# PHOENIX - TUCSON METROPOLITAN AREA AIR POLLUTANT EMISSION INVENTORY

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

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# PHOENIX-TUCSON METROPOLITAN AREA

# AIR POLLUTANT EMISSION INVENTORY

Clyde B. Morita

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
Consumer Protection and Environmental Health Service
National Air Pollution Control Administration
Division of Air Quality and Emission Data
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1. Arizona State Department of Health
2. Maricopa County Health Department
3. Pima County Air Pollution Control District

# PREFACE

This report, which presents the emission inventory of the Phoenix-Tucson metropolitan area, is another in a series of studies outlining the sources and emissions of air pollutants for major metropolitan areas in the country. These reports provide estimates of total emissions of oxides of sulfur, oxides of nitrogen, hydrocarbons, carbon monoxide and particulate matter. The emissions of these pollutants are delineated with respect to source type, season of the year, and by their geographical distribution within the area. These surveys are also intended to determine the present level of emissions and status of their control.

The general procedure for these surveys is based on the rapid survey technique.[1] The Study Area is divided into grid zones that serve as the basis for locating sources and reporting their emissions. All sources of pollutants are divided into two subgroups—point and area sources. Sources that emit large quantities of air pollutants are considered individually and located specifically within the area. This group generally contains about fifty to one hundred sources and typically includes large industries, power plants, and central refuse burning facilities. The remaining multitude of sources are considered collectively as area sources and their emissions are reported as totals for grid zones. This category includes motor vehicles, home heating, smaller industries, on-site refuse burning, etc.

Emissions for the most part are estimated using various indicators of pollutant emissions and average emission factors that are related to these. Information and data are collected on fuel consumption, refuse burning rates, vehicle miles of travel, as well as various production data. These are then translated into emission estimates by use of average emission factors.[2] These factors, for the most part, represent average emission rates for a particular industry or fuel type.

Because of the inherent difference in types of equipment, operating rates, control equipment, and efficiency of operation among the plants

and fuel users within a given category, the application of the emission factors to any individual plant or even a smaller number of similar plants or processes may result in a discrepancy between the actual and the estimated emissions. However, the estimates of total pollutants from all sources in the study area should be reasonably accurate since the emission factors are based on average conditions.

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# INTRODUCTION

The information and data presented in this report were gathered in cooperation with the acknowledged State and local agencies during a survey conducted in November, 1968. The data obtained is for the most part representative of 1967 and the emission estimates presented herein should be considered as describing the levels and conditions during that year.

The purposes of this study are to establish the magnitude and sources of air pollutant emissions in this area for incorporation into a national emission baseline, and to use the emission estimates in a diffusion model to establish the relative extent of air pollution in the area. These data are used as the basis of the engineering evaluation in the designation of an air quality control region for the Phoenix-Tucson area.

## SUMMARY OF RESULTS

The estimated annual emissions of the five surveyed pollutants in the Phoenix-Tucson metropolitan area are 2,068,000 tons of sulfur oxides, 34,300 tons of particulate matter, 535,000 tons of carbon monoxide, 125,000 tons of hydrocarbons, and 62,400 tons of oxides of nitrogen. The air pollution problem in the urbanized areas is mainly automotive in nature. However, in some of the rural areas, the eight copper smelters release thousands of tons of sulfur oxides daily. The pollution from the smelters is believed to affect portions of the metropolitan area at times.

The breakdown of pollutant emissions by source category is listed in Table 1. The following is a brief summary of pollutant emission and sources:

Sulfur Oxides — The predominant source of the more than 2 million tons of sulfur oxides emitted annually is the copper smelting industry. The eight smelters collectively emit 99.7 percent of the sulfur oxides. The contribution from all other sources is negligible.

Particulate Matter — The annual emissions of 34,300 tons of particulate matter are distributed between the various source types. Transportation sources account for 29 percent, industrial process losses 38 percent, and agricultural operations 16 percent of the total particulate matter emissions. An additional 17 percent is divided between stationary fuel combustion and solid waste disposal.

Carbon Monoxide — Motor vehicles contribute 94 percent of the 535,000 tons of carbon monoxide emitted annually. Other sources include solid waste disposal operations

TABLE 1 SUMMARY OF AIR POLLUTANT EMISSIONS IN THE PHOENIX-TUCSON STUDY AREA, 1967 (TONS/YEAR)

| Source Category | Sulfur Oxides | Particulates | Carbon Monoxide | Hydrocarbons | Nitrogen Oxides |
|---|---|---|---|---|---|
| Transportation | | | | | |
| Motor Vehicles | | | | | |
| Gasoline | 2,100 | 2,800 | 500,000 | 68,700 | 30,000 |
| Diesel | 700 | 1,900 | 1,030 | 2,400 | 3,900 |
| Aircraft | N | 2,300 | 12,000 | 4,400 | 2,000 |
| Railroads | 1,100 | 2,900 | 1,600 | 3,700 | 2,700 |
| Stationary Fuel* Combustion | | | | | |
| Industrial | 770 | 2,000 | 1,060 | 2,400 | 5,100 |
| Steam-Electric | 10 | 290 | N | N | 7,500 |
| Residential | 70 | 230 | 25 | 5 | 1,300 |
| Commercial-Institutional | 150 | 300 | 120 | 290 | 1,300 |
| Solid Waste Disposal | | | | | |
| Open Burning | N | 3,000 | 15,900 | 5,700 | 2,040 |
| Incineration | 40 | 200 | 1,500 | 20 | 80 |
| Industrial Process | 2,062,000 | 13,000 | 360 | N | 1,000 |
| Solvent Evaporation | -- | -- | -- | 35,500 | -- |
| Agriculture | 1,480 | 5,400 | 980 | 2,200 | 5,500 |
| TOTAL | 2,068,000 | 34,300 | 535,000 | 125,000 | 62,400 |

N = Negligible
* Emissions from agricultural fuel combustion included in agriculture column.

and aircraft which account for 2 and 3 percent, respectively, of carbon monoxide emissions.

Hydrocarbons

The two largest sources of the 125,000 tons of hydrocarbon emitted are motor vehicles and organic solvent evaporation. They contribute 57 percent and 28 percent, respectively, of the total hydrocarbon emissions. Other transportation sources account for approximately 6 percent, solid waste disposal 5 percent, and other sources 4 percent of hydrocarbon emissions.

Oxides of Nitrogen

Motor vehicles contribute more than 55 percent of the total of 62,400 tons of nitrogen oxides emitted annually. Fuel combustion in stationary sources accounts for 25 percent of total nitrogen oxides with natural gas combustion accounting for about three-fourths of this total. Other contributing sources are agricultural operations at 9 percent, other transportation sources at 7 percent, and solid waste disposal and industrial processes collectively at 4 percent.

## STUDY AREA

The Study Area for the Phoenix-Tucson Metropolitan Area Air Pollutant Emission Inventory consists of eight counties located in the southern part of the State of Arizona. In fact the Study Area includes 84 percent of the population and 37 percent of the land area of the State of Arizona. Figure 1 presents the Study Area in relation to the rest of the State.

The eight counties consist of the cities of Phoenix and Tucson and the following counties--Cochise, Gila, Graham, Greenlee, Maricopa, Pima, Pinal, and Santa Cruz. This area occupies 42,700 square miles and contains an estimated 1967 population of 1,390,000.[3] Most of the population (86 percent) lives in Maricopa and Pima Counties (see Table 2). This area has had a population increase of 25 percent from 1960 to 1967. This rate of increase is much higher than the national average and is probably due to the increasing popularity of this area as a tourist and retirement resort.

The Study Area contains two Standard Metropolitan Statistical Areas (SMSA) as defined by the Bureau of Budget. The Phoenix SMSA, which includes all of Maricopa County, and the Tucson SMSA, which includes all of Pima County, are the thirty-fourth and eighty-ninth largest (population wise) SMSA's, respectively, in this country. The remaining six counties were included in the Study Area primarily because of the existence of copper smelters in four of these six counties.

### Topography and Climate

The Phoenix-Tucson area is a contrast between flat desert plains and rugged mountain ranges and jutting hills. Phoenix is located in the center of the Salt River Valley, a broad, oval-shaped, nearly flat plain. The Salt River runs from east to west through the valley, but because of impounding dams upstream, it is usually dry. Tucson, located southeast of Phoenix, is practically surrounded by mountains rising to an altitude of 4,000 to 6,000 feet.

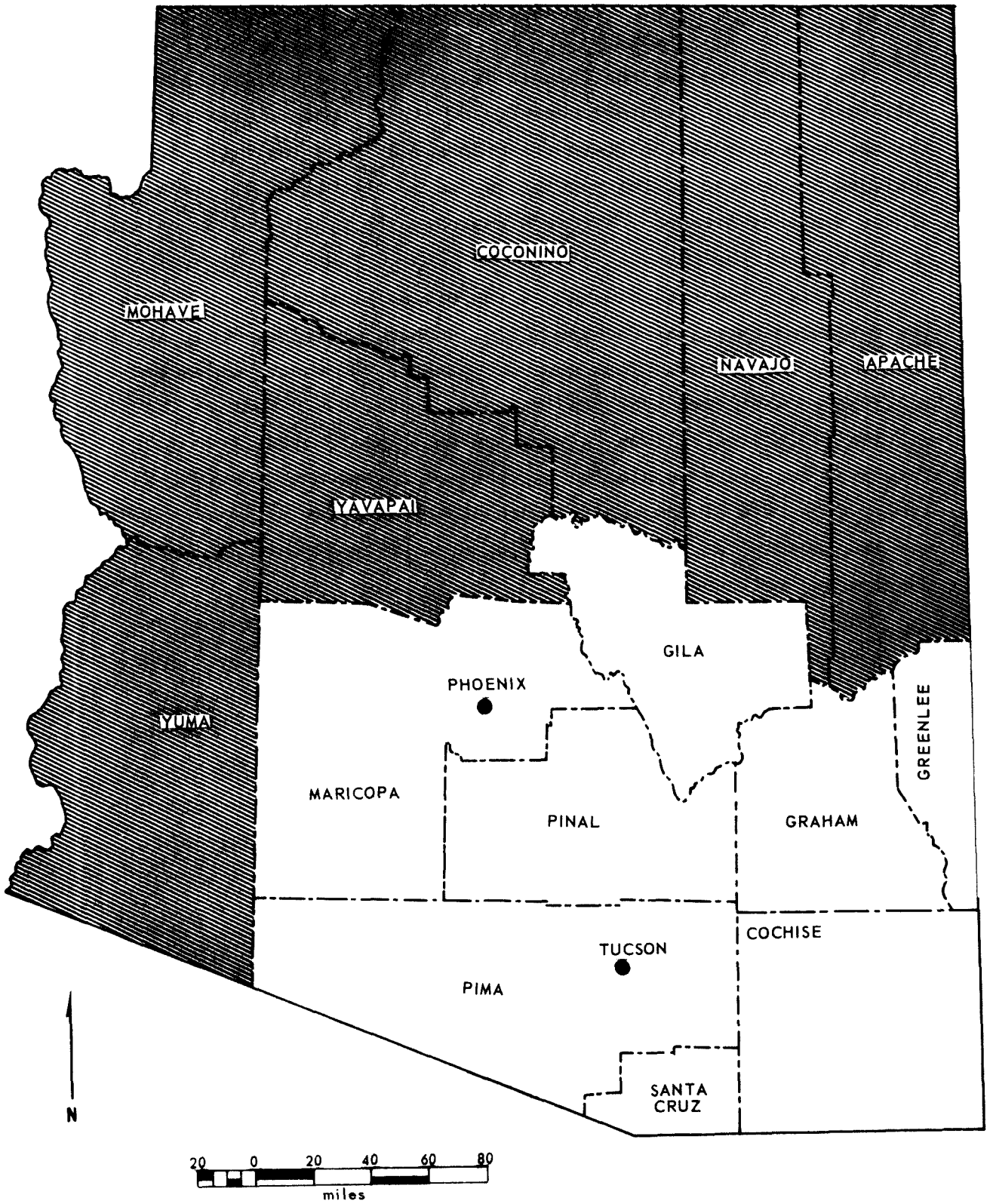


Figure 1. Location of the Phoenix-Tucson study area within the state of Arizona.

The climate of the area is characterized by a long hot season beginning in April and ending in October. Surface winds are generally light, with no important seasonal changes in either velocity or prevailing wind direction. The prevailing wind direction is easterly around Phoenix and southeasterly around Tucson.

Grid Coordinate System

For the purposes of this survey, the Study Area was divided into 67 grids. As shown on Figure 2, grids of 100, 400, 1600, and 6400 square kilometers were used to show the geographical distribution of sources and emissions. The grid system is based on the Universal Transverse Mercator System. The easting (east-west) and northing (north-south) coordinates are expressed in meters.

Different sizes of grids are used to limit the number of grid zones yet allow a satisfactory definition of the geographical gradation of emissions in areas where the majority of pollution occurs. For this reason, the smaller grids are used in the urban areas where emission densities tend to change abruptly within short distances. In areas primarily rural in nature, the use of small zones are not warranted.

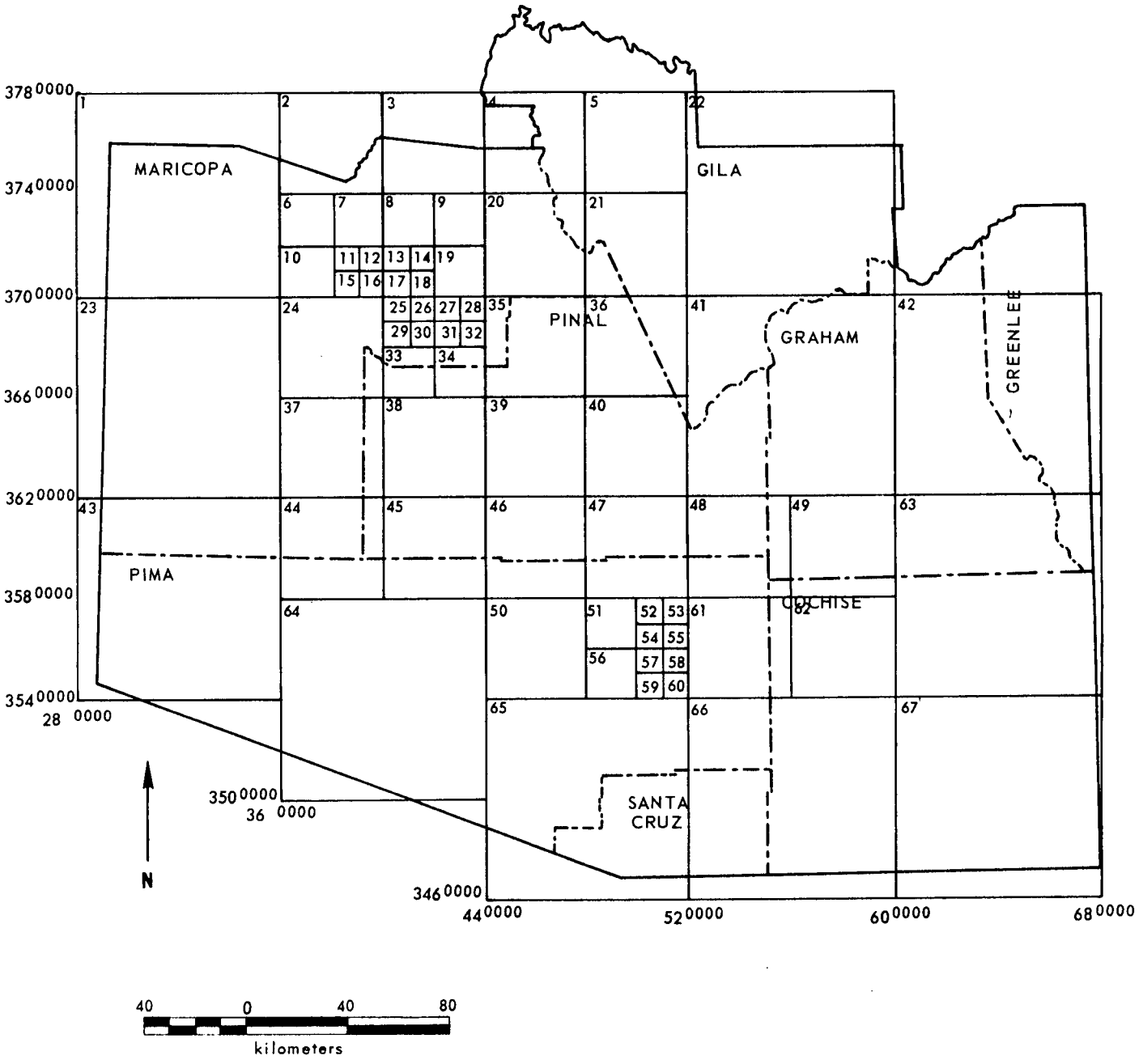


Figure 2. Grid coordinate system for the Phoenix-Tucson study area.

TABLE 2 POPULATION AND AREA CHARACTERISTICS FOR THE PHOENIX-TUCSON STUDY AREA, 1967

| County | Land Area (sq. mi.) | 1960 Population | 1967 Population | 1967 Population Density People/sq. mi. |
|---|---|---|---|---|
| Cochise | 6,260 | 55,000 | 65,700 | 10.5 |
| Gila | 4,790 | 25,700 | 27,000 | 5.6 |
| Graham | 4,640 | 14,000 | 15,800 | 3.4 |
| Greenlee | 1,880 | 11,500 | 10,400 | 5.5 |
| Maricopa | 9,250 | 663,500 | 872,100 | 94.3 |
| Pima | 9.240 | 265,700 | 322,200 | 34.9 |
| Pinal | 5,390 | 62,700 | 64,000 | 11.9 |
| Santa Cruz | 1,250 | 10,800 | 14,000 | 11.2 |
| TOTAL | 42,700 | 1,110,000 | 1,390,000 | 32.5 |

TABLE 3 MOTOR FUEL CONSUMPTION AND VEHICLE-MILES OF TRAVEL, 1967

| County | Gasoline Consumption ($10^3$ gallons) | Diesel Fuel Consumption ($10^3$ gallons) | Total Vehicle-Miles ($10^6$ Vehicle Miles/Yr.) |
|---|---|---|---|
| Cochise | 24,200 | 2,690 | 360 |
| Gila | 12,700 | 1,410 | 190 |
| Graham | 6,300 | 700 | 90 |
| Greenlee | 3,000 | 340 | 45 |
| Maricopa | 337,800 | 18,600 | 4,520 |
| Pima | 108,600 | 6,100 | 1,630 |
| Pinal | 22,300 | 2,480 | 330 |
| Santa Cruz | 5,200 | 580 | 80 |
| TOTAL | 520,100 | 32,900 | 7,240 |

## EMISSIONS BY SOURCE CATEGORY

For the purposes of compiling the basic data and emission estimates, the sources of air pollutants were classified into the following six categories:

1. Transportation
2. Fuel combustion in stationary sources
3. Solid wastes disposal
4. Industrial process losses
5. Organic solvent evaporation
6. Agriculture

Each of these categories are considered individually in this section. The data sources and necessary assumptions are presented with further breakdowns of emissions. Most of the estimates presented here are area-wide totals. The section on emissions by jurisdiction presents the emissions by source for every county.

The estimates presented herein, especially in the industrial process loss category, are for the most part partial totals. The lack of emission factors and appropriate process and control data prevent a complete inventory of all sources and emissions. However, the major sources have been included and the sources not considered should be negligible. The results should be viewed with these limitations.

### Transportation

Three types of transportation sources are considered in this survey--motor vehicles, aircraft, and railroads. Motor vehicles, which are by far the most significant source of air pollution in this category are further subdivided according to type of fuel used--gasoline and diesel.

#### Motor Vehicles

More than 7.2 billion miles were traveled by motor vehicles in 1967. In the process, 520 million gallons of gasoline and 33 million

gallons of diesel fuel were consumed for highway purposes.[3] Table 3 indicates that about 85 percent of all motor vehicle travel occurs in Maricopa and Pima Counties.

Approximately 1.5 to 2.0 percent of gasoline is lost through evaporation from the gasoline tanks and carburetor losses resulting in annual losses of about 7.8 million gallons. It was assumed that no diesel fuel was lost by evaporation. Since 1963, most new automobiles were equipped with positive crankcase ventilation (PCV) valves that reduce hydrocarbon emissions from the crankcase by about 90 percent. Due to a lag time in the automobile replacement rate, it was assumed that only 20 percent of the automobiles were not equiped with PCV valves.

The vehicle miles of travel were apportioned onto the grids by the use of traffic information (vehicle miles and traffic flow maps) obtained from Arizona Highway Department.[4] This information was available for the urban portions of Maricopa and Pima Counties. Population was used as the basis of apportionment in the other counties. Appropriate speeds were assigned to each grid depending on the type of area, and emissions were calculated on the basis of speed and vehicle miles.

The resulting emissions from motor vehicles are shown on Table 4 along with emissions from other transportation sources. Motor vehicles are by far the most significant transportation source accounting for 72 percent of the sulfur oxides, 48 percent of the particulate matter, 97 percent of the carbon monoxide, 92 percent of the hydrocarbons, and 88 percent of the oxides of nitrogen emitted from transportation sources.

## Aircraft

There are five major airports operating in the Study Area. Of these five, two are municipal airports, while the others are air force bases. Sky Harbor Airport is by far the busiest of the five airports. Collectively a total of 444,000 flights (take off and landing) were performed during 1967.[5,6,7]

Table 5 indicates that the Sky Harbor Airport is higher in emissions of carbon monoxide and hydrocarbons than the other airports, but Luke AFB emits the highest amounts of particulate matter and nitrogen oxides.

TABLE 4 AIR POLLUTANT EMISSIONS FROM TRANSPORTATION SOURCES, 1967 (TONS/YEAR)

| Source Category | Sulfur Oxides | Partic-ulates | Carbon Monoxide | Hydro-carbons | Nitrogen Oxides |
|---|---|---|---|---|---|
| Motor Vehicles | | | | | |
| Gasoline | | | | | |
| Exhaust | 2,100 | 2,800 | 501,000 | 39,000 | 30,000 |
| Evaporation | N | N | N | 30,000 | N |
| Diesel | 700 | 1,950 | 1,070 | 2,400 | 3,900 |
| TOTAL | 2,800 | 4,800 | 502,000 | 71,400 | 33,400 |
| Aircraft | | | | | |
| Jet | N | 250 | 2,460 | 780 | 1,550 |
| Turboprop | N | 10 | 40 | 10 | 20 |
| Piston | N | 2,200 | 9,400 | 1,770 | 450 |
| TOTAL | N | 2,300 | 12,000 | 2,600 | 2,000 |
| Railroads | 1,090 | 2,920 | 1,610 | 3,150 | 2,670 |
| TOTAL | 1,090 | 2,920 | 1,610 | 3,150 | 2,670 |
| GRAND TOTAL | 3,900 | 10,000 | 515,600 | 77,200 | 38,100 |

N = Negligible

Although Luke AFB has only about a third of the flights as Sky Harbor Airport, there are more jet flights annually (for training purposes). Table 4 shows the contribution of jet, turboprop and piston aircraft to the total emissions from transportation sources.

### Railroads

Railroad operations (mainly locomotive) consume about 42 million gallons of diesel fuel annually within the Phoenix-Tucson area. This quantity is about 25 percent more than the amount of diesel fuel consumed by motor vehicles. Diesel fuel consumption data were available for Maricopa and Pima Counties and estimated from state totals for the other counties.[6,7]

Railroad operations contribute approximately 8 percent of the total particulate matter emissions in the Study Area. They account for less than 4 percent of total emissions from any other pollutant.

## Fuel Combustion in Stationary Sources

Although all of the three major fuels (coal, oil, and natural gas) and liquified petroleum gases are consumed within the Study Area, natural gas is the most important by far. In 1967, natural gas accounted for 104 trillion BTU's or approximately 86 percent of the total energy consumption. As shown on Table 6, 100 billion cubic feet of natural gas, 85 million gallons of distillate fuel oil, 2.9 million gallons of redisual fuel oil, 45 million gallons of liquified petroleum gases, and only 800 tons of coal were consumed in the Study Area.

For the purposes of this survey, fuel combustion in stationary sources has been divided into five user categories--residential, commercial-institutional, industrial, steam-electric utility, and agricultural. Fuel combustion in agricultural operations has been included here, however, the emissions are presented in the Agriculture Section of this report.

Natural gas is consumed to a large extent in all five consumer categories. Steam-electric utilities consume the largest amount with residential users consuming almost as much. Distillate fuel oil, mainly

TABLE 5 AIR POLLUTANT EMISSIONS FROM AIRCRAFT
1967, (TONS/YEAR)

| Airport | Total Flights | Sulfur Oxides | Partic-ulates | Carbon Monoxide | Hydro-carbons | Nitrogen Oxides |
|---|---|---|---|---|---|---|
| Sky Harbor | 190,000 | N | 130 | 7,000 | 1,400 | 450 |
| Tucson International | 98,000 | N | 410 | 2,700 | 540 | 380 |
| Luke AFB* | 61,000 | N | 940 | 1,370 | 350 | 650 |
| Williams AFB | 58,000 | N | 490 | 510 | 150 | 330 |
| Davis-Monthan AFB | 38,000 | N | 300 | 420 | 120 | 210 |
| TOTAL | 444,000 | N | 2,270 | 12,000 | 2,560 | 2,020 |

N = Negligible

* Includes 3 separate facilities

TABLE 6 FUEL CONSUMPTION BY USER CATEGORY, 1967

| User Category | Natural Gas $10^6$ cu. ft. | Distillate Fuel Oil* $10^3$ gal. | Residual Fuel Oil $10^3$ gal. | Liquified Petro-leum Gases $10^3$ gal. | Coal Tons |
|---|---|---|---|---|---|
| Residential | 22,800 | 2,300 | -- | 31,000 | 800 |
| Commercial-Institutional | 13,300 | 2,500 | 450 | 5,000 | N |
| Industrial | 11,500 | 30,000 | 500 | 3,000 | N |
| Steam-Electric | 38,300 | 110 | N | N | N |
| Agricultural | 14,100 | 50,000 | 1,900 | 600 | N |
| TOTAL | 100,000 | 85,000 | 2,850 | 45,000 | 800 |
| BTU's, $10^{12}$ | 104 | 12 | 0.4 | 4.3 | .02 |

N = Negligible

* Includes diesel fuel

diesel fuel, is consumed predominantly in industrial and agricultural operations. The diesel fuel is used to operate pumps, generators, construction equipment, and miscellaneous types of engines. A small amount of residual fuel oil is consumed in the Study Area. It is mainly used in agricultural operations. A significant amount of liquified petroleum gases (LPG) is used for heating purposes. Most of the LPG is used in residences and mobile trailer parks where natural gas lines are not available. Only about 800 tons of coal are consumed for residential heating pruposes, mainly in the more isolated sections of the Study Area.

There are seven steam-electric generating plants within the Study Area. These plants consume 38 percent of the natural gas and about 33 percent of the total energy consumption in the Study Area. The fuel combustion by plant is summarized in Table 7. There are no air pollution control systems on any of these plants.

Whereas the natural gas consumption data, which was obtained from the gas utility companies, is fairly accurate, the fuel oil, LPG, and coal data are rough approximations. These data were primarily extrapolated from state totals published by the Bureau of Mines.[8,9] The sulfur and ash contents of the fuels used in the Study Area are summarized in Table 8.

The emissions from fuel combustion in stationary sources were apportioned to the individual grids mainly by population. In Maricopa County, industrial and commercial-institutional emissions were apportioned on the basis of land use maps.[10]

The air pollutant emissions resulting from fuel combustion in stationary sources are summarized in Table 9. The combustion of distillate fuel oil, although providing only 10 percent of the energy imput, produces the majority of air pollutants from the combustion of fuels. Only in the case of oxides of nitrogen does natural gas supply about two-thirds of the emissions. Coal, residual fuel oil, and LPG produce an insignificant amount of emissions.

Fuel combustion in stationary sources contributes about 25 percent of total nitrogen oxides emissions in the Study Area. Otherwise, it is not a significant contributor to emissions of the other four pollutants surveyed. This is a result of the predominance of natural

TABLE 7 FUEL CONSUMPTION IN STEAM-ELECTRIC GENERATING PLANTS, 1967

| Plant | County | Natural Gas $10^6$ Cubic Feet | Distillate Fuel Oil $10^3$ Gallons |
|---|---|---|---|
| Aqua Fria | Maricopa | 11,729 | 84 |
| Apache | Cochise | 1,938 | -- |
| DeMoss-Petrie | Pima | 1,152 | -- |
| Irvington | Pima | 14,773 | -- |
| Kyrene | Maricopa | 2,167 | 29 |
| Ocotillo | Maricopa | 5,405 | -- |
| Saquaro | Pinal | 1,114 | -- |
| TOTAL | | 38,278 | 113 |

TABLE 8 ANALYSIS OF FUELS CONSUMED IN THE STUDY AREA

| Fuel | Percent Sulfur* | Percent Ash* |
|---|---|---|
| Natural Gas | 0.0008 | N.A. |
| Distillate Fuel Oil | 0.3 | N.A. |
| Residual Fuel Oil | 1.5 | N.A. |
| Coal | 0.6 | 8.0 |
| Liquified Petroleum Gases | 0.0008 | N.A. |

N.A. = Not Applicable
* = By weight

TABLE 9 AIR POLLUTANT EMISSIONS FROM STATIONARY FUEL COMBUSTION SOURCES, 1967 (TONS/YEAR)[a]

| Fuel | User Category | Sulfur Oxides | Particulates | Carbon Monoxide | Hydro Carbons | Nitrogen Oxides |
|---|---|---|---|---|---|---|
| Coal | Residential | 7 | 4 | 20 | 30 | 1 |
| | Total | 7 | 4 | 20 | 30 | 1 |
| Distillate[b] Fuel Oil | Residential | 50 | 7 | 1 | 1 | 12 |
| | Commercial-Institutional | 90 | 240 | 130 | 300 | 480 |
| | Industrial | 710 | 1,820 | 1,050 | 2,400 | 3,900 |
| | Steam-Electric | N | N | N | N | N |
| | Total | 850 | 2,070 | 1,180 | 2,700 | 4,390 |
| Residual Fuel Oil | Commercial-Institutional | 60 | 5 | N | N | 20 |
| | Industrial | 60 | 5 | N | N | 20 |
| | Total | 120 | 10 | N | N | 40 |
| Liquified Petroleum Gases | Residential | N | 10 | N | N | 70 |
| | Commercial-Institutional | N | 3 | N | N | 15 |
| | Industrial | N | 1 | N | N | 5 |
| | Total | N | 14 | N | N | 90 |
| Natural Gas | Residential | 3 | 210 | 3 | N | 1,320 |
| | Commercial-Institutional | N | 130 | N | N | 760 |
| | Industrial | N | 100 | N | N | 1,230 |
| | Steam-Electric | 10 | 290 | N | N | 7,500 |
| | Total | 13 | 730 | 3 | N | 10,800 |
| GRAND TOTAL | | 1,000 | 2,800 | 1,200 | 2,700 | 15,300 |

N = Negligible
[a]Excludes emissions from agriculture
[b]Includes diesel fuel

gas as the source of heat and power.

## Solid Wastes Disposal

More than 1.3 million tons of solid wastes are generated annually within the Study Area. The bulk of this refuse is disposed of by means of landfills at which no burning takes place (see Table 10). According to a comprehensive solid wastes disposal report, 690,000 tons of refuse are disposed of at five different landfills in Maricopa County.[11] Of these five landfills, only two were classified as "sanitary landfills" in 1967. The other three sites have since been converted to sanitary landfills. An additional 165,000 tons of refuse are disposed of at landfills in Pima County. There are no municipal incinerators in the Study Area, but about 90,000 tons are disposed of at on-site commercial, industrial, and residential incinerators.

Excluding Maricopa and Pima Counties, there is a lack of information on solid waste disposal sites in the Study Area. However, open burning is prevalent, and it was assumed that all refuse generated was disposed of by open burning. An average generation rate of 4.5 pounds per capita per day was used. Emissions from solid wastes disposal were apportioned on the basis of population.

As indicated in Table 11, solid waste disposal by open burning and on-site incineration contributes 40 tons of sulfur oxides, 3,200 tons of particulate matter, 17,400 tons of carbon-monoxide, 5,720 tons of hydrocarbons, and 2,140 tons of nitrogen oxides annually. The bulk of emissions from solid wastes disposal are attributable to open burning activities.

## Industrial Process Losses

The Study Area is notably void of any heavy industrial complexes with the exception of the copper smelting industry. From an air pollution standpoint, the copper smelters, sand and gravel operations, and cotton ginning operations are the most significant industrial process sources of air pollutants. The industries that generate air pollutant emissions from their processes include 5 asphalt batching plants, a portland

TABLE 10 SOLID WASTES DISPOSAL BY JURISDICTION

1967, (TONS/YEAR)

| County | Amount Generated | Landfill | Incineration | Open Burning |
|---|---|---|---|---|
| Cochise | 51,000 | N | N | 51,000 |
| Gila | 26,000 | N | N | 26,000 |
| Graham | 13,000 | N | N | 13,000 |
| Greenlee | 10,000 | N | N | 10,000 |
| Maricopa | 895,000 | 690,000 | 80,000 | 125,000 |
| Pima | 260,000 | 165,000 | 10,000 | 85,000 |
| Pinal | 53,000 | N | N | 53,000 |
| Santa Cruz | 12,000 | N | N | 12,000 |
| TOTAL | 1,320,000 | 855,000 | 90,000 | 375,000 |

N = Negligible

TABLE 11 AIR POLLUTANT EMISSIONS FROM SOLID WASTE DISPOSAL, 1967 (TONS/YEAR)

| County | Source | Sulfur Oxides | Partic-ulates | Carbon Monoxide | Hydro Carbons | Nitrogen Oxides |
|---|---|---|---|---|---|---|
| Cochise | Open Burning | -- | 410 | 2,160 | 770 | 280 |
| Gila | Open Burning | -- | 205 | 1,080 | 340 | 140 |
| Graham | Open Burning | -- | 105 | 560 | 200 | 70 |
| Greenlee | Open Burning | -- | 80 | 420 | 160 | 50 |
| Maricopa | Open Burning | -- | 1,000 | 5,370 | 1,970 | 690 |
| | Incineration | 36 | 120 | 390 | 20 | 80 |
| Pima | Open Burning | -- | 680 | 3,600 | 1,260 | 480 |
| | Incineration | 4 | 80 | 1,070 | 10 | 4 |
| Pinal | Open Burning | -- | 430 | 2,270 | 810 | 290 |
| Santa Cruz | Incineration | -- | 90 | 490 | 175 | 60 |
| TOTAL | | 40 | 3,200 | 17,400 | 5,720 | 2,140 |

cement manufacturing plant, numerous cotton ginning operations, 8 copper smelters, 8 metal operations, 20 sand and gravel plants, 2 chemical plants, and a number of miscellaneous operations.

As is the case in any emission inventory, the lack of emission factors and process information for some industrial processes did not allow a complete estimation of process emissions. Most notably lacking are emission factors for particulate matter from copper smelting operations. Despite the fact that most of the smelters are equipped with electrostatic precipitators, significant quantities of dust and fumes are emitted. However, the lack of an emission factor prevented a quantitative analysis of particulate matter emissions from smelters.

The 5 asphalt batching plants produce about 860,000 tons per year of asphalt. The plants range in size from 120 to 1100 tons per day. The three largest plants are equipped with a combination of cyclones and wet scrubbers while the other two plants are uncontrolled.

A portland cement plant located in Pima County produces 1.8 million barrels of cement annually by the dry process. The kilns are equipped with electrostatic precipitators, and the rotary driers are equipped with fabric baghouses.

The State of Arizona leads the nation in copper production. All of the copper smelters located in Arizona are included in the Study Area. In 1967, the 8 copper smelters produced 502,000 tons of copper. This tonnage accounted for about 53 percent of the total U.S. production of copper.[3] Arizona's production would have been even higher except for an industry-wide strike from July, 1967, to March, 1968. All of the smelters use reverberatory furnaces and converters. Most of the plants are equipped with electrostatic precipitators for recovery purposes. In addition, about 94,000 tons per year of sulfuric acid is produced from a sulfur recovery plant located next to one of the smelters.

There are about 20 sand and gravel operations processing more than 2.3 million tons of aggregate per year. A few of the plants utilize wet scrubbers on the crushing units, but most are uncontrolled. In addition to the handling of aggregate, about 700,000 cubic yards of concrete are produced at the plants that contain ready-mix facilities.

There are 5 steel foundries and 3 non-ferrous foundries operating in the Study Area. About 170,000 tons of steel castings are produced annually. Most of the steel is produced in electric arc furnaces that are equipped with wet scrubbers or baghouses.

In 1967, 245,000 acres of land were devoted to the production of cotton in Arizona.[3] 90 percent of this acreage was located in the Study Area as shown on Table 12. At an annual yield of 901 pounds of cotton per acre, about 99,000 tons of cotton were produced in the Study Area. Cotton ginning operations are a large source of fires, lint and dust during the harvest months. Most of the gins are equipped with cyclones.

There are a couple of chemical plants in the Study Area. Among these are producers of sulfuric acid, nitric acid, ammonium nitrate, ammonia and nitroglycerin. The quantities of these chemicals produced is not significant.

There are a number of miscellaneous establishments in the Study Area that contribute a small amount to the total air pollutant emissions. They include a beet sugar processing plant, a brick manufacturing plant and a number of grain mills.

The various industries in the area were contacted for fuel use and process information. Much of these data were available in the State and local agencies' files. From this information, industrial process losses were determined with appropriate emission factors.[2]

Air pollutants from industrial process losses amount to 2,062,000 tons of suffur oxides, 13,000 tons of particulate matter and 1,000 tons of oxides of nitrogen. The emissions of carbon monoxide and hydrocarbons are negligible. The breakdown of air pollutant emissions by process types is shown on Table 13.

The copper smelting industry generated more than 2 million tons of sulfur oxides. The Study Area thus has one of the highest rates of sulfur oxides emissions in the nation. According to a recent NAPCA survey, an estimated 31 million tons of sulfur oxides are emitted annually by all sources in the nation.[12] Thus, the Study Area contains about 7 percent of the total emissions of sulfur oxides throughout the country.

TABLE 12 DISTRIBUTION OF CROP ACREAGE BY COUNTY, 1967 (ACRES)

| County | Alfalfa | Citrus | Cotton | Grains | Vegetables | Total |
|---|---|---|---|---|---|---|
| Cochise | 8,300 | -- | 8,654 | 90,050 | 2,100 | 114,604 |
| Gila | 400 | -- | 11 | 50 | -- | 761 |
| Graham | 5,300 | -- | 13,200 | 38,550 | -- | 59,000 |
| Greenlee | 1,500 | -- | 1,215 | 2,950 | -- | 5,815 |
| Maricopa | 97,700 | 16,700 | 92,300 | 226,000 | 52,120 | 510,880 |
| Pima | 1,800 | 50 | 16,140 | 31,700 | 2,030 | 52,460 |
| Pinal | 21,000 | 380 | 87,400 | 99,000 | 7,090 | 222,270 |
| Santa Cruz | 800 | -- | 120 | 1,000 | -- | 2,420 |
| STATE TOTAL | 196,000 | 41,335 | 245,000 | 589,000 | 93,750 | 1,222,000 |

TABLE 13 AIR POLLUTANT EMISSIONS FROM INDUSTRIAL PROCESS SOURCES, 1967 (TONS/YEAR)

| Source | Sulfur Oxides | Particulates | Carbon Monoxide | Hydro Carbons | Nitrogen Oxides |
|---|---|---|---|---|---|
| Asphalt Batching | N | 620 | N | N | N |
| Cement Manufacturing | N | 450 | N | N | 260 |
| Cotton Ginning | N | 2,400 | N | N | N |
| Copper Smelting | 2,062,000 | N.A. | N.A. | N.A. | N.A. |
| Grain Milling | N | 950 | N | N | N |
| Metal Operations | N | 330 | 360 | N | N |
| Sand and Gravel Operations | N | 8,230 | N | N | N |
| Other | 290 | N | N | N | 730 |
| TOTAL | 2,062,000 | 13,000 | 360 | N | 1,000 |

N = Negligible

N.A. = Not available

The dust and fumes generated from sand and gravel operations accounts for about 60 percent of the particulate matter generated by industrial process losses. Cotton ginning operations contribute an additional 20 percent. The remainder of particulate emissions is generated by diverse sources.

## Organic Solvent Evaporation

Hydrocarbons are emitted during the evaporation of organic solvents used for various purposes. For the purpose of this survey, hydrocarbon emissions from evaporation due to gasoline marketing and "cutback" asphalt are included in this section also. Solvents are used for many miscellaneous purposes such as dry cleaning, painting, degreasing, printing, etc.

### Solvent Use

The Maricopa County Health Department estimates the per capita solvent usage as 24.5 pounds of solvents per year in Maricopa County.[13] Of this total, 3.9 pounds are used for dry cleaning, 8.1 pounds are used for surface coating operations (including painting), and 12.5 pounds are used for industrial and other domestic uses. Using these values but adjusting the per capita consumption of solvents for industrial uses by the ratio of manufacturing employment for the other counties, the resulting hydrocarbon emissions are shown on Table 14. It was assumed that all solvents used are eventually emitted into the air by evaporation.

### Gasoline Marketing

There are four major points (excluding evaporation from the motor vehicle) of hydrocarbon emissions in the storage and handling of gasoline. They are:

1. Breathing and filling losses from storage tanks.
2. Filling losses from loading tank conveyances.
3. Filling losses from loading underground storage tanks at service stations.
4. Spillage and filling losses in filling automobile gas tanks at service stations.

Based on estimates of gasoline marketing losses from the Maricopa County Health Department, it is estimated that about 0.8 percent of the 520 million gallons consumed is lost by evaporation.[13] The resulting hydrocarbon emissions by county are shown on Table 14.

### Asphalt-"Cutback"

The yearly use of cutback asphalt for the Study Area amounts to about 25,000 tons annually. About half of this total was used for road in Maricopa County. Assuming that the volatile solvent used is 30 percent of the cutback asphalt and 95 percent of the solvents are eventually airborne, 7,200 tons per year of hydrocarbons are emitted (see Table 14).

## Agriculture

Agriculture is an important aspect of Arizona's economy. The value of agricultural crops in 1967 was estimated at 273 million dollars. Agricultural operations can be a significant contributor to air pollution, especially during the harvest season.

Among the operations that can contribute significant amounts of emissions are: the burning of brush, crops, and fields; the application of pesticides by aircraft; and the combustion of fuels to operate farm machinery. In this survey, only the latter two categories were considered.

### Pesticide Application

An estimate of particulate emissions from the aircraft spraying of pesticides was available for Maricopa County.[13] Emissions for the other counties were estimated by proportioning the crop acreage by county to the Maricopa County statistics. The resulting emissions are 3,300 tons of particulate matter in 1967.

### Combustion of Fuels

From the data listed in the previous sections, 14.1 billion cubic feet of natural gas, 50 million gallons of distillate fuel oil, 1.9 million gallons of residual fuel oil, and 6 million gallons of liquified petroleum gases were consumed for agricultural operations.

TABLE 14 SUMMARY OF HYDROCARBON EMISSIONS FROM ORGANIC SOLVENT EVAPORATION, 1967 (TONS/YEAR)

| County | Solvent Use | Gasoline Marketing | Asphalt (Cut-back) | TOTAL |
|---|---|---|---|---|
| Cochise | 620 | 620 | 870 | 2,100 |
| Gila | 260 | 320 | 390 | 970 |
| Graham | 130 | 160 | 220 | 510 |
| Greenlee | 70 | 80 | 90 | 240 |
| Maricopa | 10,900 | 7,750 | 3,320 | 22,000 |
| Pima | 3,150 | 2,790 | 1,100 | 7,040 |
| Pinal | 590 | 570 | 1,040 | 2,200 |
| Santa Cruz | 100 | 130 | 190 | 420 |
| TOTAL | 15,800 | 12,400 | 7,200 | 35,500 |

TABLE 15 AIR POLLUTANT EMISSIONS FROM AGRICULTURAL OPERATIONS, 1967 (TONS/YEAR)

| Source | Sulfur Oxides | Partic-ulates | Carbon Monoxide | Hydro Carbons | Nitrogen Oxides |
|---|---|---|---|---|---|
| Fuel Combustion | | | | | |
| Distillate Fuel Oil | 1,240 | 1,960 | 980 | 2,200 | 4,620 |
| Residual Fuel Oil | 240 | 20 | N | N | 70 |
| Natural Gas | N | 130 | N | N | 810 |
| Liquified Petroleum Gas | N | 5 | N | N | 20 |
| Pesticide Application | N | 3,300 | N | N | N |
| TOTAL | 1,480 | 5,400 | 980 | 2,200 | 5,520 |

N = Negligible

Most of this fuel was used to operate farm machinery such as tractors, pumps, generators, and harvesting equipment.

A summary of emissions from agricultural operations is presented in Table 15. The maximum contribution to any pollutant is 15 percent of the total emissions of particulate matter. This percentage is somewhat higher during the harvest months when there is an increase in agricultural activities.

## EMISSIONS BY JURISDICTION

The previous section presents the emissions by source category and, in some cases, by jurisdiction. The emissions by county and source are summarized here in Tables 16 through 19. Table 16, Table 17, and Table 18 show the emissions in Maricopa, Pima, and Pinal Counties, respectively. The emissions are shown for the remaining five counties collectively in Table 19.

As is expected due to a higher degree of urbanization than the other counties, Maricopa County and Pima County contribute the majority of air pollutants with the exception of sulfur oxides. As shown on Table 20, Maricopa County contributes a minumum of 40 percent of any pollutant and Pima County contributes a minumum of 22 percent of any pollutant (excepting sulfur oxides). On the other hand, Maricopa and Pima Counties, collectively, account for only 8 percent of total sulfur oxides emissions. Naturally, the reason Cochise, Gila, Greenlee, and Pinal Counties account for 92 percent of the sulfur oxides emissions is because seven of the eight copper smelters are located in those counties.

TABLE 16 SUMMARY OF AIR POLLUTANT EMISSIONS IN MARICOPA COUNTY, 1967 (TONS/YEAR)

| Source Category | Sulfur Oxides | Partic-ulates | Carbon Monoxide | Hydro Carbons | Nitrogen Oxides |
|---|---|---|---|---|---|
| Transportation | | | | | |
| Motor Vehicles | 1,700 | 2,790 | 321,600 | 44,800 | 21,000 |
| Other | 120 | 1,870 | 9,020 | 4,040 | 2,060 |
| Total | 1,820 | 4,660 | 330,600 | 48,800 | 23,100 |
| Fuel Combustion in Stationary Sources | | | | | |
| Industrial | 90 | 240 | 130 | 300 | 1,310 |
| Steam-Electric | 10 | 150 | N | N | 3,760 |
| Residential | 40 | 140 | 15 | 3 | 810 |
| Commercial-Institutional | 10 | 30 | 15 | 40 | 520 |
| Total | 150 | 560 | 160 | 340 | 6,400 |
| Solid Waste Disposal | 40 | 1,120 | 5,760 | 1,990 | 770 |
| Industrial Process | 290 | 5,090 | 310 | N | N |
| Solvent Evaporation | N | N | N | 22,000 | N |
| Agriculture | 140 | 2,220 | 200 | 460 | 1,160 |
| GRAND TOTAL | 2,400 | 13,700 | 337,000 | 73,600 | 31,400 |

N = Negligible

TABLE 17 SUMMARY OF AIR POLLUTANT EMISSIONS IN PIMA COUNTY, 1967 (TONS/YEAR)

| Source Category | Sulfur Oxides | Particulates | Carbon Monoxide | Hydro Carbons | Nitrogen Oxides |
|---|---|---|---|---|---|
| Transportation | | | | | |
| Motor Vehicles | 630 | 1,040 | 111,700 | 15,900 | 7,590 |
| Other | 150 | 1,110 | 3,310 | 1,280 | 1,400 |
| Total | 780 | 2,150 | 115,000 | 17,200 | 9,000 |
| Fuel Combustion in Stationary Sources | | | | | |
| Industrial | 440 | 1,170 | 630 | 1,420 | 2,640 |
| Steam-Electric | 3 | 120 | N | N | 3,110 |
| Residential | 15 | 60 | 4 | N | 360 |
| Commercial-Institutional | 80 | 170 | 70 | 160 | 500 |
| Total | 540 | 1,520 | 700 | 1,580 | 6,610 |
| Solid Waste Disposal | 4 | 760 | 4,670 | 1,270 | 480 |
| Industrial Process | 154,000 | 6,780 | 50 | N | 260 |
| Solvent Evaporation | N | N | N | 7,040 | N |
| Agriculture | 230 | 370 | 130 | 290 | 710 |
| GRAND TOTAL | 155,500 | 11,600 | 121,000 | 27,400 | 17,100 |

N = Negligible

TABLE 18 SUMMARY OF AIR POLLUTANT EMISSIONS IN PINAL COUNTY, 1967 (TONS/YEAR)

| Source Category | Sulfur Oxides | Partic-ulates | Carbon Monoxide | Hydro Carbons | Nitrogen Oxides |
|---|---|---|---|---|---|
| Transportion | | | | | |
| Motor Vehicles | 150 | 270 | 20,400 | 3,130 | 1,630 |
| Other | 180 | 490 | 270 | 610 | 270 |
| Total | 330 | 760 | 20,700 | 3,740 | 1,900 |
| Fuel Combustion in Stationary Sources | | | | | |
| Industrial | 80 | 190 | 100 | 230 | 430 |
| Steam-Electric | N | 10 | N | N | 220 |
| Residential | 5 | 10 | N | N | 60 |
| Commercial-Institutional | 20 | 30 | 10 | 30 | 90 |
| Total | 110 | 240 | 110 | 260 | 800 |
| Solid Waste Disposal | N | 430 | 2,270 | 810 | 290 |
| Industrial Process | 303,000 | 920 | N | N | N |
| Solvent Evaporation | N | N | N | 2,200 | N |
| Agriculture | 600 | 1,540 | 350 | 780 | 2,010 |
| GRAND TOTAL | 304,000 | 3,900 | 23,400 | 7,800 | 5,000 |

N = Negligible

TABLE 19 SUMMARY OF AIR POLLUTANT EMISSIONS IN FIVE-COUNTY AREA,* 1967 (TONS/YEAR)

| Source Category | Sulfur Oxides | Particulates | Carbon Monoxide | Hydro Carbons | Nitrogen Oxides |
|---|---|---|---|---|---|
| Transportation | | | | | |
| Motor Vehicles | 320 | 600 | 47,300 | 7,300 | 3,700 |
| Other | 650 | 1,730 | 1,000 | 1,170 | 970 |
| Total | 970 | 2,330 | 48,300 | 8,500 | 4,700 |
| Fuel Combustion in Stationary Sources | | | | | |
| Industrial | 160 | 400 | 200 | 450 | 720 |
| Steam-Electric | N | 10 | N | N | 410 |
| Residential | 10 | 20 | 5 | N | 70 |
| Commercial-Institutional | 40 | 70 | 20 | 60 | 190 |
| Total | 210 | 500 | 220 | 510 | 1,400 |
| Solid Waste Disposal | N | 890 | 4,700 | 1,650 | 580 |
| Industrial Process | 1,604,000 | 210 | N | N | 740 |
| Solvent Evaporation | N | N | N | 4,300 | N |
| Agriculture | 510 | 1,270 | 300 | 670 | 1,620 |
| GRAND TOTAL | 1,605,000 | 5,200 | 54,000 | 15,600 | 9,000 |

N = Negligible

* Cochise, Gila, Graham, Greenlee, and Santa Cruz Counties

TABLE 20 RELATIVE CONTRIBUTION OF EACH COUNTY TO TOTAL AIR POLLUTANT EMISSIONS, (PERCENT)

| County | Sulfur Oxides | Partic-ulates | Carbon Monoxide | Hydro Carbons | Nitrogen Oxides |
|---|---|---|---|---|---|
| Cochise | 27 | 7 | 5 | 6 | 8 |
| Gila | 30 | 3 | 2 | 3 | 3 |
| Graham | N | 4 | 1 | 2 | 2 |
| Greenlee | 20 | 1 | 1 | 1 | 1 |
| Maricopa | N | 40 | 63 | 59 | 50 |
| Pima | 8 | 33 | 23 | 22 | 27 |
| Pinal | 15 | 11 | 4 | 6 | 8 |
| Santa Cruz | N | 1 | 1 | 1 | 1 |

N = Negligible

## EMISSIONS BY GRID

For the purpose of defining the geographical variation of air pollutant emissions in the Study Area, the resulting emissions were apportioned on the grid coordinate system. The emissions were divided into two source groups--point and area sources. Twenty-nine point sources are identified individually with respect to location and emissions. Each of these point sources emits more than 1 ton per day of any pollutant.

### Contribution of Point Sources

Figure 3 shows the location of all point sources in the area. Collectively the twenty-nine point sources account for 99.7 percent of sulfur oxides, 32 percent of particulate matter, 16 percent of nitrogen oxides, and only 2 percent of carbon monoxide and 2 percent of hydrocarbon emissions. The percent contribution to carbon monoxide emissions is low because motor vehicles, which are area sources contribute 94 percent of total carbon monoxide emissions. Similarly, the contribution to total hydrocarbon emissions is low since two groups of area sources, motor vehicles and organic solvent evaporation, are the major contributors. Table 21 presents the emissions of point sources. It is assumed that the seasonal variations in point source emissions are negligible.

Area sources are sources of emissions that are insignificant by themselves, but as a group emit a significant amount. Examples of area sources are motor vehicles, residences, light commercial and industrial establishments, and backyard burning. The emissions from area sources have been added to that for point sources to obtain total emissions by grid as shown on Table 22.

The emissions are presented for an annual average day, an average winter (December, January, February) day, and an average summer (June, July, August) day. The annual average daily emission rates were obtained by dividing yearly totals by 365 days per year. Seasonal averages were calculated by the use of space heating variations in fuel consumption and variations in motor vehicular traffic activity. Other sources were assumed to be constant throughout the year.

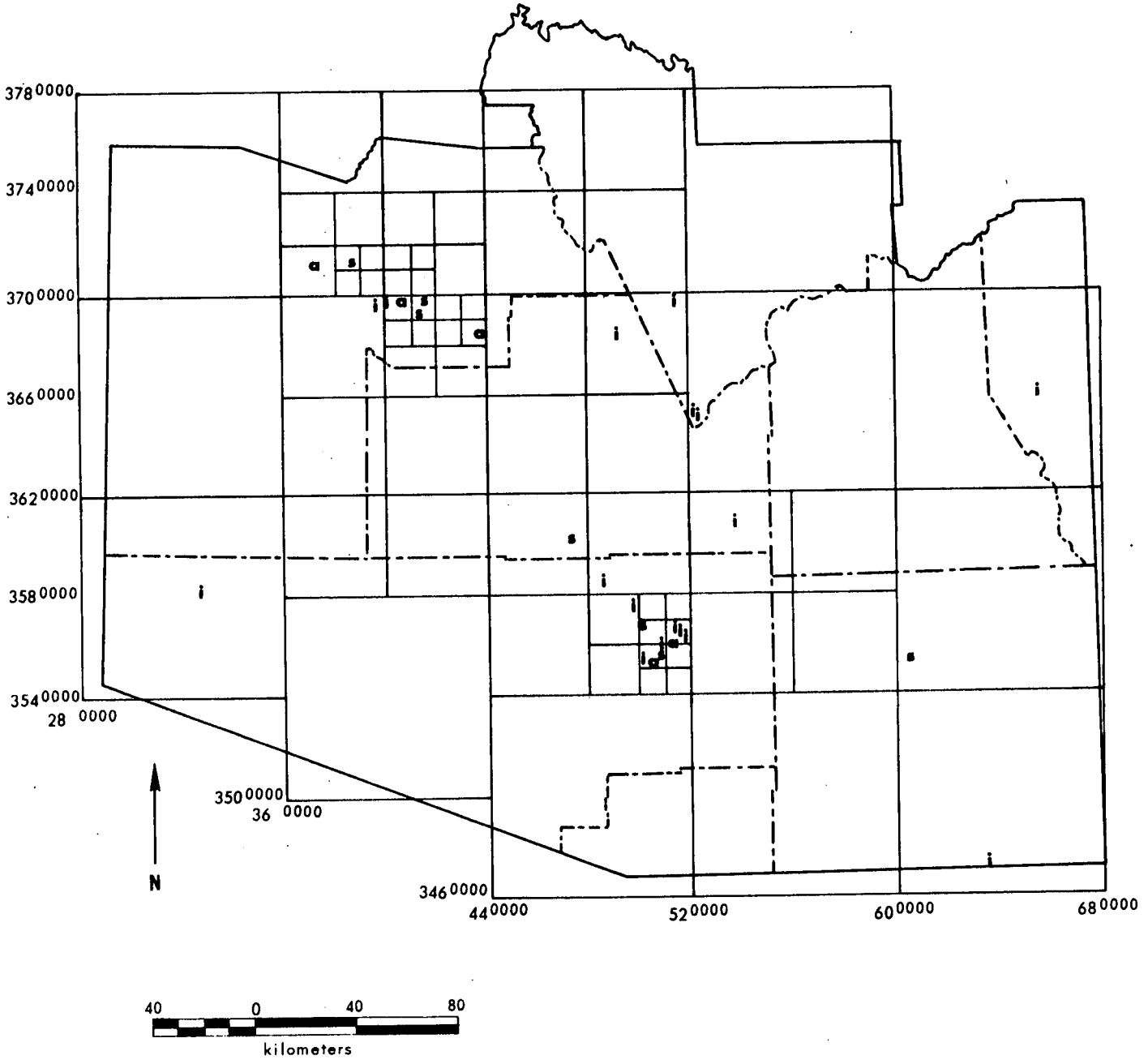


Figure 3. Location of point sources in the Phoenix-Tucson area

i industry

s steam-electric utility

a airport

TABLE 21 SUMMARY OF EMISSIONS FROM POINT SOURCES IN THE PHOENIX-TUCSON AREA, (TONS/AVERAGE DAY)

| Source | Easting (100 m.) | Northing (100 m.) | Sulfur Oxides | Partic-ulates | Carbon Monoxide | Hydro Carbons | Nitrogen Oxides |
|---|---|---|---|---|---|---|---|
| Industry | 4862 | 35860 | -- | 1.23 | -- | -- | 0.72 |
| Industry | 5012 | 35549 | -- | 2.50 | -- | -- | -- |
| Industry | 5168 | 35627 | -- | 2.50 | -- | -- | -- |
| Industry | 5095 | 35585 | -- | 2.13 | -- | -- | -- |
| Industry | 5156 | 35658 | -- | 3.97 | -- | -- | -- |
| Industry | 4985 | 35745 | -- | 3.30 | -- | -- | -- |
| Industry | 5315 | 35678 | -- | 1.50 | -- | -- | -- |
| Industry | 4000 | 36980 | -- | 3.06 | -- | -- | -- |
| Industry | 3977 | 36974 | -- | 2.41 | -- | -- | -- |
| Industry | 3260 | 35820 | 420 | -- | -- | -- | -- |
| Industry | 6360 | 34680 | 1520 | -- | -- | -- | -- |
| Industry | 6550 | 36590 | 1150 | -- | -- | -- | -- |
| Industry | 5215 | 36520 | 560 | -- | -- | -- | -- |
| Industry | 5205 | 36525 | 610 | -- | -- | -- | -- |
| Industry | 5130 | 36975 | 450 | -- | -- | -- | -- |
| Industry | 5360 | 36080 | 650 | -- | -- | -- | -- |
| Industry | 4920 | 36830 | 180 | -- | -- | -- | -- |
| Power Plant | 6050 | 35530 | -- | .04 | -- | -- | 1.04 |
| Power Plant | 4153 | 36982 | -- | .11 | -- | -- | 2.89 |
| Power Plant | 4130 | 36910 | -- | .05 | -- | -- | 1.15 |
| Power Plant | 3872 | 37132 | -- | .27 | -- | -- | 6.28 |
| Power Plant | 4720 | 36020 | -- | .02 | -- | -- | 0.60 |
| Power Plant | 5095 | 35582 | -- | .30 | -- | -- | 7.88 |
| Power Plant | 5008 | 35680 | -- | .02 | -- | -- | 0.62 |
| Airport | 4060 | 36980 | -- | .35 | 19.10 | 3.85 | 1.22 |
| Airport | 3720 | 37120 | -- | 2.57 | 3.75 | 0.96 | 1.79 |
| Airport | 4380 | 36850 | -- | 1.35 | 1.39 | 0.40 | 0.91 |
| Airport | 5050 | 35540 | -- | 1.12 | 7.31 | 1.47 | 1.05 |
| Airport | 5110 | 35600 | -- | .82 | 1.14 | 0.32 | 0.57 |

TABLE 22 SUMMARY OF EMISSIONS BY GRID IN THE PHOENIX-TUCSON AREA, 1967 (TONS/DAY)

| Grid | Easting (100 m.) | Northing (100 m.) | Area (sq. mi) | SOx S | SOx W | SOx A | PART. S | PART. W | PART. A | CO S | CO W | CO A | HC S | HC W | HC A | NOx S | NOx W | NOx A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3200 | 37400 | 2471 | .24 | .23 | .23 | 1.03 | .99 | 1.02 | 32.62 | 29.84 | 31.08 | 5.55 | 5.13 | 4.71 | 2.50 | 2.34 | 2.40 |
| 2 | 3800 | 37600 | 618 | .05 | .05 | .05 | .08 | .07 | .07 | 8.11 | 7.42 | 7.73 | 1.29 | 1.18 | 1.23 | .61 | .56 | .58 |
| 3 | 4200 | 37600 | 618 | .06 | .06 | .06 | .10 | .09 | .09 | 8.16 | 7.47 | 7.78 | 1.45 | 1.34 | 1.39 | .63 | .59 | .61 |
| 4 | 4600 | 37600 | 618 | .09 | .08 | .08 | .18 | .18 | .18 | 10.10 | 9.27 | 9.64 | 1.93 | 1.80 | 1.86 | .82 | .78 | .79 |
| 5 | 5000 | 37600 | 618 | .01 | .01 | .01 | .05 | .05 | .05 | 1.80 | 1.66 | 1.72 | .31 | .29 | .30 | .15 | .15 | .15 |
| 6 | 3700 | 37300 | 154 | .20 | .19 | .20 | .29 | .28 | .28 | 24.50 | 22.41 | 23.34 | 4.47 | 4.15 | 4.29 | 1.92 | 1.81 | 1.85 |
| 7 | 3900 | 37300 | 154 | .12 | .12 | .12 | .49 | .71 | .65 | 16.31 | 14.92 | 15.54 | 2.88 | 2.67 | 2.76 | 1.27 | 1.19 | 1.22 |
| 8 | 4100 | 37300 | 154 | .13 | .14 | .13 | .52 | .52 | .52 | 8.34 | 7.65 | 7.96 | 2.37 | 2.26 | 2.31 | .77 | .78 | .76 |
| 9 | 4300 | 37300 | 154 | .07 | .07 | .07 | .37 | .37 | .37 | 8.19 | 7.50 | 7.81 | 1.66 | 1.55 | 1.60 | .66 | .64 | .64 |
| 10 | 3700 | 37100 | 154 | .26 | .26 | .26 | 3.56 | 4.13 | 3.65 | 28.43 | 26.33 | 27.26 | 6.11 | 5.79 | 5.93 | 3.81 | 3.74 | 3.75 |
| 11 | 3850 | 37150 | 39 | .22 | .22 | .22 | .52 | .52 | .52 | 16.55 | 15.27 | 15.78 | 4.14 | 3.93 | 4.02 | 7.73 | 7.70 | 7.72 |
| 12 | 3950 | 37150 | 39 | .57 | .56 | .57 | .61 | .98 | .88 | 28.77 | 26.41 | 27.46 | 9.44 | 9.11 | 9.26 | 2.62 | 2.80 | 2.66 |
| 13 | 4050 | 37150 | 39 | .31 | .30 | .31 | .38 | .38 | .38 | 28.05 | 25.69 | 26.74 | 6.09 | 5.76 | 5.90 | 2.12 | 2.10 | 2.09 |
| 14 | 4150 | 37150 | 39 | .07 | .07 | .07 | .11 | .10 | .11 | 8.19 | 7.50 | 7.81 | 1.66 | 1.55 | 1.60 | .66 | .64 | .63 |
| 15 | 3850 | 37050 | 39 | .15 | .15 | .15 | .21 | .20 | .20 | 18.53 | 16.95 | 17.65 | 3.38 | 3.16 | 3.26 | 1.32 | 1.26 | 1.28 |
| 16 | 3950 | 37050 | 39 | 1.14 | 1.10 | 1.12 | 1.76 | 1.79 | 1.76 | 97.76 | 89.54 | 93.19 | 21.31 | 20.22 | 20.79 | 6.72 | 6.78 | 6.65 |
| 17 | 4050 | 37050 | 39 | 1.98 | 1.93 | 1.95 | 1.56 | 2.64 | 2.55 | 142.11 | 130.25 | 135.52 | 34.98 | 33.44 | 34.12 | 10.33 | 10.66 | 10.32 |
| 18 | 4150 | 37050 | 39 | .50 | .50 | .50 | .50 | .53 | .51 | 19.50 | 17.93 | 18.63 | 7.87 | 7.65 | 7.75 | 1.97 | 2.18 | 2.02 |
| 19 | 4300 | 37100 | 154 | .16 | .16 | .16 | 1.46 | 1.45 | 1.46 | 16.38 | 14.99 | 15.61 | 3.32 | 3.11 | 3.20 | 1.33 | 1.28 | 1.29 |
| 20 | 4600 | 37200 | 618 | .13 | .20 | .15 | .19 | .20 | .19 | 14.66 | 13.44 | 13.97 | 2.77 | 2.58 | 2.66 | 1.26 | 1.18 | 1.21 |
| 21 | 5000 | 37200 | 618 | .14 | .22 | .17 | .28 | .29 | .28 | 11.28 | 10.40 | 10.79 | 2.69 | 2.60 | 2.62 | 1.05 | 1.03 | 1.03 |
| 22 | 5600 | 37400 | 2471 | .08 | .07 | .07 | .18 | .17 | .17 | 8.59 | 7.88 | 8.19 | 1.57 | 1.46 | 1.51 | .73 | .68 | .70 |

TABLE 22 SUMMARY OF EMISSIONS BY GRID (cont.)

| Grid | Easting (100 m.) | Northing (100 m.) | Area (sq. mi.) | SOx | | | PART. | | | CO | | | HC | | | NOx | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | S | W | A | S | W | A | S | W | A | S | W | A | S | W | A |
| 23 | 3200 | 36600 | 2471 | .16 | .16 | .16 | 2.19 | 2.86 | 2.70 | 16.38 | 15.00 | 15.61 | 3.22 | 3.11 | 3.20 | 1.33 | 1.28 | 1.29 |
| 24 | 3800 | 36800 | 618 | .45 | .47 | .46 | 4.51 | 5.09 | 4.93 | 25.15 | 23.08 | 24.00 | 7.66 | 7.35 | 7.49 | 2.38 | 2.46 | 2.38 |
| 25 | 4050 | 36950 | 39 | 1.03 | .99 | 1.01 | 5.69 | 5.70 | 5.68 | 103.43 | 96.34 | 99.49 | 22.87 | 21.90 | 22.34 | 7.73 | 7.70 | 7.63 |
| 26 | 4150 | 36950 | 39 | .64 | .61 | .62 | 1.40 | 1.39 | 1.39 | 75.33 | 68.94 | 71.78 | 13.47 | 12.65 | 13.01 | 8.81 | 8.68 | 8.69 |
| 27 | 4250 | 36950 | 39 | .71 | .68 | .69 | .91 | 1.00 | .98 | 85.98 | 78.68 | 81.92 | 15.14 | 14.19 | 14.61 | 5.41 | 5.24 | 5.28 |
| 28 | 4350 | 36950 | 39 | .09 | .09 | .09 | .12 | .35 | .29 | 9.34 | 8.55 | 8.90 | 1.89 | 1.78 | 1.83 | .69 | .68 | .68 |
| 29 | 4050 | 36850 | 39 | .11 | .11 | .11 | .19 | .18 | .18 | 16.30 | 14.91 | 15.53 | 2.75 | 2.54 | 2.63 | 1.24 | 1.16 | 1.19 |
| 30 | 4150 | 36850 | 39 | .12 | .12 | .12 | .19 | .18 | .18 | 16.31 | 14.92 | 15.54 | 2.88 | 2.67 | 2.82 | 1.27 | 1.19 | 1.22 |
| 31 | 4250 | 36850 | 39 | .96 | .96 | .96 | .22 | .45 | .38 | 18.53 | 16.95 | 17.65 | 3.51 | 3.29 | 3.39 | 1.33 | 1.28 | 1.29 |
| 32 | 4350 | 36850 | 39 | .15 | .15 | .15 | 1.56 | 1.66 | 1.65 | 19.94 | 18.34 | 18.94 | 3.78 | 3.56 | 3.66 | 2.23 | 2.17 | 2.19 |
| 33 | 4100 | 36700 | 154 | .07 | .07 | .07 | .42 | .42 | .42 | 9.42 | 8.62 | 8.98 | 1.63 | 1.51 | 1.57 | .73 | .69 | .70 |
| 34 | 4300 | 36700 | 154 | .13 | .12 | .13 | .60 | 1.15 | 1.02 | 11.84 | 10.86 | 11.30 | 2.64 | 2.48 | 2.55 | 1.11 | 1.07 | 1.08 |
| 35 | 4600 | 36800 | 618 | .13 | .12 | .13 | .64 | 1.37 | 1.20 | 11.84 | 10.86 | 11.30 | 2.64 | 2.48 | 2.55 | 1.11 | 1.07 | 1.08 |
| 36 | 5000 | 36800 | 618 | 630.00 | 630.00 | 630.00 | .46 | .45 | .45 | 19.04 | 17.52 | 18.19 | 3.96 | 3.74 | 3.84 | 1.56 | 1.51 | 1.52 |
| 37 | 3800 | 36400 | 618 | .07 | .07 | .07 | .11 | .10 | .11 | 7.37 | 6.74 | 7.02 | 1.60 | 1.50 | 1.55 | .66 | .63 | .64 |
| 38 | 4200 | 36400 | 618 | .17 | .16 | .16 | .41 | 1.21 | 1.02 | 15.07 | 13.90 | 14.41 | 3.41 | 3.23 | 3.31 | 1.37 | 1.33 | 1.33 |
| 39 | 4600 | 36400 | 618 | .15 | .16 | .15 | .38 | 1.45 | 1.17 | 10.45 | 9.66 | 10.01 | 2.90 | 2.78 | 2.83 | .95 | .96 | .94 |
| 40 | 5000 | 36400 | 618 | .05 | .05 | .05 | .13 | .14 | .13 | 3.40 | 3.16 | 3.27 | .98 | .94 | .96 | .33 | .33 | .33 |
| 41 | 5600 | 36600 | 2471 | 1170.0 | 1170.0 | 1170.00 | .56 | .56 | .56 | 16.30 | 15.07 | 15.61 | 4.13 | 3.94 | 4.03 | 1.56 | 1.55 | 1.53 |
| 42 | 6400 | 36600 | 2471 | 1150.0 | 1150.0 | 1150.00 | .68 | 1.19 | 1.07 | 23.16 | 21.36 | 22.16 | 5.52 | 5.26 | 5.38 | 2.00 | 1.99 | 1.97 |
| 43 | 3200 | 35800 | 2471 | 420.00 | 420.00 | 420.00 | .32 | .32 | .33 | 29.38 | 26.88 | 27.99 | 5.23 | 4.86 | 5.02 | 2.29 | 2.16 | 2.21 |
| 44 | 3800 | 36000 | 618 | .08 | .10 | .09 | .14 | .13 | .13 | 10.00 | 9.16 | 9.53 | 1.81 | 1.68 | 1.74 | .84 | .78 | .80 |
| 45 | 4200 | 36000 | 618 | .04 | .06 | .05 | .10 | .10 | .10 | 4.38 | 4.04 | 4.19 | .97 | .92 | .95 | .38 | .37 | .37 |

TABLE 22 SUMMARY OF EMISSIONS BY GRID (cont.)

| Grid | Easting (100 m.) | Northing (100 m.) | Area (sq. mi.) | S | W | A | S | W | A | S | W | A | S | W | A | S | W | A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 46 | 4600 | 36000 | 618 | .14 | .14 | .13 | .29 | 1.69 | 1.36 | 16.07 | 14.73 | 15.33 | 3.07 | 2.85 | 2.95 | 2.03 | 1.94 | 1.98 |
| 47 | 5000 | 36000 | 618 | .12 | .11 | .11 | 1.57 | 1.62 | 1.57 | 13.28 | 12.16 | 12.66 | 2.57 | 2.39 | 2.47 | 1.90 | 1.83 | 1.95 |
| 48 | 5400 | 36000 | 618 | 650.00 | 650.00 | 650.00 | .23 | .23 | .23 | 8.59 | 7.91 | 8.21 | 2.04 | 1.94 | 1.99 | .71 | .70 | .70 |
| 49 | 5800 | 36000 | 618 | .01 | .01 | .01 | .03 | .03 | .03 | .80 | .74 | .77 | .27 | .26 | .26 | .07 | .07 | .07 |
| 50 | 4600 | 35600 | 618 | .06 | .06 | .06 | .08 | .07 | .07 | 5.90 | 5.40 | 5.62 | 1.18 | 1.11 | 1.14 | .47 | .46 | .46 |
| 51 | 4900 | 35700 | 154 | .16 | .15 | .15 | 3.49 | 3.48 | 3.48 | 13.28 | 12.16 | 12.66 | 2.91 | 2.73 | 2.81 | 1.19 | 1.16 | 1.16 |
| 52 | 5050 | 35750 | 39 | .18 | .18 | .18 | .24 | .24 | .24 | 14.89 | 13.64 | 14.20 | 3.43 | 3.24 | 3.33 | 1.26 | 1.26 | 1.24 |
| 53 | 5150 | 35750 | 39 | .02 | .02 | .02 | .04 | .03 | .03 | 2.98 | 2.73 | 2.84 | .58 | .55 | .56 | .23 | .23 | .23 |
| 54 | 5050 | 35650 | 39 | 1.41 | 1.39 | 1.40 | 1.35 | 1.51 | 1.43 | 79.71 | 73.14 | 76.43 | 23.03 | 22.19 | 22.56 | 6.79 | 7.37 | 6.93 |
| 55 | 5150 | 35650 | 39 | .43 | .41 | .42 | 9.65 | 9.67 | 9.65 | 36.33 | 33.28 | 34.69 | 8.10 | 7.72 | 7.90 | 2.99 | 3.06 | 2.98 |
| 56 | 4900 | 35500 | 154 | .06 | .06 | .06 | .08 | .07 | .07 | 6.67 | 6.10 | 6.36 | 1.23 | 1.15 | 1.19 | .47 | .46 | .46 |
| 57 | 5050 | 35550 | 39 | .35 | .34 | .35 | 6.66 | 6.66 | 6.65 | 46.10 | 42.82 | 44.27 | 8.60 | 8.18 | 8.37 | 11.41 | 11.38 | 11.36 |
| 58 | 5150 | 35550 | 39 | .21 | .21 | .21 | .23 | .23 | .23 | 16.84 | 15.42 | 16.05 | 3.83 | 3.63 | 3.72 | 1.29 | 1.31 | 1.28 |
| 59 | 5050 | 35450 | 39 | .11 | .11 | .11 | .17 | .16 | .16 | 13.17 | 12.05 | 12.55 | 2.41 | 2.23 | 2.31 | 1.13 | 1.06 | 1.09 |
| 60 | 5150 | 35450 | 39 | .04 | .04 | .04 | .05 | .05 | .05 | 2.68 | 2.45 | 2.55 | .73 | .69 | .71 | .26 | .26 | .25 |
| 61 | 5400 | 35600 | 618 | .08 | .08 | .08 | .45 | .44 | .44 | 8.82 | 8.07 | 8.40 | 1.62 | 1.51 | 1.56 | .69 | .66 | .67 |
| 62 | 5800 | 35600 | 618 | .06 | .06 | .06 | .16 | .16 | .16 | 3.73 | 3.47 | 3.59 | 1.21 | 1.17 | 1.19 | .39 | .39 | .39 |
| 63 | 6400 | 35800 | 2471 | .16 | .16 | .16 | .41 | .61 | .56 | 12.25 | 11.30 | 11.72 | 3.01 | 2.87 | 2.93 | 2.20 | 2.17 | 2.17 |
| 64 | 4000 | 35400 | 2471 | .08 | .08 | .08 | .11 | .10 | .10 | 7.93 | 7.25 | 7.55 | 1.57 | 1.46 | 1.51 | .69 | .66 | .67 |
| 65 | 4800 | 35000 | 2471 | .26 | .25 | .26 | .53 | .52 | .52 | 25.06 | 23.01 | 23.92 | 5.34 | 5.02 | 5.17 | 2.25 | 2.16 | 2.18 |
| 66 | 5600 | 35000 | 2471 | .40 | .41 | .40 | .87 | .86 | .86 | 34.74 | 31.96 | 33.19 | 7.92 | 7.49 | 7.68 | 5.17 | 5.07 | 5.08 |
| 67 | 6400 | 35000 | 2471 | 1520.00 | 1520.00 | 1520.00 | .94 | 1.09 | 1.05 | 31.02 | 28.61 | 29.68 | 7.64 | 7.26 | 7.50 | 2.92 | 2.85 | 2.76 |

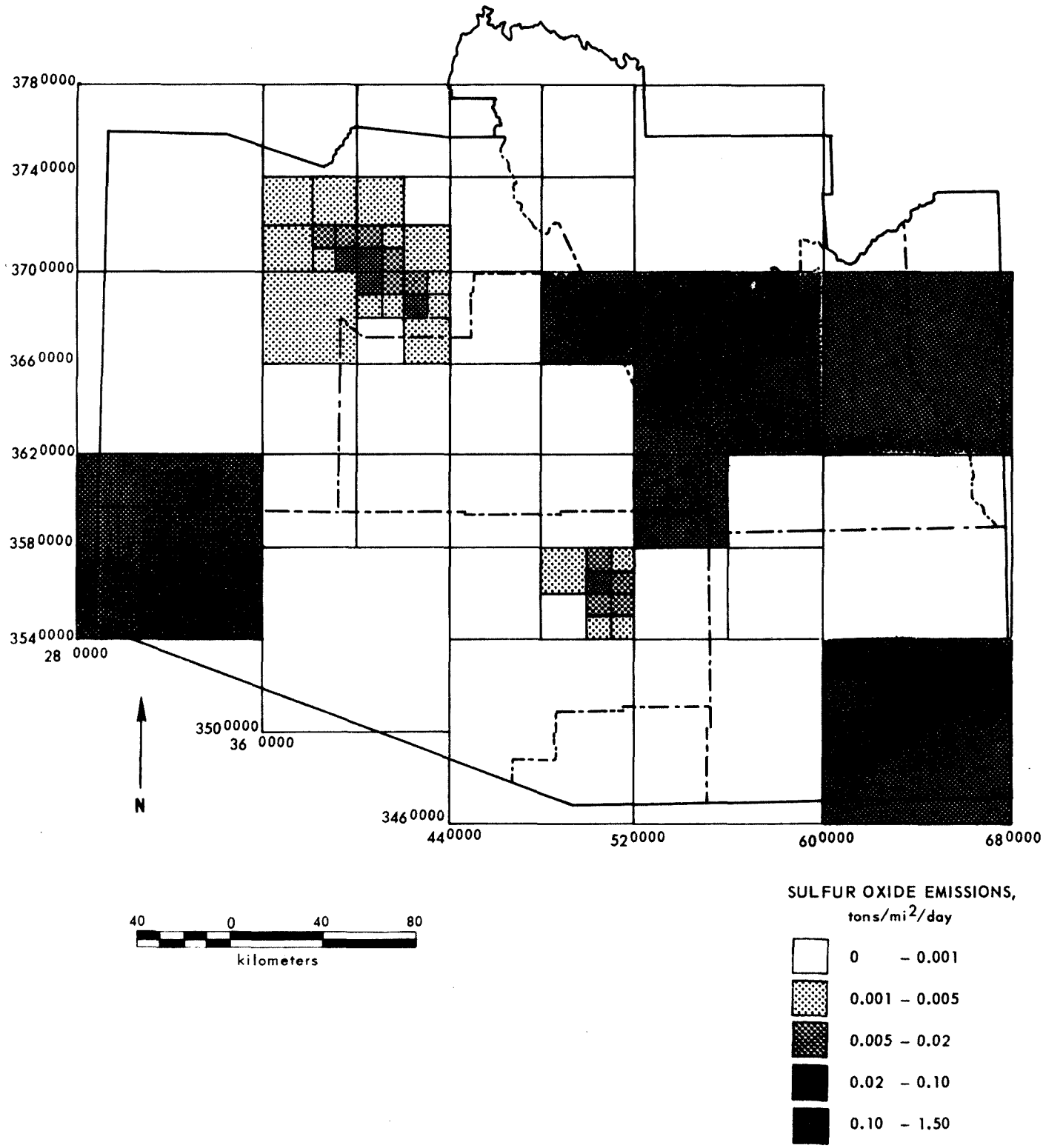


Figure 4. Sulfur oxide emission density map of the Phoenix-Tucson area, 1967.

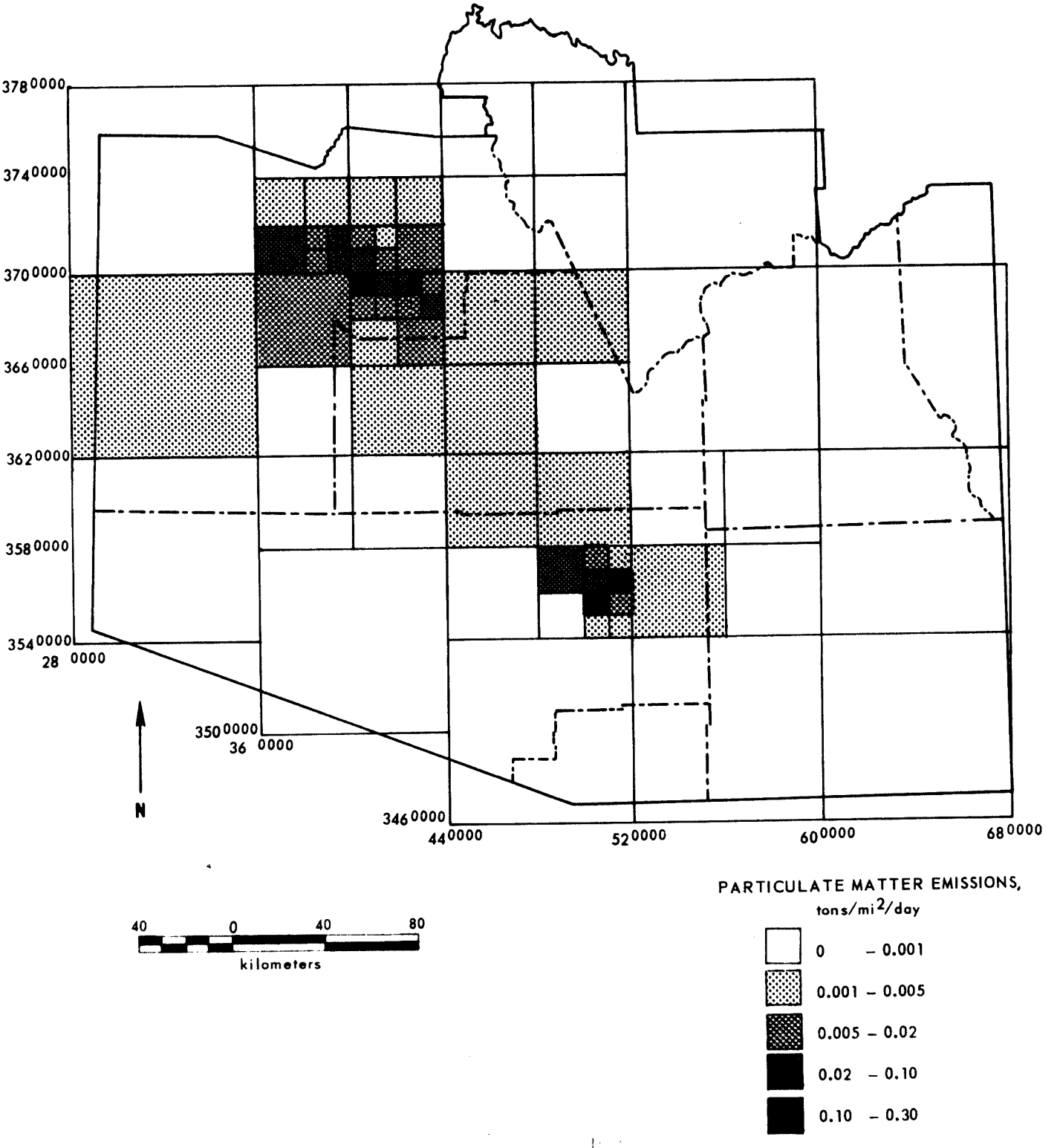


Figure 5. Particulate matter emission density map of the Phoenix-Tucson area, 1967.

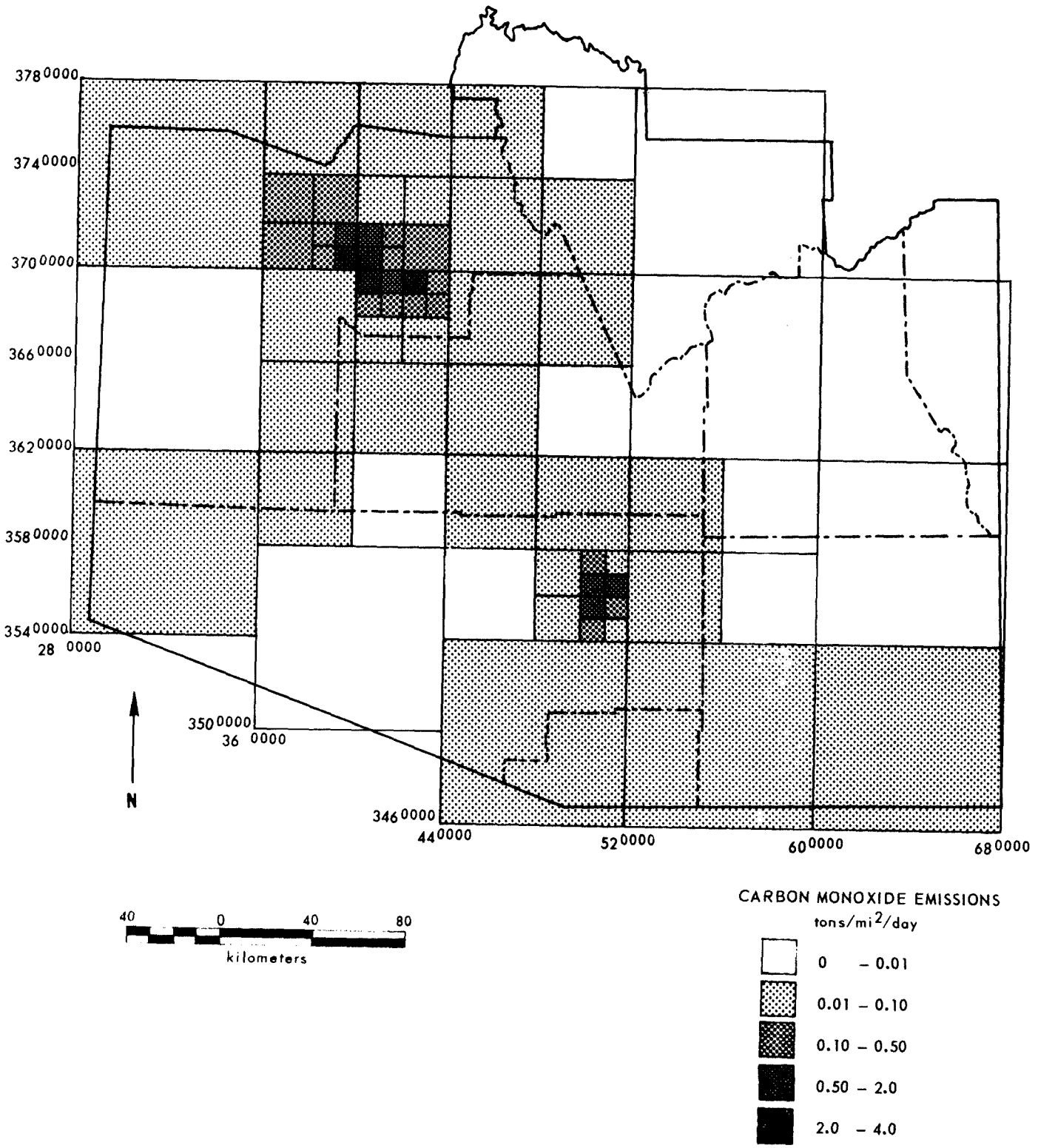


Figure 6. Carbon monoxide emission density map of the Phoenix-Tucson area, 1967.

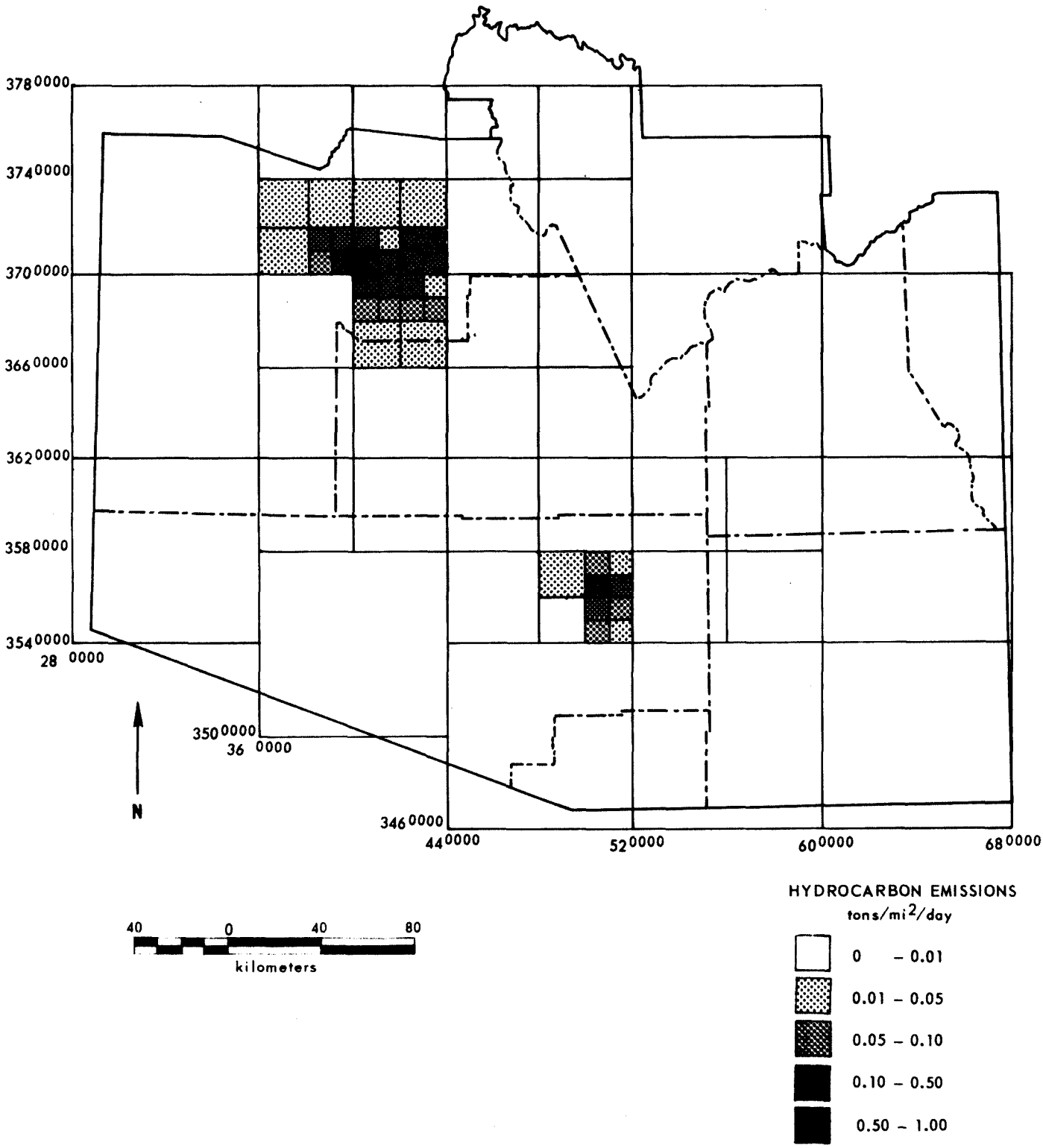


Figure 7. Hydrocarbon emission density map of the Phoenix-Tucson area, 1967.

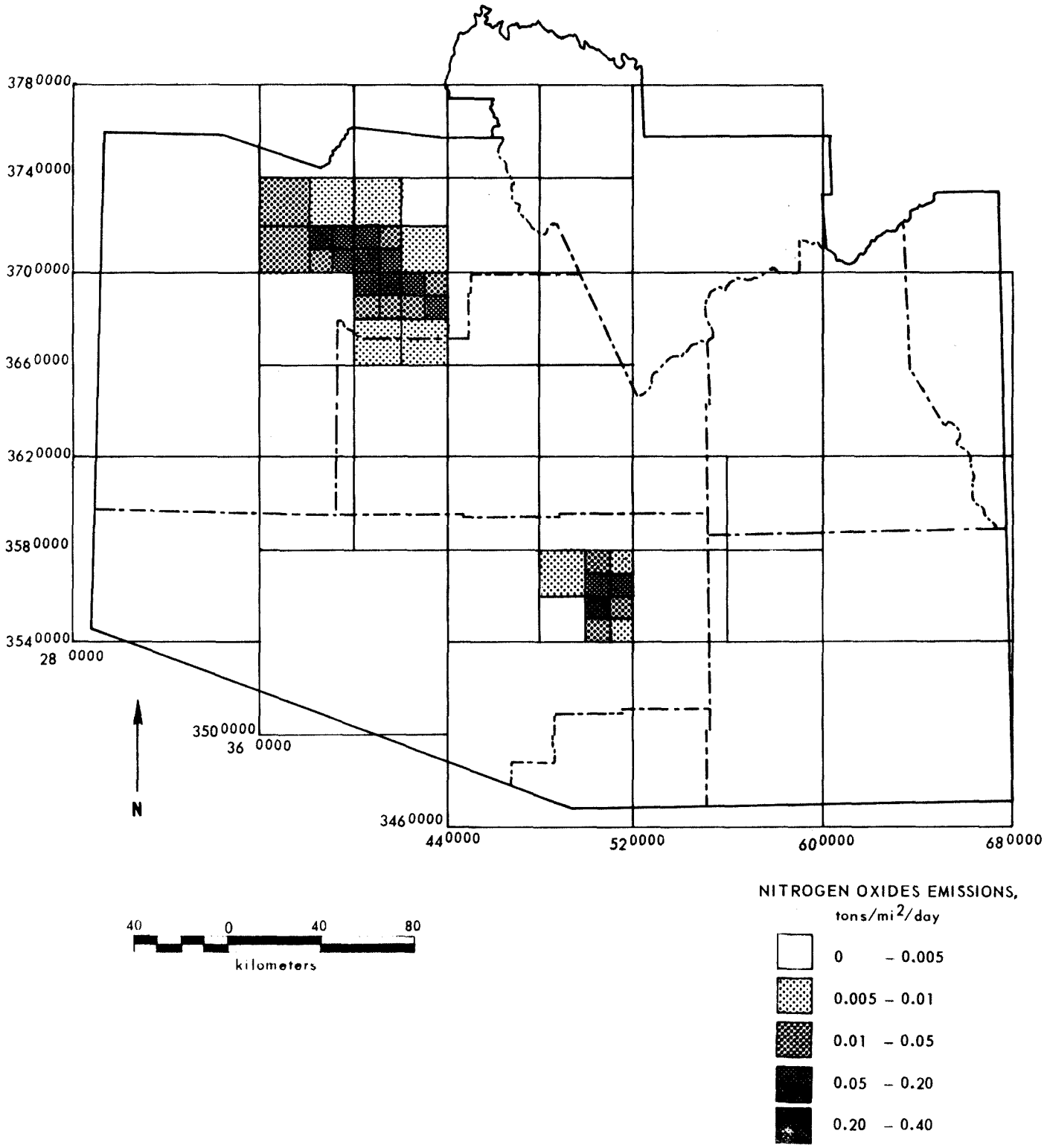


Figure 8. Nitrogen oxides emission density map of the Phoenix-Tucson area, 1967.

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