROCARBON (RHC) EMISSION TRENDS

FIGURE 3

coming from crankcase emission control. With the 41 percent growth in VMT, the net change was a 7 percent increase over the period from heavy-duty vehicles. Emissions from other mobile sources have increased by 56 percent. The organic chemicals category, the largest contributor of RHC in the stationary source category, has been reduced by approximately 33 percent from 1966 to 1974 due to APCD Rule 66 in the late 1960's and to substitution of water-based coatings for organic solvent coatings in the early 1970's. Emissions from gasoline marketing, which is a major source of organic fuel emissions, have increased by 26 percent, although filling of underground gasoline station tanks has been partially controlled by local APCD rules. An important part of the organic fuels and combustion category is the "geogenic source" that was recently pointed out by Mayrsohn and Crabtree [18]. It is assumed that this source remained constant over the ten year period.

The trends in RHC emissions presented in Figure 3 are pessimistic when compared to 1971 EQL projections which predicted substantial reductions (about 40 to 50 percent) in Basin-wide RHC emissions over the decade. There are three reasons why EQL's latest estimates indicate lesser reductions. First, the new reactivity factors used in EQL's present analysis assign greater weight to stationary source categories which have not undergone substantial decreases. Relative to prior reactivity schemes, the new reactivity scheme de-emphasizes the significant decreases in light-duty vehicle emissions. Second, test data now indicate that the evaporative controls for new vehicles work much less efficiently than was assumed in 1971. Finally, the test data on emission and deterioration factors for vehicle exhaust imply significantly smaller reductions than would be the case if all new vehicles attained the standards and did not deteriorate.

Figure 4 presents trends in Basin-wide CO emissions from 1965 to 1974. As seen in Figure 4, EQL's estimates indicate that total CO emissions have remained nearly constant over the decade; the net reduction from 1965 to 1974 was only 4 percent. Much of the net change occurred



SOUTH COAST AIR BASIN CO EMISSION TRENDS (1965-1974)

FIGURE 4

in 1974, when there was a significant dip in driving per vehicle as a result of the gasoline shortage.

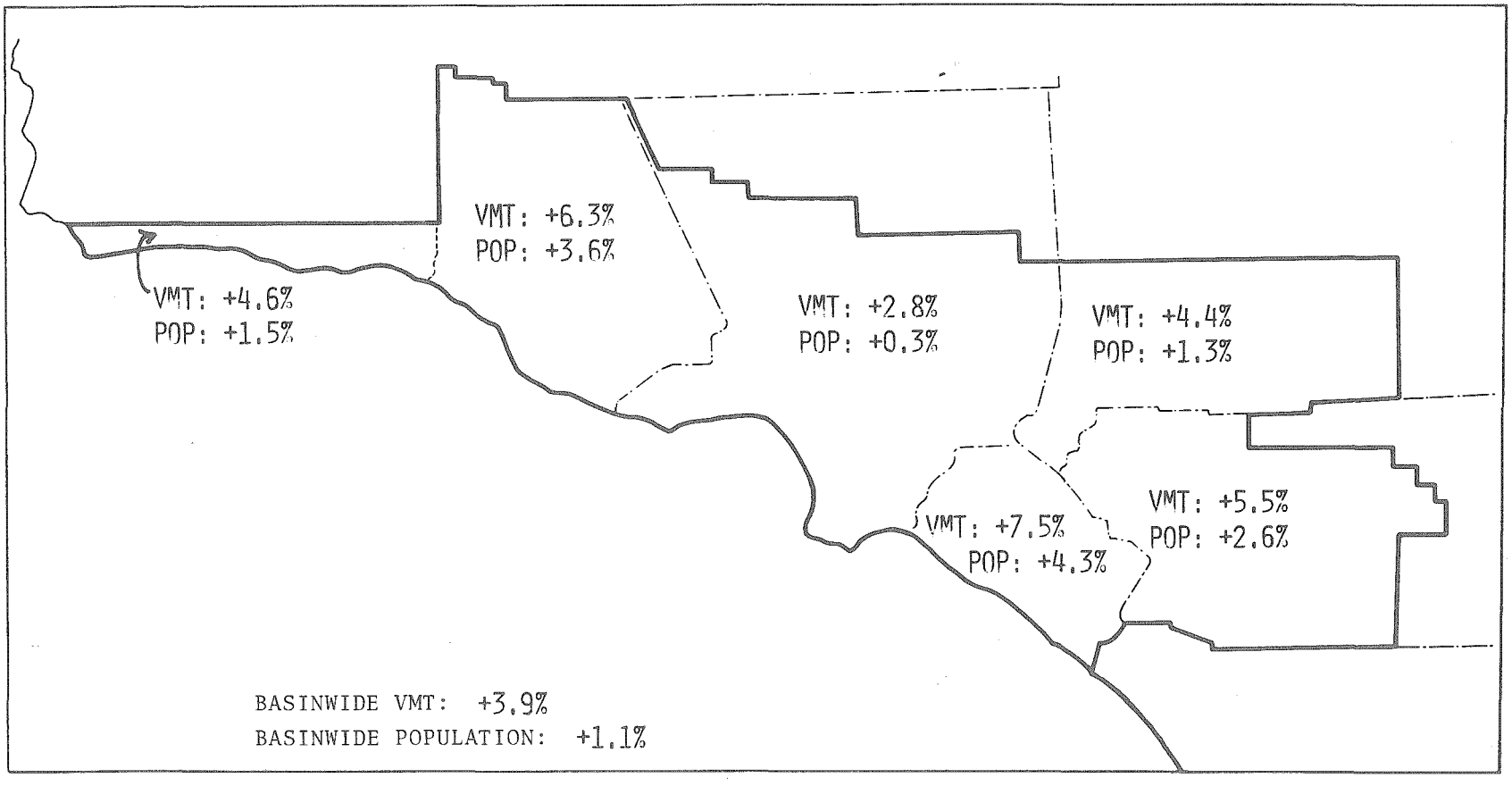
Figure 4 illustrates that light-duty vehicles contribute more than 80 percent of the CO emissions in the Basin. During the decade, CO emissions from the average light-duty vehicle on the road were reduced 37 percent by the California new car control program. However, since there was a 41 percent increase in light-duty VMT, the net reduction of CO emissions from light-duty vehicles was only 11 percent during the period. A 33 percent increase in CO emissions from heavy-duty vehicles occurred during the decade, reflecting a mere 6 percent reduction in average vehicle emissions in the face of a 41 percent growth in VMT. The increase in heavy-duty vehicle emissions cancelled most of the modest reductions that were achieved in light-duty vehicle emissions.

As with other pollutants, EQL's 1971 projections for carbon monoxide emissions appear overly optimistic when compared to emission trend estimates made in retrospect. The basic reason for the disagreement is that recent test data indicate lesser degrees of control for light-duty vehicles than would have been the case if the automotive standards had been met throughout the lifetimes of the vehicles.

Geographical Distribution of Emission Trends

The spatial distribution of emissions, as well as the total amount of emissions, is important to ambient air quality. Accordingly, trends in the spatial distribution of emissions should be considered in analyzing air quality trends. This section illustrates the large scale trends in the spatial distribution of emissions within the Basin by documenting emission trends on a county-by-county basis. This information should be useful in explaining the spatial pattern of air quality trends in the following section.

There is reason to expect that the spatial distribution of emission trends has been very nonuniform in the South Coast Air Basin. Although similar emission control policies apply to each county, growth rates vary considerably from county to county. Figure 5 illustrates the spatial



AVERAGE YEARLY VMT AND POPULATION GROWTH RATES, 1965-1974

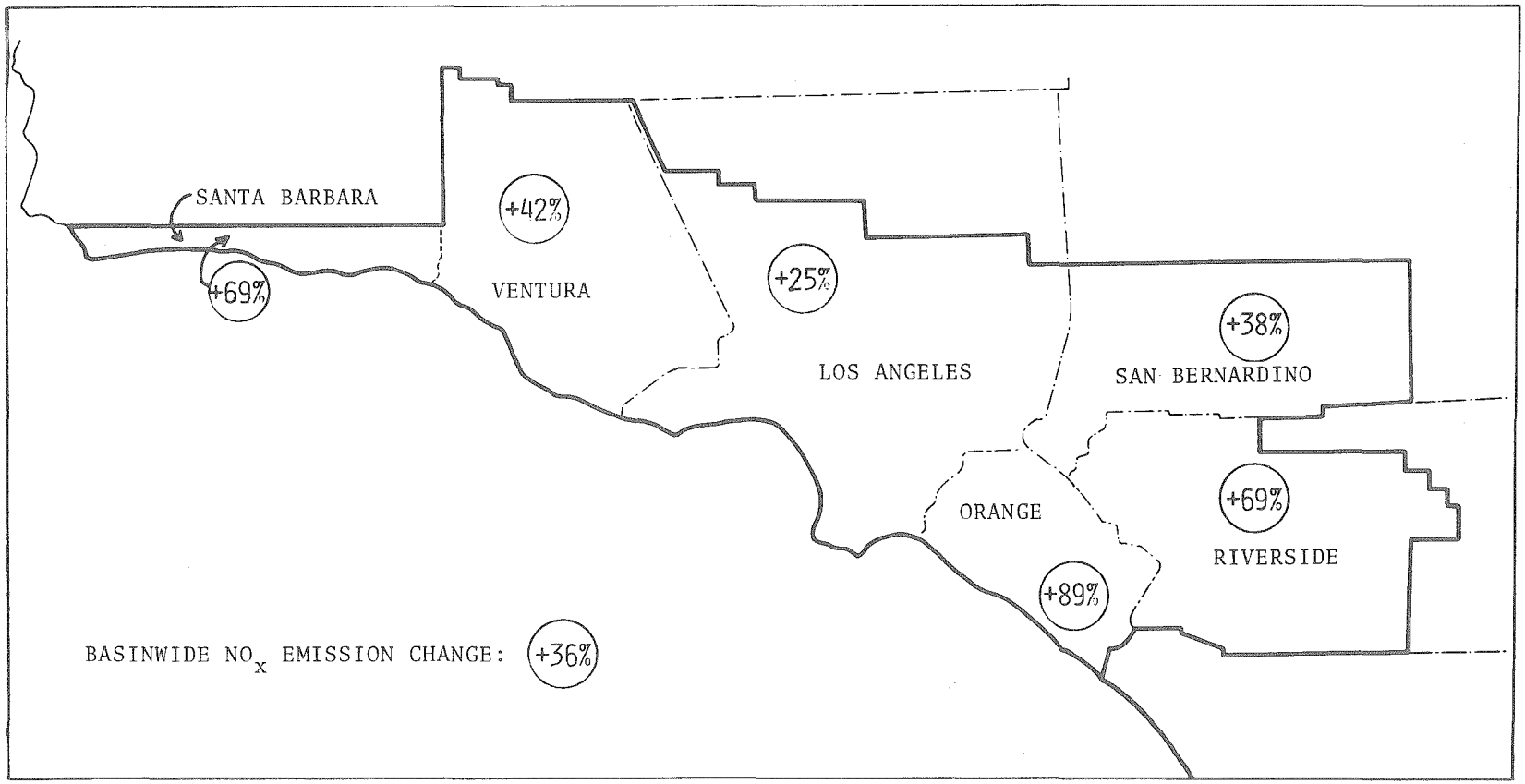
FIGURE 5

pattern of VMT and population growth from 1965 to 1974. Growth rates for each individual county are presented within the boundaries of those counties, while Basin-wide figures are given in the lower left-hand corner of the figure.

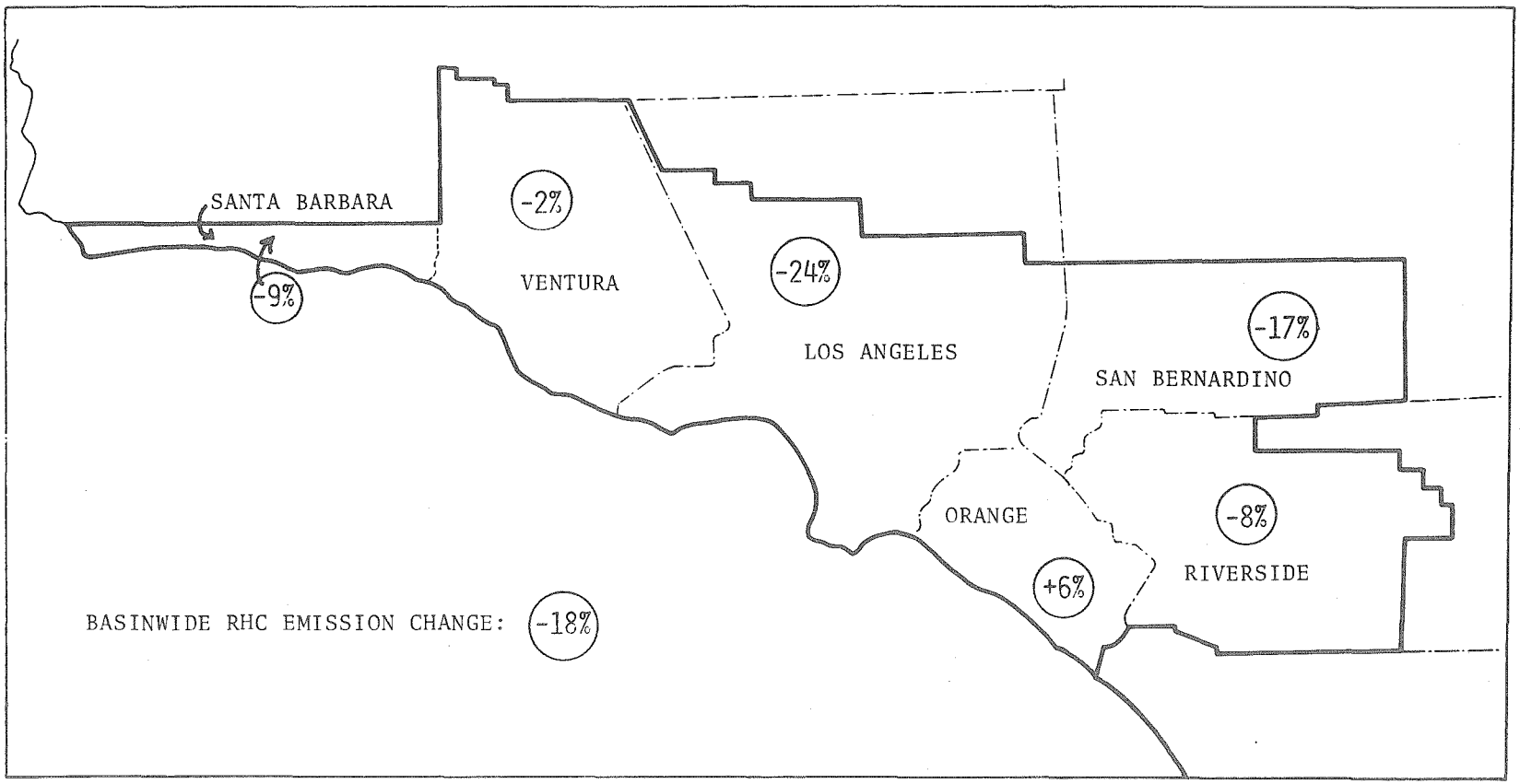
As indicated in Figure 5, the average VMT and population growth rates for the Basin are 3.9 percent per year and 1.1 percent per year, respectively. Los Angeles County has been growing at a rate considerably slower than the other five counties within the Basin. The fastest growing county, Orange County, has a VMT growth rate (7.5 percent per year) triple that of Los Angeles County (2.8 percent per year) and a population growth rate (4.3 percent per year) more than ten times that of Los Angeles County (0.3 percent per year). These differential growth rates, compounded year by year over the decade, led to a spreading out of emissions away from Los Angeles County to the outlying counties. Los Angeles County accounted for about 75 percent of Basin-wide emissions of CO, NO_x, and RHC in 1965, but only for about 65 percent in 1974.

Figure 6 illustrates the spatial distribution of NO_x emission changes over the decade. The net percentage change in NO_x emissions over the decade is presented for each of the six counties and for the entire Basin. Each county experienced an increase in NO_x emissions over the decade, with the Basin-wide total increasing by 36 percent. Following the spatial trends in population and VMT growth, Los Angeles County NO_x emissions grew by the smallest amount, 25 percent. NO_x emissions in Orange County rose drastically, an estimated 89 percent increase over the decade.

Figure 7 presents the county-by-county distribution of RHC emission changes. Over the decade, Basin-wide RHC emissions decreased by 18 percent. Following the order of population and VMT growth rates, Los Angeles County showed the largest decrease, 24 percent, while the outlying counties experienced lesser decreases. In fact, Orange County evidently underwent an actual increase in RHC emissions of 6 percent over the decade.



TRENDS IN NO_x EMISSIONS, 1965-1974
FIGURE 6



TRENDS IN RHC EMISSIONS, 1965-1974
FIGURE 7

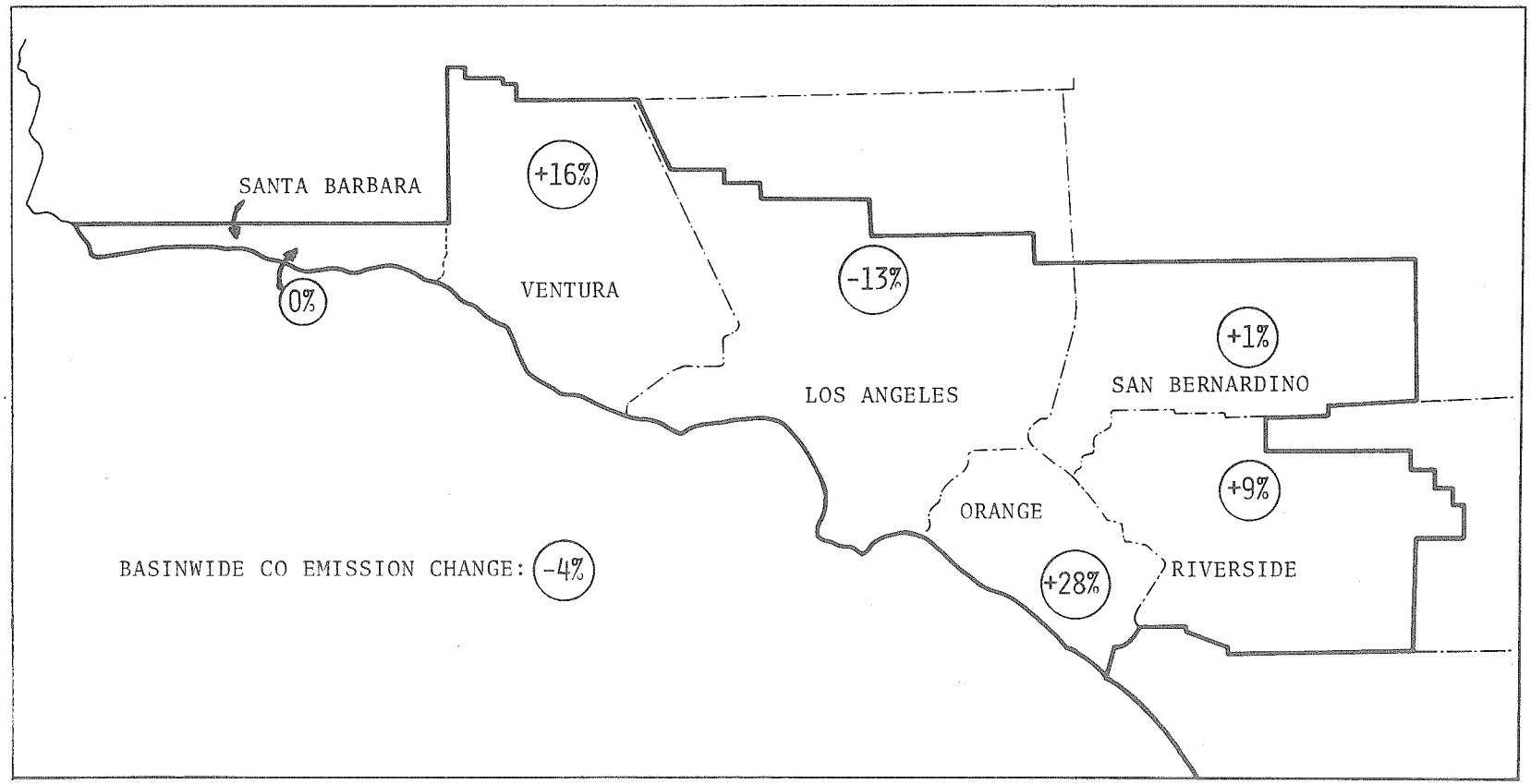
Figure 8 illustrates the county-by-county distribution of carbon monoxide emission changes over the nine year period. As noted before, the Basin-wide total of CO emissions decreased by about 4 percent over the nine years. Due to differences in VMT growth, CO emission changes among the counties range from a 13 percent decrease in Los Angeles to a 28 percent increase in Orange County. All counties except Los Angeles experienced increases, but the Basin total still decreased because Los Angeles accounts for about two-thirds of CO emissions in the Basin.

III Recent Air Quality Trends

Having documented emission trends in the South Coast Air Basin over the past decade, the next logical step is to compare the emission trends to air quality trends. This juxtaposition should serve as a partial check on both the emission and air quality data bases. The comparison should also provide some insight as to the adequacy of simple proportional (rollback) models for relating emissions and air quality. This section presents data on air quality trends and analyzes these data in terms of the changes in total emissions and the spatial distribution of emissions.

Methodology

The data base for determining air quality trends in the South Coast Air Basin consisted of computer tapes of hourly average pollutant measurements obtained from the California Air Resources Board. These tapes contained data from all stations in the South Coast Air Basin which reported to the Air Resources Board during the years 1963 to 1974. A search was conducted among personnel of the ARB and the County APCD to determine whether monitoring changes occurred which could affect air quality trends. It was determined that the locations of monitors in a few cities had been altered during the period of interest. Data from these locations were eliminated from the study. All stations in the Los Angeles County experienced a monitoring change for carbon monoxide in April 1968. CO data from Los Angeles County prior to April 1968 were



TRENDS IN CARBON MONOXIDE EMISSIONS, 1965-1974

FIGURE 8

adjusted according to correction factors determined statistically by Tiao, et al. [19]. Oxidant data were adjusted for differences between the Los Angeles County calibration method and the methods used by other agencies* [20]. The oxidant adjustment affected absolute levels, not trends.

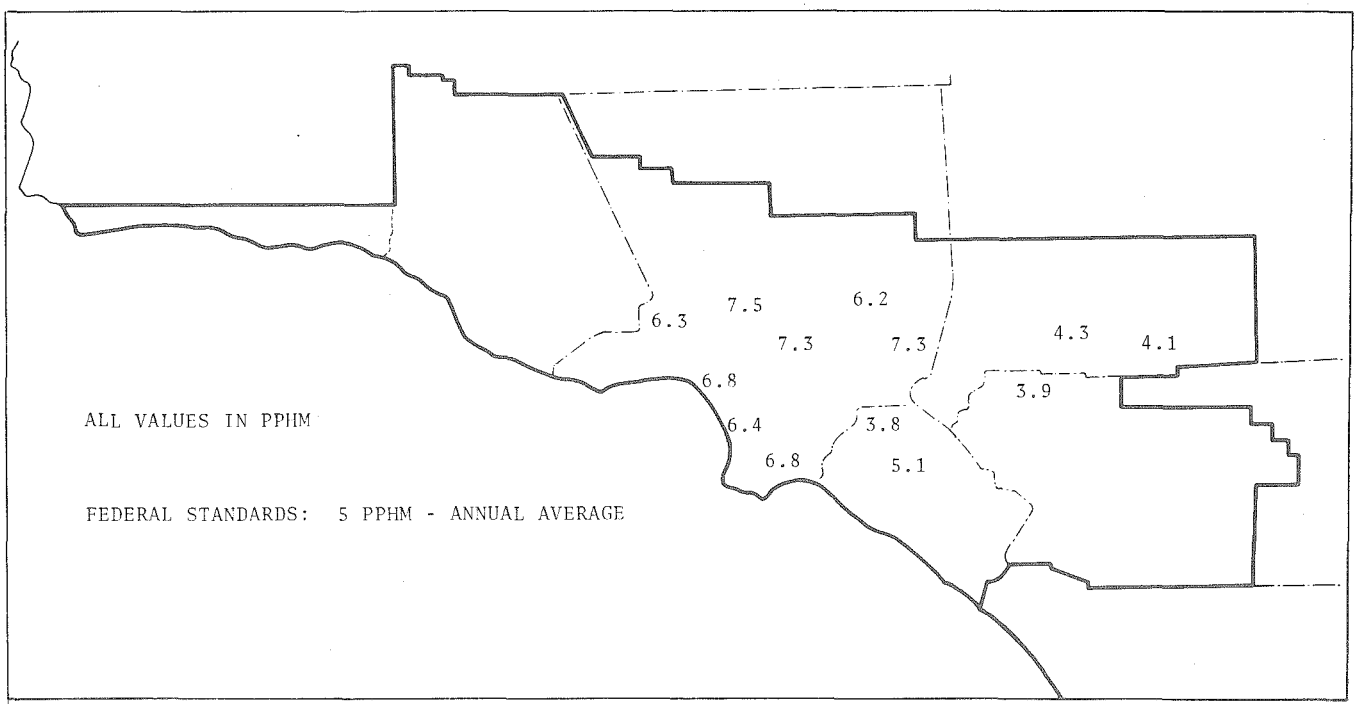
Two types of trend analyses were performed with the aerometric data. The purpose of the first was to examine overall air quality changes from the mid-1960's to 1974 at each air monitoring site. For each pollutant (NO_x, NO_2, oxidant, or CO), a least-squares trend line was fitted to the yearly averages of daily maximum one hour concentrations. The percentage change in this trend line from 1965 to 1974 was used as the measure of overall air quality changes for each site. Yearly averages of daily maxima were eliminated from the analysis if the averages were based on a very limited number of sampling days. The analysis was performed only for stations with at least eight years of adequate data. For each pollutant, this elimination process typically left around twelve stations for the determination of air quality trends.

The purpose of the second type of analysis was to examine detailed, year-to-year trends. For each pollutant, yearly values of various air pollution indices were plotted against time. The air pollution indices included the average of the max one hour concentrations on the worst five days each year, the average of daily max one hour concentrations for the entire year, and the yearly average of all hours. For oxidant, the hours per year exceeding various levels (8 pphm, 20 pphm, and 30 pphm) were also examined. The detailed analysis of trends in air pollution indices was carried out only for six stations (west Los Angeles, downtown Los Angeles, Azusa, Anaheim, San Bernardino, and Riverside.

Trends in NO_x and NO_2 Air Quality

Before studying changes in air quality levels for nitrogen oxides, it is worthwhile to examine overall levels and to compare these levels to the National Ambient Air Quality Standards (NAAQS). Figure 9 illustrates

*The adjustment was to multiply Los Angeles County data by 1.06 and non-Los Angeles County data by 0.8.



TYPICAL ANNUAL AVERAGE NO_2 CONCENTRATIONS
IN THE EARLY 1970'S
FIGURE 9

typical* annual average nitrogen dioxide levels in the early 1970's for 13 stations. The value for each monitoring site is plotted at the location of that site. As seen in Figure 9, the central portions of Los Angeles County exhibit the highest levels of annual average NO_2, about one and one half times the federal standard of 5 pphm. The western coastal areas of Los Angeles County also tend to exceed the federal standard. Stations outside of Los Angeles County experience NO_2 air quality about equal to or better than the federal standard.

In studying air quality changes for nitrogen oxides, trends will be examined for both total nitrogen oxides (NO_x) and nitrogen dioxide (NO_2). Figure 10 compares changes in total NO_x air quality to changes in NO_x emissions. The circled numbers in Figure 10 represent the net percentage emission changes for each county over the decade (also given in Figure 6). For instance, Los Angeles County experienced a 25 percent increase in NO_x emissions over the decade, Orange County experienced an 89 percent increase, Riverside underwent a 69 percent increase, etc. The net percentage changes in ambient NO_x concentrations over the decade are also plotted in Figure 10 for eleven monitoring sites. For instance, ambient NO_x levels increased by 8 percent at downtown Los Angeles, 76 percent at Anaheim, 47 percent at San Bernardino, etc. Basin-wide averages in emission trends and ambient concentration trends are presented in the lower left-hand corner of Figure 10.

The agreement between calculated NO_x emissions changes and measured NO_x air quality changes is strikingly good. Total Basin-wide NO_x emissions increased by 36 percent over the decade, while average NO_x concentrations at the eleven monitoring sites increased by 35 percent.** Even the spatial distribution of emissions and air quality trends agree on a

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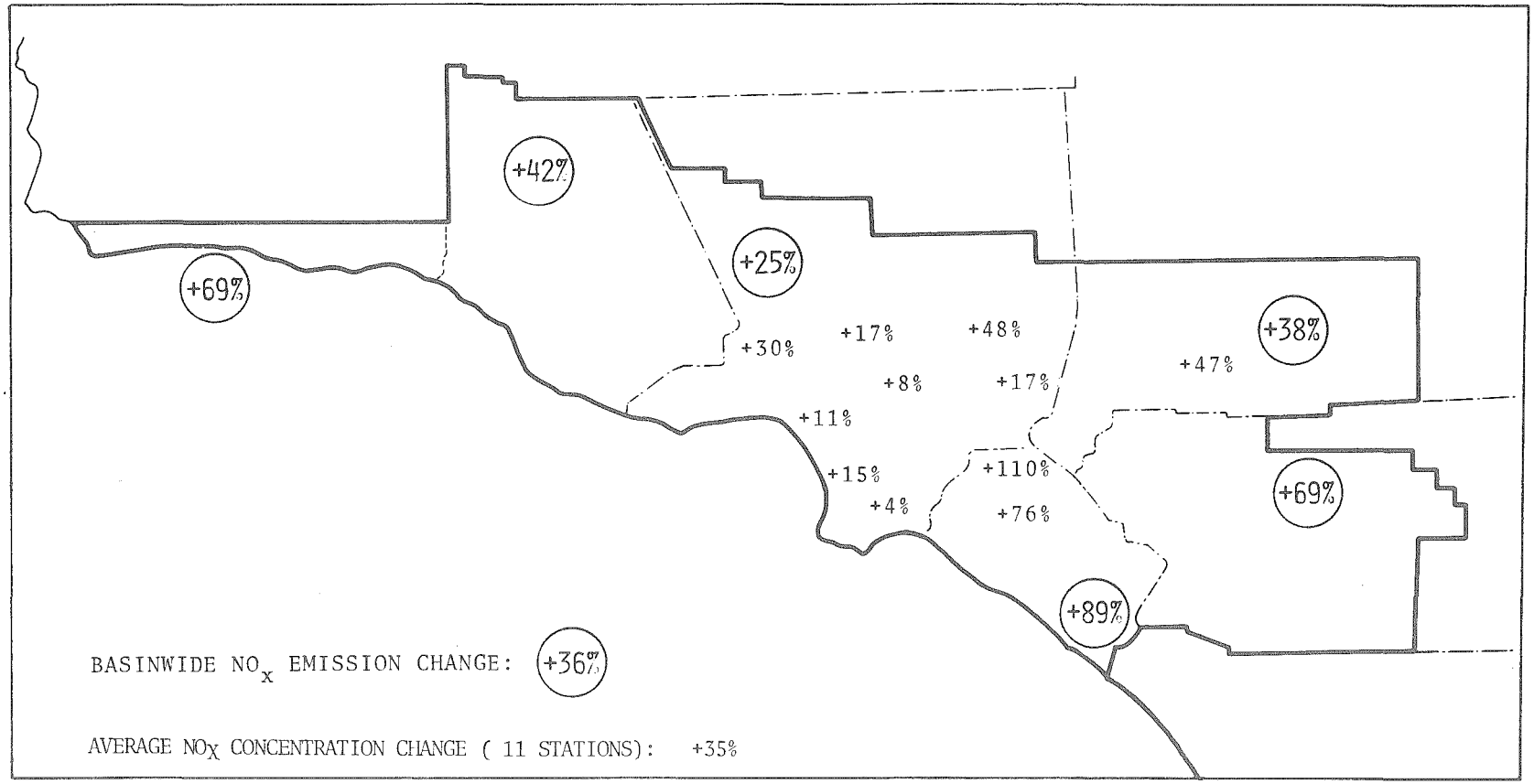
*The average from 1971 to 1974.

**This is measured by the average of the percent changes among the stations. An alternative measure, the change in the average of the eleven stations, was a +30 percent. It is our opinion that the latter measure gives too much weight to stations in Los Angeles County. Eight of the stations are in Los Angeles County, and those stations have higher average concentrations. Neither measure precisely represents Basin-wide concentration changes.



TRENDS IN NO_X EMISSIONS AND AIR QUALITY, 1965-1974

FIGURE 10

county-by-county basis. NO_x emissions grew by 89 percent in Orange County, while the two Orange County stations showed an ambient NO_x increase of 93 percent. NO_x emissions increased by 25 percent in Los Angeles County, while the eight Los Angeles County stations experienced a 19 percent increase in measured NO_x concentrations.

Of greater interest with respect to the NAAQS are ambient trends for NO_2. Figure 11 compares NO_x emission trends to ambient NO_2 trends. Again, the circled numbers represent net percentage emission changes over the decade, Basin-wide and county by county. The other numbers represent NO_2 air quality changes from 1965 to 1974 at eleven monitoring sites. The agreement between NO_x emission changes and NO_2 air quality changes is not nearly as good as was the case for NO_x air quality changes. Basin-wide NO_x emissions increased by 36 percent, while NO_2 concentrations increased by only 20 percent* when averaged among the eleven monitoring sites. The spatial pattern of NO_2 changes is, however, in agreement with the relative NO_x emission changes in the various counties; i.e., Orange and San Bernardino Counties experienced much greater ambient NO_2 increases than Los Angeles County.

We are not sure why NO_2 concentrations increased less over the decade than did NO_x emissions and NO_x concentrations. The most plausible explanation involves NO_2's role as a product of NO_x emissions and the photochemical smog reactions. Reductions in hydrocarbon emissions and oxidant concentrations over the decade may have decreased the amount of NO_x that is converted to NO_2.

The NO_2 air quality changes presented in Figure 11 are based on trends in yearly averages of daily max one hour concentrations. It is important to determine if other air pollution indices for NO_2 show similar trends. An examination of the detailed year-to-year changes in NO_2 for several stations revealed that the trends in extreme levels and in the annual mean <u>did</u> follow the trend in yearly average of daily max one hour

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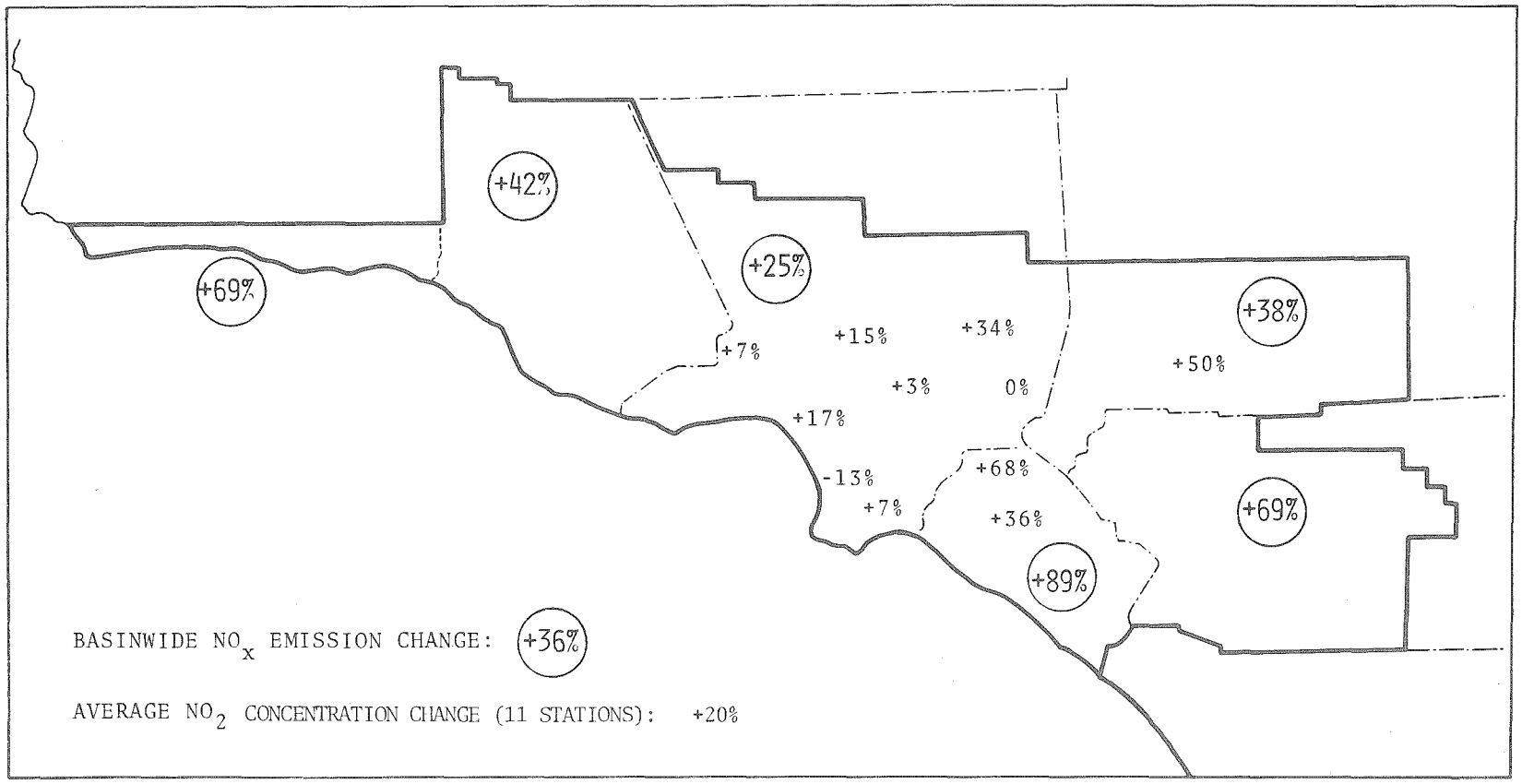
*Again, this is the average of the percent changes. The change in the average was +16 percent.



TRENDS IN NO_x EMISSIONS AND NO_2 AIR QUALITY, 1965-1974
FIGURE 11

concentrations. The similarity in the trends for these various air quality indices is illustrated in Figure 12 for Anaheim, downtown Los Angeles, and San Bernardino. For instance, all three air pollution indices for NO_2 nearly doubled in Anaheim from 1963 to 1974.

Trends in Oxidant Air Quality

Perhaps the most significant air pollution problem in the South Coast Air Basin, at least in comparison to the federal air quality standards, is the photochemical oxidant problem. Again, before studying trends in air quality, it is worthwhile to examine present levels and to compare these to the NAAQS. Figure 13 illustrates typical yearly max one hour concentrations of oxidant during the early 1970's at seventeen monitoring sites in the South Coast Air Basin. Each of the monitoring sites exceeds the federal air quality standard (8 pphm for one hour) by at least a factor of two. The areas in the central and eastern portions of the Basin experienced the highest oxidant levels and typically exceeded the federal standard by a factor of four to six each year. It is expected that the eastern-central portions of the Basin would exhibit the worst oxidant air quality, since these areas are generally downwind of the source-intensive, western-central portions of the Basin and since oxidant, a secondary contaminant, forms from precursor emissions as those emissions are transported across the Basin.

Figure 14 illustrates percentage changes in oxidant concentrations over the past decade and compares these to changes in RHC emissions. The circled numbers represent RHC emission trends (county by county and Basin-wide), while the other numbers represent trends in ambient oxidant levels. Basin-wide, the agreement between emission and air quality trends is quite good; total RHC emissions decreased by 18 percent over the decade, while the average improvement in oxidant levels at thirteen stations was 19 percent.* Also, the spatial distribution of air quality changes agrees qualitatively with the spatial distribution of emission changes, at least in the sense that Los Angeles County experienced the greatest improvement in both emissions and air quality.

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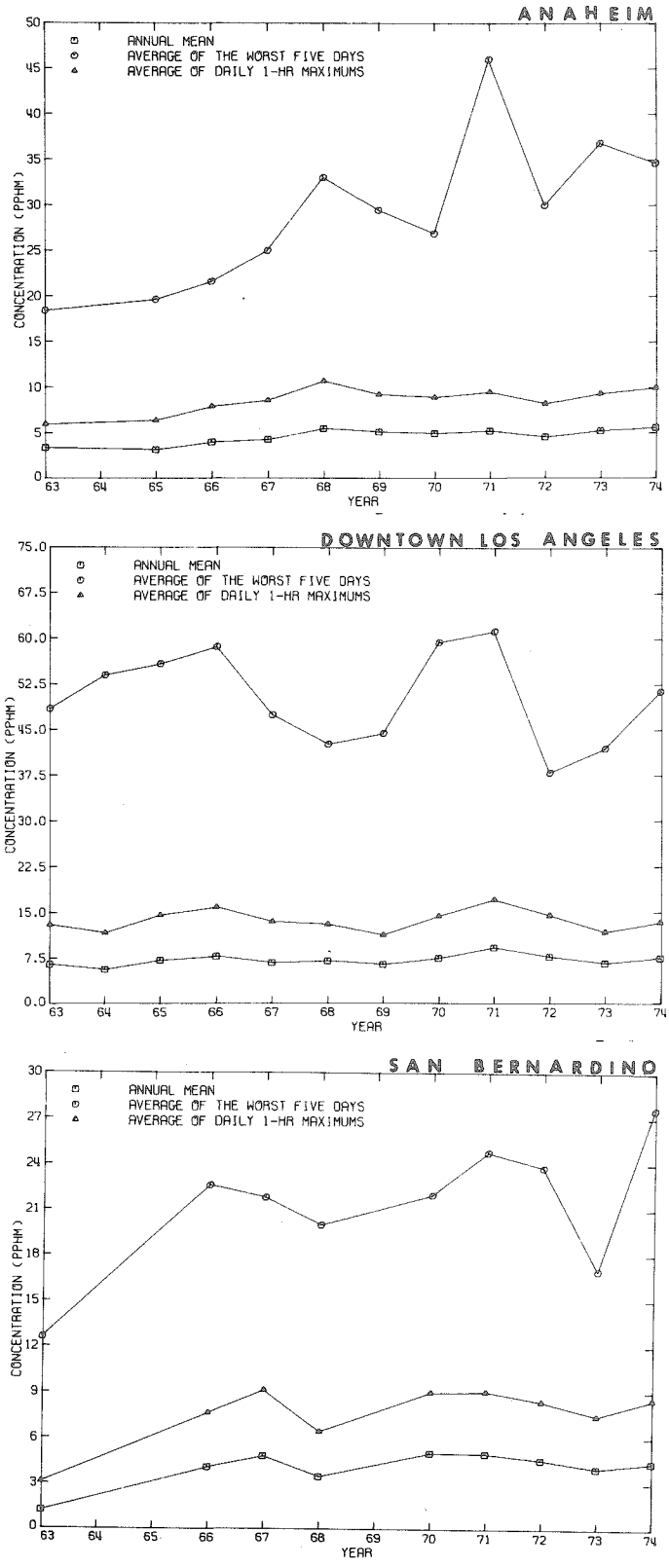
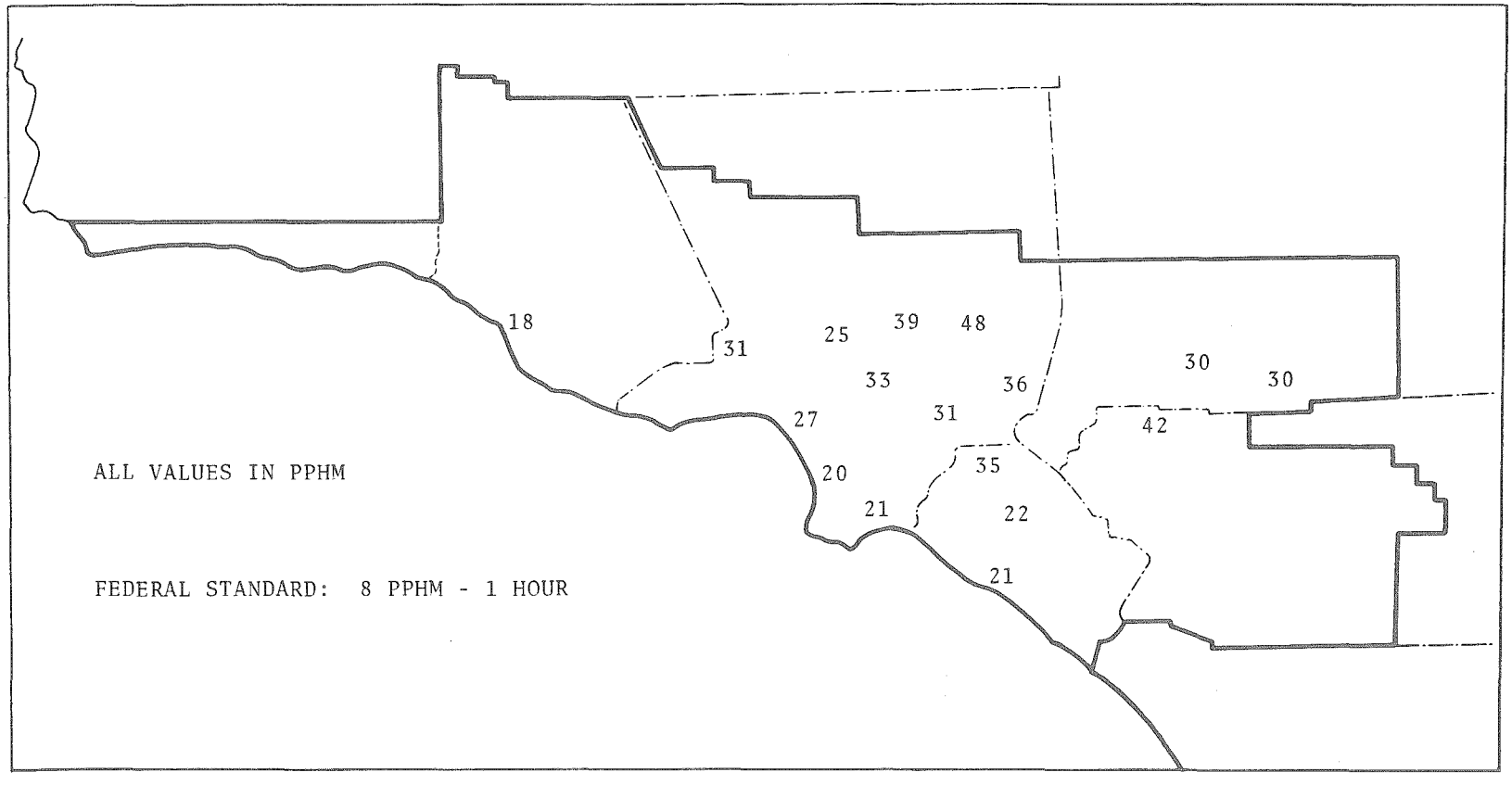
*This is the average of the percent changes. The change in the average among the stations was a 20 percent improvement.



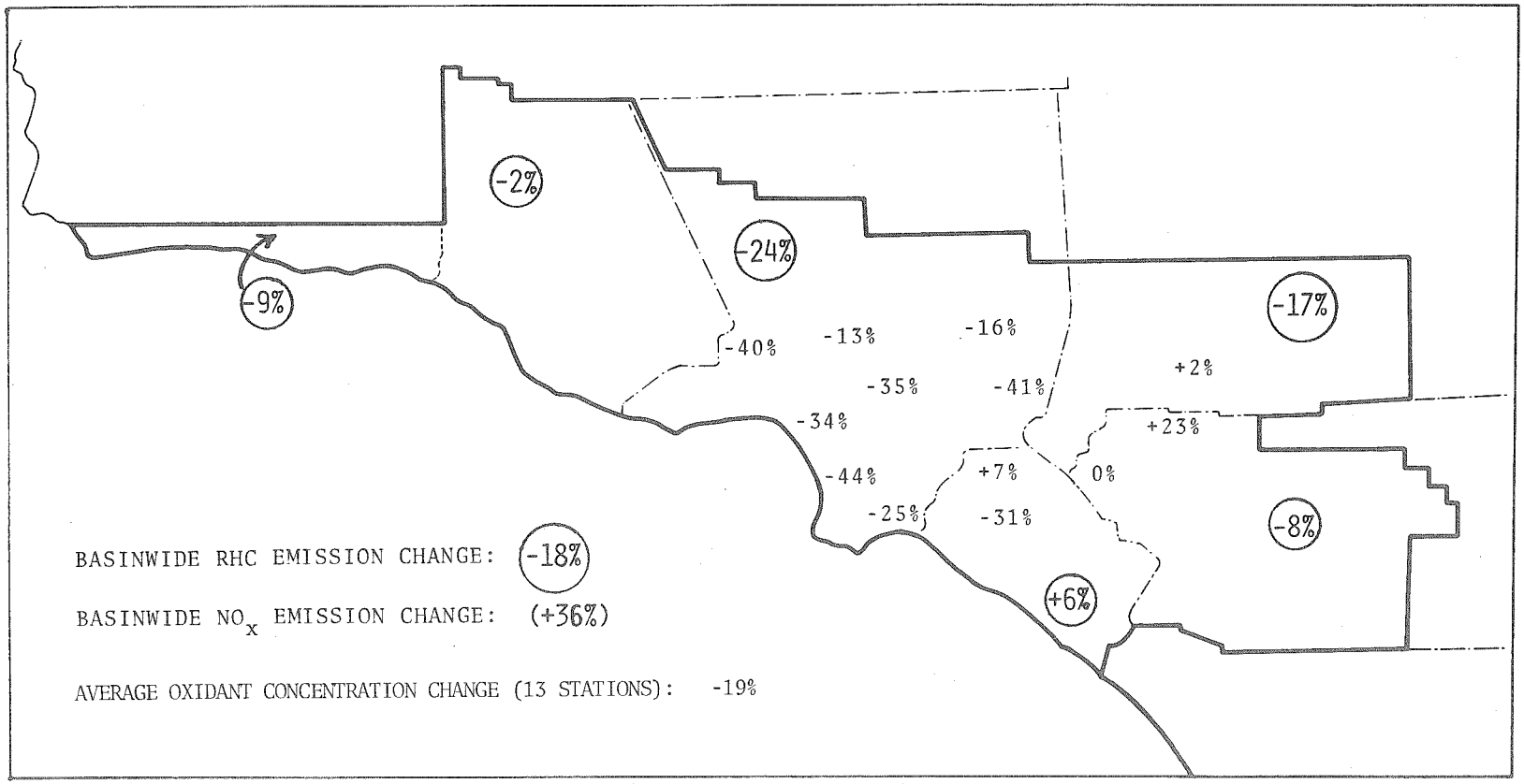
DETAILS OF NITROGEN DIOXIDE AIR QUALITY TRENDS, 1963-1974

FIGURE 12



TYPICAL YEARLY MAXIMUM ONE HOUR OXIDANT CONCENTRATIONS IN THE EARLY 1970'S

FIGURE 13

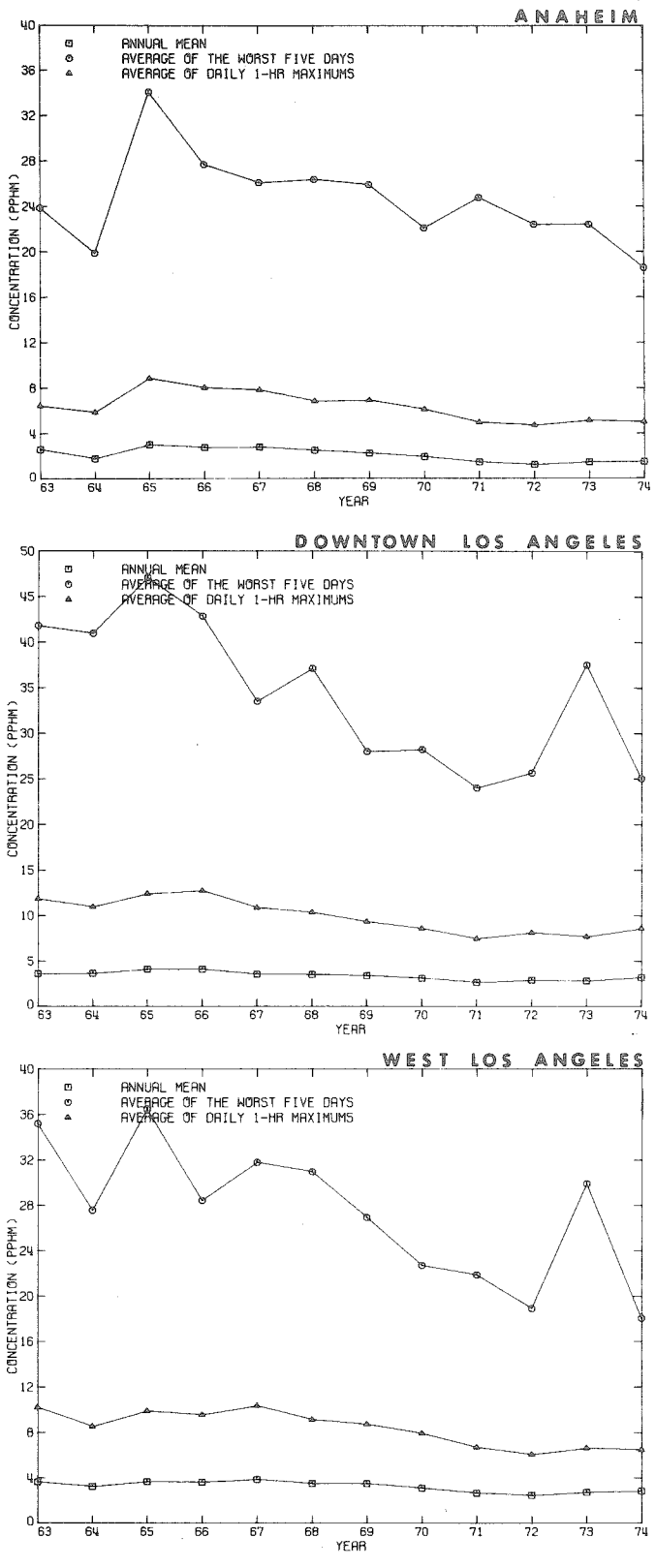


TRENDS IN RHC EMISSIONS AND OXIDANT AIR QUALITY, 1965-1974

FIGURE 14

The spatial pattern of oxidant air quality trends can be even better explained by considering what has been termed the "dual role" of NO_x emissions in oxidant formation. From the present understanding of photochemistry, it can be argued that, at the existing ratio of RHC to NO_x, increases in NO_x emissions would tend to decrease oxidant concentrations in the source-intensive areas of the Basin (the central and western-coastal areas). However, increases in NO_x emissions will not improve oxidant air quality, and may actually deteriorate oxidant air quality, in the downwind (eastern-inland) portions of the Basin. This helps to explain why the coastal areas of Los Angeles County show the greatest improvement in oxidant concentrations (a 30 to 40 percent decrease from 1965 to 1974). These source-intensive areas have experienced a 24 percent decrease in RHC emissions, and they have been aided by the NO_x emission increase. The dual role of NO_x also helps to explain the lesser rates of improvement in the eastern-inland portions of the Basin. In particular, Riverside may have experienced a 23 percent increase in oxidant concentrations because it is downwind of Orange County, which had a 6 percent increase in RHC emissions and a large increase (89 percent) in NO_x emissions. Although some anomalies remain in oxidant air quality trends at the various stations, the apparent contradiction at Anaheim (a 31 percent decrease in oxidant within a county with a 6 percent increase in RHC emissions) might be partially explained by the large NO_x emission increases at that source-intensive location.

The air quality trends for oxidant can be studied in more detail by examining year-to-year changes in various air quality indices. Figure 15 illustrates year-to-year trends in oxidant at Anaheim, west Los Angeles, and downtown Los Angeles for three air quality indices: average max one hour on the five days of greatest oxidant, yearly average of daily max one hour, and yearly average of all hours. This figure demonstrates that the locations in the western-central portions of the Basin which showed considerable improvement in oxidant air quality tended to experience that improvement rather continuously from 1965 to 1974. Also, the improvement occurred in all three air quality indices.



DETAILS OF OXIDANT AIR QUALITY TRENDS, 1963-1974

FIGURE 15

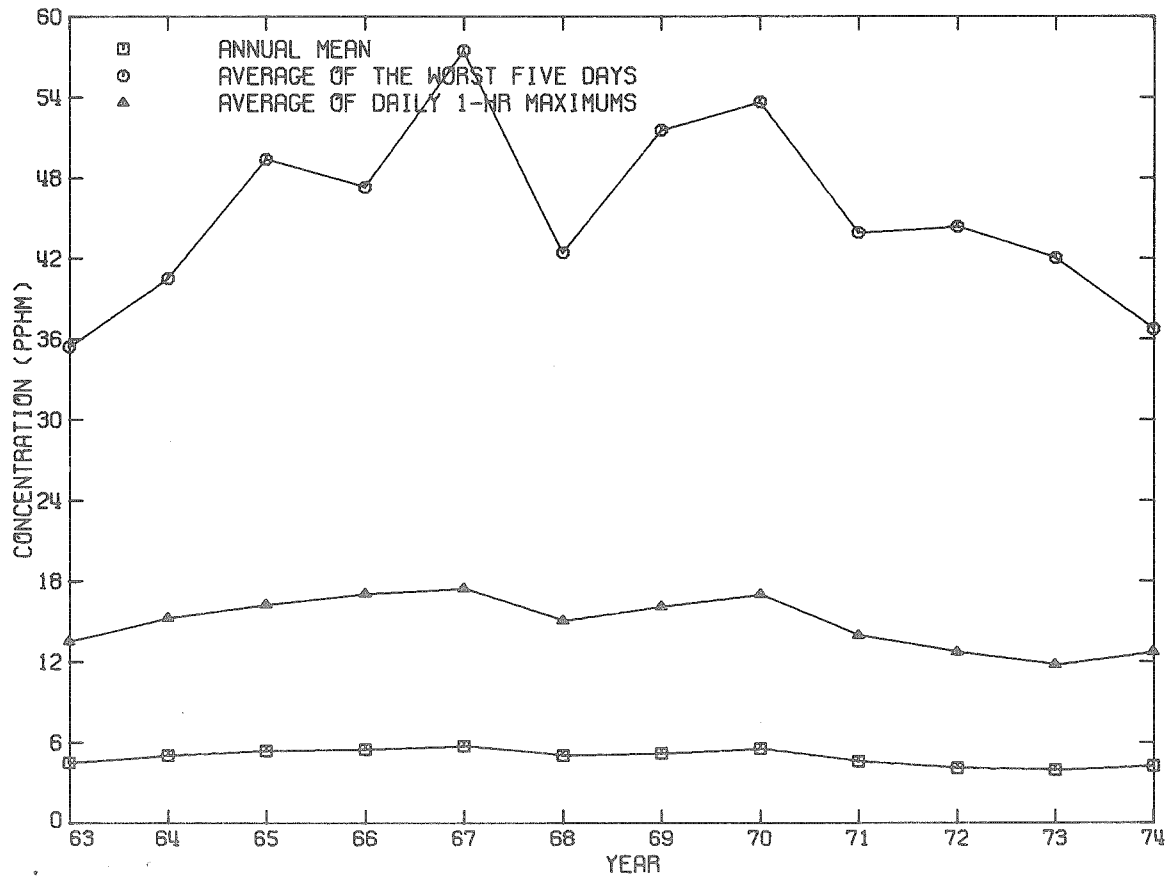
Some stations in the eastern part of the Basin which showed deterioration or little improvement in oxidant concentrations over the decade have shown signs of better air quality recently. For instance, Azusa experienced only a 16 percent improvement over the decade, but has undergone more rapid reductions in oxidant concentrations since 1970 (Figure 16). The very recent improvement in the eastern portions of the Basin could be due to the leveling off of NO_x emissions in the past two to three years.

A very interesting feature of oxidant trends is that the frequency of concentrations exceeding high levels (20 to 30 pphm) apparently has been reduced significantly more than the frequency of concentrations exceeding the federal standard (8 pphm). Figure 17 shows trends in the number of hours per year above 8, 20 and 30 pphm at west Los Angeles, downtown Los Angeles, and Azusa. At each site, there has been a much greater percentage decrease in the number of hours per year above the higher levels than in the number of hours per year above the standard. This may be an indication that elimination of high oxidant is an achievable goal for oxidant control strategy even though it is generally agreed that attainment of the standard is unlikely and maybe impossible.

Trends in Carbon Monoxide Air Quality

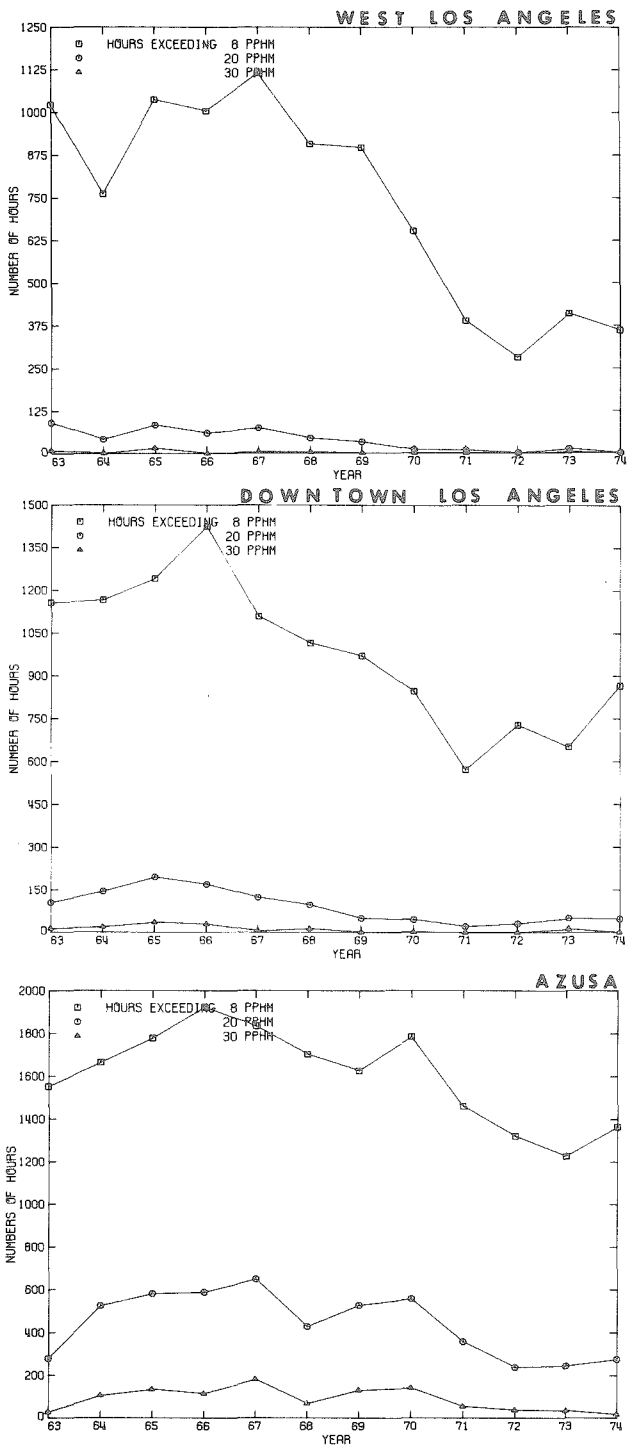
In comparing air quality trends for nitrogen oxides and oxidant to emission trends for NO_x and RHC, results were obtained which made sense, at least qualitatively. A similar study was performed with air quality and emission trends for carbon monoxide. The carbon monoxide case makes little sense. Perhaps the results for carbon monoxide reveal some of the pitfalls in working with air quality and emission data bases, both of which involve considerable uncertainties and sources of error. The results are presented below in order to encourage comments and discussion.

Again, before examining air quality changes, it is useful to illustrate the present status of air quality with respect to the NAAQS. Figure 18 presents typical max eight hour concentrations for thirteen stations



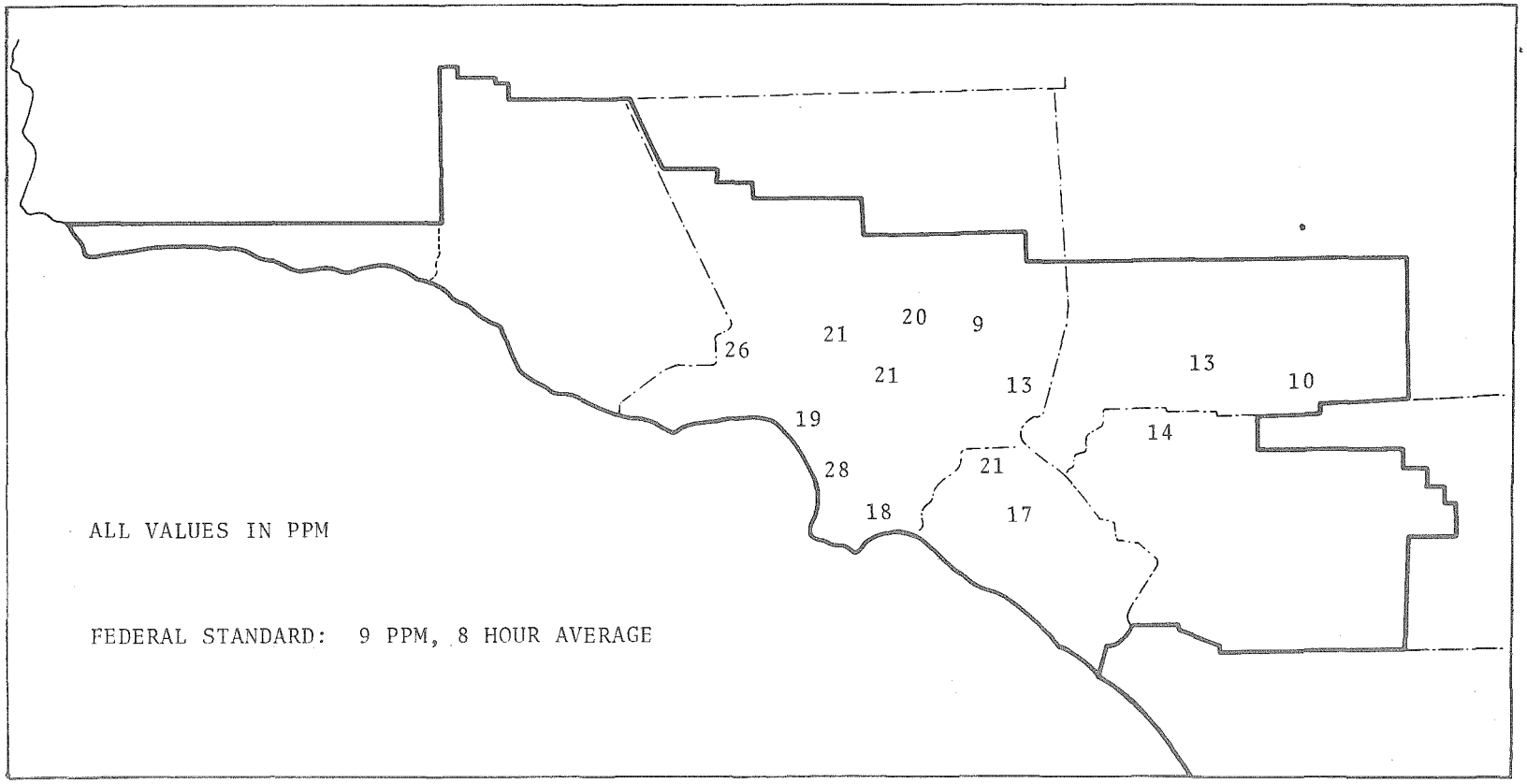
DETAILS OF OXIDANT AIR QUALITY TRENDS AT AZUSA 1963-1974

FIGURE 16



TRENDS IN HOURS PER YEAR THAT OXIDANT EXCEEDS SPECIFIED LEVELS, 1963-1974

FIGURE 17



TYPICAL MAX 8-HOUR CO CONCENTRATION IN THE EARLY 1970'S

FIGURE 18

in the early 1970's. It is apparent that the western parts of the Basin which have the greatest traffic density experience the greatest CO concentrations. At Lennox, in the western part of Los Angeles County, the federal standard of 9 ppm was typically exceeded by a factor of three during the early 1970's. These high levels in the western portion of the Basin point out the need for considerable reductions in carbon monoxide emissions in order to meet federal air quality standards.

Figure 19 presents overall air quality changes for carbon monoxide from 1965 to 1974 at eleven locations in the South Coast Air Basin and compares these to emission changes. The net percent change in CO levels at each site is represented by the number plotted at that site. Also plotted (in circles) are the emission changes in each county as computed previously. Basin-wide values are again presented in the lower left-hand corner of the figure.

The trends in CO emissions do not agree well with the trends in CO air quality. The improvements in CO air quality are greater in each county than would be implied by the emission trends. The Basin-wide change in CO emissions is only -4 percent, while the average CO concentration change at the eleven stations was -23 percent.* The disagreement is particularly large in Orange County where a calculated 28 percent increase in emissions is associated with a decrease in measured concentrations of 32 percent at Anaheim and 16 percent at La Habra.

We are not sure of the reason for the discrepancy between estimated emission trends and measured air quality trends for carbon monoxide. The four most plausible explantions are listed below:

(1) The emission calculations may be faulty. In particular, there is uncertainty concerning the level of CO emissions from uncontrolled vehicles. Potential errors also exist in deterioration factors and estimates of VMT growth. A recent paper by Los Angeles Air Pollution District personnel [21] highlights some of the uncertainties in estimating motor vehicle emissions.

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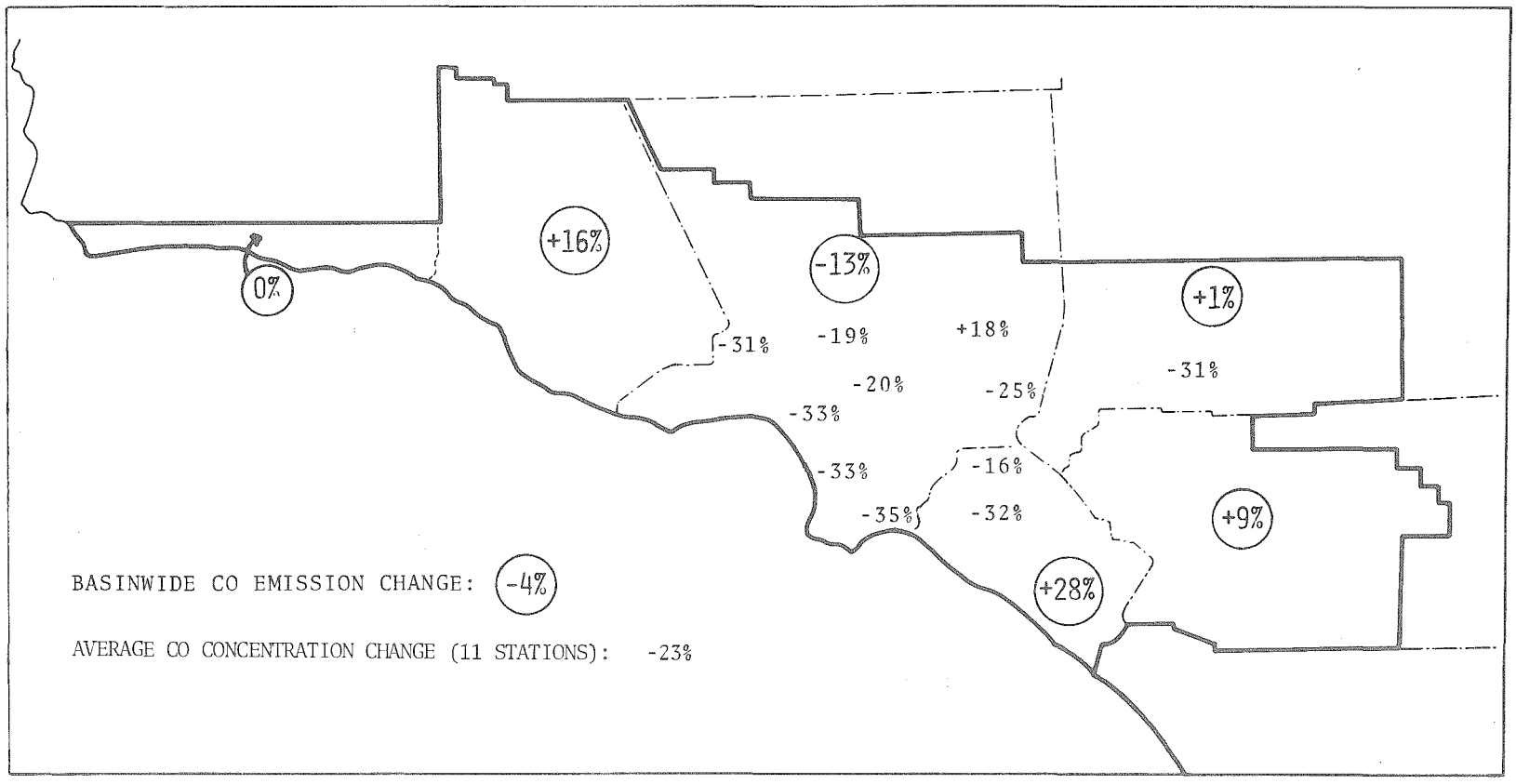
*This is the average of the changes. The change in the average among the stations was -25 percent.



TRENDS IN CARBON MONOXIDE EMISSIONS AND AIR QUALITY, 1965-1974

FIGURE 19

(2) The air quality data for CO may be in error. These errors may not be constant from year to year and may interfere with the trend analysis.

(3) The apparent air quality trends may be in part due to meteorological fluctuations. Possibly, the meteorology of the last few years (e.g., 1971-1974) was generally less favorable to producing CO pollution than the conditions of the first few years (e.g., 1965-1968). Attempts should be made to factor out meteorology from the trends in future work.

(4) Actually, in one sense, it is not surprising that measured CO has decreased more than Basin-wide CO emissions. Measured CO air quality depends significantly on localized emissions. Most of the monitoring sites in the analysis are located in older central business districts. On a local scale, these older CBD's are near saturation in traffic and have experienced little if any VMT growth in the past decade. Within each county, as well as in the Basin as a whole, the growth pattern has involved a spreading of emissions. Outlying areas have grown more rapidly than the already established CBD's. For instance, Orange County has grown more rapidly in the coastal and southern areas than in the northern Anaheim/La Habra area. Similarly, in Los Angeles County, much of the VMT growth has occurred in newly developed areas. Since the monitoring sites used here tend to be located in slow growth areas on the local scale, they may experience better CO air quality improvement than would be indicated by changes in total CO emissions. These monitoring sites may reflect the improvement in emission rates per vehicle, rather than net emission changes on a Basin-wide or county-wide scale.*

IV Conclusions

1. The projections of reductions in emissions of reactive hydrocarbons, nitrogen oxides, and carbon monoxide which were made in the

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*As a possible contradiction to this last argument, it should be noted that the emission trends and air quality trends for NO_x do agree very well, even though the NO_x air quality trends would be subject to the same effect of slow local growth.

early 1970's have turned out to be overly optimistic. This situation is caused partly by the fact that test data for automobiles do not show as large emission reductions as would have been expected from the timetable of tightening emission standards. Evaporative emissions, for example, are much higher than called for by federal and state standards. For reactive hydrocarbons, the new reactivity scale we are using now leads to a more pessimistic picture because it gives greater weight to source categories that have been reduced little in the last ten years. For NO_x, the shortage of natural gas for industrial interruptibles and power plants and the resultant unforeseen switch to fuel oil have produced higher emissions than we originally projected for stationary sources. The occurrences of these unforeseen circumstances should serve as a warning in making future emission projections. A sensitivity analysis of air quality to the possible range of emissions should be included as part of future studies.

2. Emission trends reflect a competition between reductions from emission control and increases from source growth. Since the geographical distribution of source growth, in particular traffic growth, has been very nonuniform over the South Coast Air Basin, the geographical distribution of emission trends is also very nonuniform. Among the counties in the Basin, Los Angeles County has grown the slowest, while Orange County has expanded at the greatest rate. This nonuniform spatial distribution of emission trends is important in interpreting air quality trends. What appear to be contradictory air quality trends at different locations in the Basin can often be explained by the geographical distribution of emission trends. In analyzing future strategies, the geographical distribution of emission changes should be accounted for.

3. Emissions of CO and RHC from light-duty vehicles have been controlled to a greater degree than other sources. Thus, other source categories such as heavy-duty vehicles, motorcycles, aircraft, and various stationary sources are becoming relatively more important in the total emission picture.

4. The Basin-wide trend in NO_x emissions over the past decade (a 36 percent increase) agrees well with the Basin-wide trend in ambient NO_x concentrations (about a 35 percent increase). The geographical distribution of NO_x emission trends and NO_x air quality trends on a county-by-county basis also agree. However, the deterioration in NO_2 air quality (about 20 percent over the last ten years) is less than the increase in NO_x emissions. We are not sure why this is the case, but it is possible that the controls on RHC emissions served to aid NO_2 air quality.

5. The Basin-wide reductions in RHC emissions (18 percent over the last decade) agree well with the Basin-wide improvement in oxidant air quality (19 percent over the decade). The geographical trends in oxidant agree, qualitatively, with the geographical trends in RHC emissions, especially for Los Angeles County. If we account for the dual role of NO_x, and postulate that the increase in NO_x emissions improved oxidant air quality near the source-intensive areas, but may have caused a deterioration in oxidant air quality downwind of the source areas, we obtain an even better clarification of the geographical distribution of oxidant trends. This explanation accounts for the considerable improvements in oxidant air quality in the western areas of the Basin and the lack of improvement in the downwind eastern parts of the Basin.

6. Histograms of the number of hours that oxidant concentrations exceed various levels show a much greater improvement in dosages at high levels (20 to 30 pphm) than in dosages at low levels, 8 pphm. Thus, it appears that the present control strategy has been much more effective in controlling the high oxidant ambient concentrations, probably because of the sensitivity of the peaks in oxidant concentrations to RHC concentration levels. This factor may be important in formulating goals for control strategies. Although attainment of the federal standard is probably not a practical objective, it may be possible to implement a realistic strategy which will eliminate the days of 20 or 30 pphm oxidant.

7. Estimated CO emission trends and CO air quality trends do not agree. CO air quality seems to have improved much more rapidly than reductions in CO emissions. Some possible causes for this anomalous behavior have been examined in this paper, but the resolution of these anomalies requires further investigation.

8. The history of air pollution control in the SCAB in the time frame 1965-1974 is the history of the battle between the rate of reduction in emission factors (emissions per unit of activity) and the growth rates in emission sources, especially moving sources. In the next decade, 1975-1985, growth rates may be lower, especially in the five counties outside of Los Angeles County. Average emission factors will be reduced as new cars meeting much stricter standards come on the road, so significant improvements in air quality are expected, especially at higher levels of oxidant concentration of the order of 20 pphm.

It also deserves mentioning that the new tighter, light-duty vehicle standards will accentuate the trend toward the growing importance of other sources. By 1985, sources such as heavy-duty vehicles, other transportation sources, and stationary sources appear likely to dominate the pollution picture. To achieve large improvements in air quality in the future, stricter controls for many of these other source categories will also be required.

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APPENDIX A

Basis for Emission Trend Estimates

This Appendix provides a detailed description of the methodology used to derive emission trend estimates for NO_x, RHC, and CO. The description is organized according to mobile and stationary sources.

1. Mobile Sources

Mobile sources include light-duty vehicles (motor vehicles weighing less than 6,000 pounds in gross weight), heavy-duty vehicles, aircraft, ships and railroads, as well as motorcycles and off-road vehicles. The data sources and assumptions for calculating emissions from each of these categories are summarized below.

A. Light-Duty Vehicles

The State of California started compulsory crankcase hydrocarbon (HC) emission control with 1963 model-year cars, and exhaust NO_x emission control with 1971 model-year cars. The California exhaust emission standards have been the effective standards in the past decade since the federal exhaust emission standards, which were promulgated at later dates, were generally less strict. The actual emission performance of vehicles on the road in this period has been tested by an EPA contractor [A1, A2] and by the California Air Resources Board (ARB) laboratories [A3].

In order to estimate the average per-mile emission factors for vehicles on the road in any year, we have used the EPA suggested procedure (AP-42) [A4] that includes in its formula the low-mileage emission rate in grams per mile based on the 1975 Federal Test Procedure, the deterioration factors of emission control devices by age, the speed-correction factors reflecting specific driving patterns in the area, and the distribution of regional vehicle-miles among cars of all ages. Data on the low-mileage exhaust emission rates of CO, HC, and NO_x are shown in Table A-1. Both these data and the data on deterioration factors are based on

the ARB analysis of test data [A5]. The speed-correction factors were calculated from the empirical speed-emission relationships published by the EPA [A4] with the assumption of 55 percent driving at local speed and 45 percent driving at highway speed. The assumption on speed-correction factors and the data on age distribution are based on a recent JPL study [A6].

Relatively high uncertainty surrounds the exhaust emission factors for pre-1966 uncontrolled vehicles. The emission factors used here represent an average of test data obtained by an EPA contractor [A1] for 73 Los Angeles area cars of model year 1957-1965. These values, which also appear in a recent ARB report [A7], differ from the five-city average numbers used by EPA [A4]. The emission factors for uncontrolled vehicles in Table A-1 have been adopted because they are specific to Los Angeles and because the resulting rates of emissions from uncontrolled to controlled cars are in better agreement with ARB test results than is the ratio obtained using EPA five-city factors.

Evaporative HC emissions have been regulated since 1970, according to a carbon canister test procedure which, as subsequently realized, fails to capture the majority of emissions. Test data based on an enclosure procedure (Shield House for Evaporative Determination, or SHED) have shown much higher emissions than indicated by the results of the canister procedure [A8, A9]. The values shown in Table A-1 are based on SHED data.

Reactivity factors for exhaust and evaporative hydrocarbon emissions were obtained from a recent TRW study [A10]. These reactivity factors are based on a two-group reactivity classification scheme proposed by Dimitriades [A11] and on composition data gathered in the TRW study. Reactivity factors for all subsequent source categories are also based on the TRW report.

A retrofit program was adopted by the State of California in 1964 to eliminate crankcase HC emissions from uncontrolled, pre-1963 cars

TABLE A-1

LOW MILEAGE EMISSION FACTORS FOR LIGHT-DUTY MOTOR VEHICLES IN LOS ANGELES (GRAMS/MILE)

YEAR	HYDROCARBON EXHAUST	HYDROCARBON, EVAPORATIVE AND CRANKCASE	CARBON MONOXIDE	NITROGEN OXIDES
Pre-1965	11.0 gm/mi	2.9 gm/mi	96.4 gm/mi	2.94 gm/mi
1966	6.0	2.9	59.9	8.00
1967	4.7	2.9	59.8	6.10
1968	5.1	2.9	44.8	6.70
1969	4.4	2.9	49.2	6.10
1970	4.6	1.8	49.5	4.60
1971	3.0	1.8	46.1	3.60
1972	3.0	1.8	37.4	3.70
1973	2.7	1.8	36.5	3.20
1974	2.6	1.8	30.5	2.20

when they change ownership. The effect of this program was accounted for in our calculation by assuming that one-sixth of the pre-1963 model-year cars was resold, and therefore controlled, each year.

The average number of vehicle-miles traveled (VMT) per day by all the vehicles in a region is needed to calculate the daily emissions from light-duty vehicles for each year. The source of our regional VMT estimates is VMT information available for years 1960, 1967, 1970, and 1974 from the Los Angeles Regional Transportation Study [A12, A13, A14]. The changes in regional VMT are governed by the changes in regional registration and in driving per vehicle. Official registration data from 1960 to 1974 have been used to interpolate for the VMT estimates in the missing years. The effect of the 1974 gasoline shortage is also included by assuming that the per-vehicle driving continued to increase from 1970 to 1973 according to the 1967-1970 rate, with a sudden drop in 1974. This assumption is made rather than assuming a uniform decrease in per-vehicle driving for these years as a straight line interpolation of 1970 and 1974 data would indicate.

About 92 percent of total VMT is attributed to light-duty vehicles, seven percent to gasoline-powered heavy-duty vehicles, and one percent to diesel-powered heavy-duty vehicles. This breakdown is based on a vehicle registration study by the ARB staff [A15] and information on daily VMT per vehicle contained in the JPL study [A6].

B. Heavy-Duty Vehicles

We have used the same methodology as in light-duty vehicles to estimate the average gm/mile emission factors for the in-use heavy-duty vehicles. The formula as well as the data on emission rate for both gasoline-powered and diesel-powered vehicles are those of EPA [A4] except for the evaporative HC emission data.* The age distribution data comes

*EPA has assumed a reduction from 3 gm/mi evaporative HC to 0.2 gm/mi in 1972. We have assumed no reduction here, since the SHED data for light-duty vehicles have revealed the ineffectiveness of test procedures for the existing control program.

from the JPL study [A6]. These data, together with the VMT data discussed previously, allow calculation of daily emissions from the heavy-duty vehicles.

C. Aircraft

Results of recent studies have been adopted to establish a base-year (1972) estimate of aircraft emissions. Projections to other years are according to the growth rate of the number of flights. The 1972 RHC emission estimate comes from the TRW reactivity study [A10], while the 1972 NO_x and CO estimates are from an ARB inventory contained in another TRW report [A16]. Growth rates of nine percent per year for jet flights and four percent per year for piston flights are assumed according to data contained in a Los Angeles Air Pollution Control District report [A17].

D. Ships and Railroads

Emissions from these sources are very small compared to emissions from other sources. Data for 1972 emissions come from TRW reports [A10, A16] and are assumed to be constant through the years.

E. Motorcycles and Off-Road Vehicles

The 1972 RHC emission data are from a TRW study [A10]. A five percent per year growth rate is assumed to reflect a 3.6 percent per year increase of construction and manufacturing activities [A18] and a nine percent per year growth motorcycle registration. The 1972 CO emission data for motorcycles are from the JPL study [A6]. These emissions increases are assumed to increase at the growth rate of motorcycle registration. Motorcycle NO_x emissions are trivial compared with other sources, and are neglected in this study. CO and NO_x emissions from off-road vehicles are also considered negligible.

The mobile source emission trends obtained for the whole Basin must be distributed among the six counties in the Basin to study emission changes in individual counties from 1965 to 1974. For light-duty and

heavy-duty vehicles, the geographic distribution of emissions is assumed to follow the distribution of VMT. Based on the LARTS data [A14] for five counties, the traffic count data for six counties, and the county registration data through the past nine years, we were able to estimate the percentage distributions of VMT by county in 1965 as well as in 1974. The two distributions reflect the varied growth rates among the counties. For example, the data show that Los Angeles County contributed 70 percent of the VMT in the Basin in 1965, but only 63 percent in 1974. Orange County contributed 13 percent in 1965 and 18 percent in 1974.

Airplane emissions in 1972 are apportioned according to data in the TRW study [A16] and the APCD reports from various counties [A19]. Aircraft emissions are assumed to grow at a uniform rate in each county. Emissions from ships and railroads are apportioned according to data in the California State Implementation Plan of 1970 [A20]. Emissions from motorcycles and off-road vehicles are apportioned by population. Again, the 1965 and 1974 population distributions reflect this disparity in growth rates from county to county.

2. Stationary Sources

Since the major contributing stationary sources are different for different pollutants, the discussion for stationary sources is organized by type of pollutant.

A. Reactive Hydrocarbon (RHC)

The 1972 emission inventory is obtained from the TRW reactivity study [A10], except that an additional amount of RHC is assumed to represent the "geogenic source". This reflects the recent finding of geogenic natural gas as a sizable portion of non-methane HC in the atmosphere over Los Angeles County [A21]. Reactivities for the geogenic source and all other sources are based on the TRW report and Dimitriades' two-class reactivity classifications scheme [A11].

The first category of stationary source RHC emissions is related to the production, refining, marketing, and combustion of organic fuels.

There has been no significant change in the emission levels of petroleum production and refining in the past decade [A22]. Emissions resulting from gasoline marketing have grown with the amount of gasoline consumed in the Basin per year.* The effect of control for underground tanks at gas stations has been included, affecting the projected trend from 1965 to 1970. (Submerged filling reduced the HC emissions from uncontrolled splash filling by 40 percent [A23].) The minor emissions from fuel combustion and burning are assumed to have grown at the Basin energy consumption growth rate, about 3.9 percent per year [A24]. The total emissions in the Basin are distributed among counties by consulting available distribution data for petroleum production and refining, VMT data for gasoline marketing, and population data for fuel combustion.

The second stationary source RHC category is related to the use of organic chemicals: surface coating, dry cleaning, degreasing, printing, and chemical processing. This category was controlled in 1966 (under Rule 66 in Los Angeles County), but the effect is very difficult to estimate because the potentially controllable emissions sources are scattered and numerous. The Los Angeles APCD Profile of 1970 [A25] has estimated an 11 percent reduction of total hydrocarbons from 1965 to 1970 as a result of Rule 66, and a 20 percent reduction in total hydrocarbons from 1970 to 1974 from continued organic chemical control programs. We have assumed a 20 percent reduction of reactive HC from 1965 to 1970 to approximately account for substitutive controls, and another 20 percent reduction from 1970 to 1974. Since the solvent control rule has been adopted by all other counties in the Basin [A19], the emissions in the whole Basin are distributed among counties according to population.

B. Carbon Monoxide (CO)

The stationary source CO emissions mainly arise from incineration and burning. They contribute only about one percent of the total CO

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*In the absence of gasoline data, we have used VMT growth rates instead, admitting that the VMT growth rates may be an underestimate of the gasoline growth rates due to the worsening of the average fuel economy of automobiles in recent years.

emissions in the time period concerned. The 1972 inventory was obtained from the ARB data contained in a TRW study [A10]. These source categories are assumed to be constant through the past decade since both regulation and growth occurred in the period. Total emissions in the Basin are distributed among counties by consulting the 1970 State Implementation Plan [A20] and county reports [A17, A19].

C. Oxides of Nitrogen (NO_X)

Stationary source NO_X emissions arise from utility power plants, petroleum refineries, and other industrial, commercial, and residential combustion sources. The 1972 emission inventory for the whole Basin as well as for every county is based on the KVB study [A26].

The demand for electric power has been growing by about 7 percent per year in the past decade, but effective control actions have also been taken to result in a net reduction of power plant NO_X emissions during the past nine years. In Los Angeles County, these actions include increased natural gas supply and substitution of low sulfur fuel oil for high sulfur oil (which also emits more NO_X in burning) in the sixties, the Rule 68 retrofit program and the industry's own effort in 1969-1970, and increased use of electricity generated outside the Basin in the early seventies [A17, A27]. However, the supply of natural gas for utility power plants started to decrease in 1971-1972 and is now rapidly diminishing. Southern California Edison has projected a mere 1.5 percent contribution of gas-generated electricity by 1976 [A28].

Using KVB data for 1972 utility NO_X emissions as a starting point and the NO_X changes from 1966 to 1973 for power plants in Los Angeles County [A17] as a guideline, we have estimated power plant NO_X emission trends for the whole Basin. This generalization is based on the fact that the regional utility system operates as a power pool so that growth of local use does not require increased local electric generation. The estimate for 1965 is extrapolated from the 1966-1967 data. The estimate for 1974 is based on the JPL study [A6] which accounted for the projected natural gas shortage. The distribution among counties is based on the

KVB study. The county-by-county distribution is assumed constant through the years, except for a minor adjustment to account for increased capacity in Ventura County in 1973-1974 [A19].

Emissions from oil refineries are assumed to be constant through the nine years [A22]. The distribution by county is also assumed to be constant.

Emissions from other combustion sources in the Basin are assumed to grow at a rate corresponding to the growth of non-electric energy use in the Basin, which averages 2.6 percent per year from 1965 to 1970 [A24]. This trend is extended to 1974. These emissions are distributed among counties according to population distribution which changes through the years.

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