COLUMBUS, OHIO METROPOLITAN AREA
AIR POLLUTANT EMISSION INVENTORY

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FRANKLIN COUNTY, OHIO AIR POLLUTANT EMISSION INVENTORY

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PREFACE

This report, which presents the emission inventory for the Columbus Metropolitan Area, is another in a series of surveys outlining the sources and emissions of air pollutants for major metropolitan areas in the country. These surveys, conducted by the National Inventory of Air Pollutant Emissions and Control Branch of the Air Pollution Control Office, provide estimates of the present levels of air pollutant emissions and status of their control. The pollutants which include sulfur oxides, particulates, carbon monoxide, hydrocarbons and nitrogen oxides, are delineated with respect to source type, season of the year and geographical distribution within the area. The general procedure for the surveys is based upon the rapid survey technique for estimating air pollutant emissions.[1]

ACKNOWLEDGMENTS

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We are grateful to Mr. Gene Nagel of the Columbus Division of Air Pollution Control for his assistance. We also sincerely appreciate the contributions made by Mr. Dean Seizert of Columbia Gas of Ohio and Mr. Robert Carrer of Columbus and Southern Ohio Electric Company.

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INTRODUCTION

This report is a summary of the Columbus air pollutant emission inventory conducted in September, 1970.* Since all inventories are based upon a calendar year, the data and emission estimates presented here are representative of 1968 and should be considered as indicating the conditions as existed during that year.

The Study Area, which was chosen by the Division of Meteorology for its topographic characteristics, consists of Franklin County in which Columbus is centrally located. This area covers approximately 538 square miles and had a 1968 population of 855,602.

A grid coordinate system was used to show the geographical distribution of emissions within the county. The Study Area was subdivided into 48 grid zones ranging in size from 4 square kilometers in the heavily populated and industrialized areas to 100 kilometers in the rural areas.

All sources of emissions were classified into five categories--transportation, stationary fuel combustion, solid-waste disposal, industrial processes and evaporative losses. Each of these source categories was divided into two subgroups--point sources and area sources. Facilities, which emit large quantities of air pollutants, were considered individually as point sources, while the many remaining contributors such as motor vehicles, residential and commercial fuel users, small industries and on-site refuse burning equipment, were considered collectively as area sources. For this report, 23 individual sources, which had emissions approximately 0.1 tons per average annual day for any pollutant, were classified as point sources.

Emissions were estimated by using various indicators such as fuel consumption, refuse burning rates, vehicle-miles, production data, and control efficiencies and emission factors relating these indicators to emission rates.[2] These factors represent average emission rates for a particular source category. Since individual sources have inherent differences that cannot always be taken into consideration, discrepancies between the actual and estimated emissions are more likely in individual sources than in the total emissions for a source category.

As in all emission surveys, the data presented are estimates and should not be interpreted as absolute values. The estimates are, in some cases, partial totals due to the lack of emission factors and production or consumption data. Despite these limitations, these estimates are of sufficient accuracy and validity in defining the extent and distribution of air pollutant emissions in the Study Area.

*As a supplement to the air pollutant inventory, a heat emission inventory was also conducted in which the dates of primary interest were for the year 1968.

SUMMARY

The annual emissions as estimated by the Franklin County Air Pollutant Emission Inventory are:

	(Tons per Year)
Sulfur Oxides	29,800
Particulates	40,400
Carbon Monoxide	339,000
Hydrocarbons	58,200
Nitrogen Oxides	33,300

The following is a brief description of the air pollutant emissions as presented in Table 1 and Table 2.

Sulfur Oxides: The largest portion of the sulfur oxides emitted came from commercial and institutional sources located in the Study Area which had coal fired units. Together these accounted for 37 percent of total sulfur oxides. The combustion of fossil fuels by other stationary sources accounted for 55 percent of the sulfur oxides emitted. The remaining 8 percent was distributed under motor vehicles, refuse disposal and small industries.

Particulates: The majority of the particulate emissions (91%) came from the combustion of coal in the Study Area. Steam-electric utilities, which included 3 major power plants accounted for 37 percent of the total particulate emissions. The combustion of coal from large commercial and institutional establishments such as the university, penitentiary, and Air Force base, accounted for an additional 50 percent. The remaining portion comes mainly from transportation sources (7%), industrial and residential fuel combustion (4%), and miscellaneous sources (2%).

Carbon Monoxide: In most metropolitan areas the largest source of carbon monoxide emissions is from automobiles and other motor vehicles. This was also true in Columbus as motor vehicles contributed 93 percent of the carbon monoxide emitted annually. Other transportation sources including railroad and aircraft operations contributed another 5 percent.

The only other significant source of carbon monoxide was from the inefficient combustion of fuel at residential, commercial and institutional establishments. This category accounted for about 2 percent of the total emissions.

Hydrocarbons: Exhaust gases from motor vehicles was the primary source of hydrocarbon emissions, accounting for over 42 percent of the total. Evaporative losses from motor vehicles which includes losses from the gas tank, carburetor and engine crankcase accounted for 25 percent of total hydrocarbon emissions. Other smaller evaporative loss sources including gasoline storage and handling, industrial solvent usage, dry cleaning plants, and miscellaneous solvent usage, collectively accounted for 20 percent of total emissions. Other sources included railroad and aircraft operations (7% of total) and stationary fuel combustion (2% of total).

Nitrogen Oxides: The largest source of nitrogen oxides was the exhaust gas from motor vehicles which accounted for 64 percent of total nitrogen oxide emissions. The combustion of coal, oil, and gas at other stationary sources accounted for 36 percent of total emissions.

Emissions from open burning were negligible since Franklin County law prohibits it. All municipal solid waste disposal is done by landfill operations thus resulting in no air pollutant emissions. The resulting emissions from incinerations arise mainly from commerical, institutional, and residential incinerations.

TABLE 1 SUMMARY OF AIR POLLUTANT EMISSIONS IN STUDY AREA, 1968

(Tons/Year)

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation					
Motor Vehicles	1,350	1,900	316,400	24,600	18,950
Other	250	900	16,500	4,100	2,200
Subtotal	1,600	2,800	332,900	28,700	21,150
Stationary Fuel Combustion					
Industry	7,000	900	200	100	2,900
Steam-Electric	7,100	14,800	100	50	4,800
Residential	2,300	800	800	200	2,200
Commercial and Institutional	10,900	20,200	4,200	850	2,100
Subtotal	27,300	36,700	5,300	1,200	12,000
Refuse Disposal					
Incineration	40	130	600	300	150
Open Burning	0	0	0	0	0
Subtotal	40	130	600	300	150
Industrial Processes	820	640	200	0	0
Evaporative Losses	--	--	--	28,000	--
GRAND TOTAL[a]	29,800	40,400	339,000	58,200	33,300

a = Totals have been rounded.

TABLE 1A SUMMARY OF AIR POLLUTANT EMISSIONS IN STUDY AREA, 1968

(1000 kg/year)

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Motor Vehicles	1,220	1,720	287,000	22,300	17,200
Other	230	820	15,000	3,720	2,000
Subtotal	1,450	2,540	302,000	26,020	19,200
Stationary Fuel Combustion					
Industrial	6,350	820	180	90	2,630
Steam-Electric	6,440	13,400	90	45	4,350
Residential	2,080	730	730	185	2,000
Commercial and Institutional	9,880	18,300	3,800	770	1,900
Subtotal	24,750	33,250	4,800	1,090	10,880
Refuse Disposal					
Incineration	40	120	530	270	130
Open Burning	0	0	0	0	0
Subtotal	40	120	530	270	130
Industrial Processes	740	590	170	0	0
Evaporative Losses	--	--	--	25,320	--
GRAND TOTAL	27,000	36,500	307,500	52,700	30,210

TABLE 2 PERCENTAGE CONTRIBUTION OF EACH SOURCE CATEGORY TO TOTAL EMISSIONS IN THE COLUMBUS STUDY AREA

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Transportation					
Motor Vehicles	4.5	4.7	93.3	42.3	57.0
Other	.8	2.2	4.8	7.1	6.6
Subtotal	5.3	6.9	98.1	49.5	63.6
Stationary Fuel Combustion					
Industry	23.6	2.2	.1	.2	8.7
Steam-Electric	24.0	37.3	.1	.1	14.3
Residential	7.7	1.9	.2	.3	6.6
Commercial and Institutional	36.7	50.0	1.2	1.5	6.4
Subtotal	92.0	91.4	1.6	2.1	36.0
Refuse Disposal					
Incineration	.1	.3	.2	.4	.4
Open Burning	0	0	0	0	0
Subtotal	.1	.3	.2	.4	.4
Process Losses	2.6	1.4	.1	0	0
Evaporative Losses	--	--	--	48.0	--
TOTAL	100	100	100	100	100

DESCRIPTION OF STUDY AREA

The Study Area for the emission survey of the Columbus Metropolitan Area consists of Franklin County which is located in the center of Ohio. Figure 1 shows the location of the Franklin County Study Area relative to other large cities in its vicinity.

Figure 2 represents a more detailed drawing of the Franklin County Study Area showing the major urban areas. It should be pointed out that the boundaries of these areas do not correspond to city limits, but rather give a general outline of the major clusters of population. The Study Area occupies 538 square miles and contained an estimated 1968 population of 855,602, which is approximately a 25 percent increase since 1960. The population density map (Figure 3) shows the heaviest concentrations near the city of Columbus.

TOPOGRAPHY[4]

Franklin County, located in the center of Ohio, is in the drainage area of the Ohio River. The major river in the county is the Scioto River which flows from the northwest corner, through the center of Columbus, and then straight south toward the Ohio River. The land is flat with the only variation in elevation coming from the narrow valleys associated with small drainage streams.

Columbus is the major city in the county with an elevation of 812 feet above m.s.l. at the Columbus International Airport. The rolling

Figure 1. Map of Franklin county study area and surrounding cities.

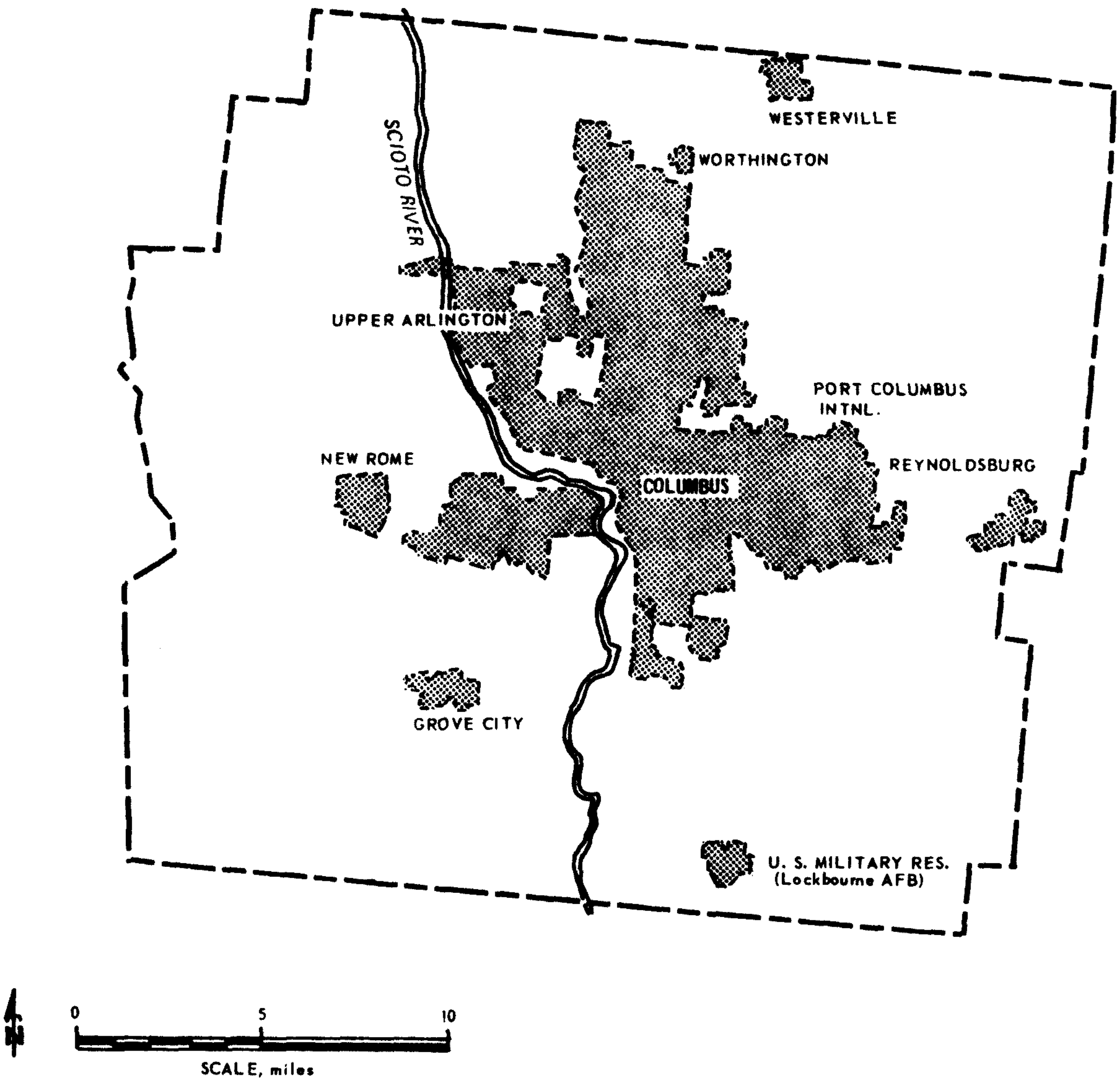

Figure 2. Detailed map of Franklin county study area.

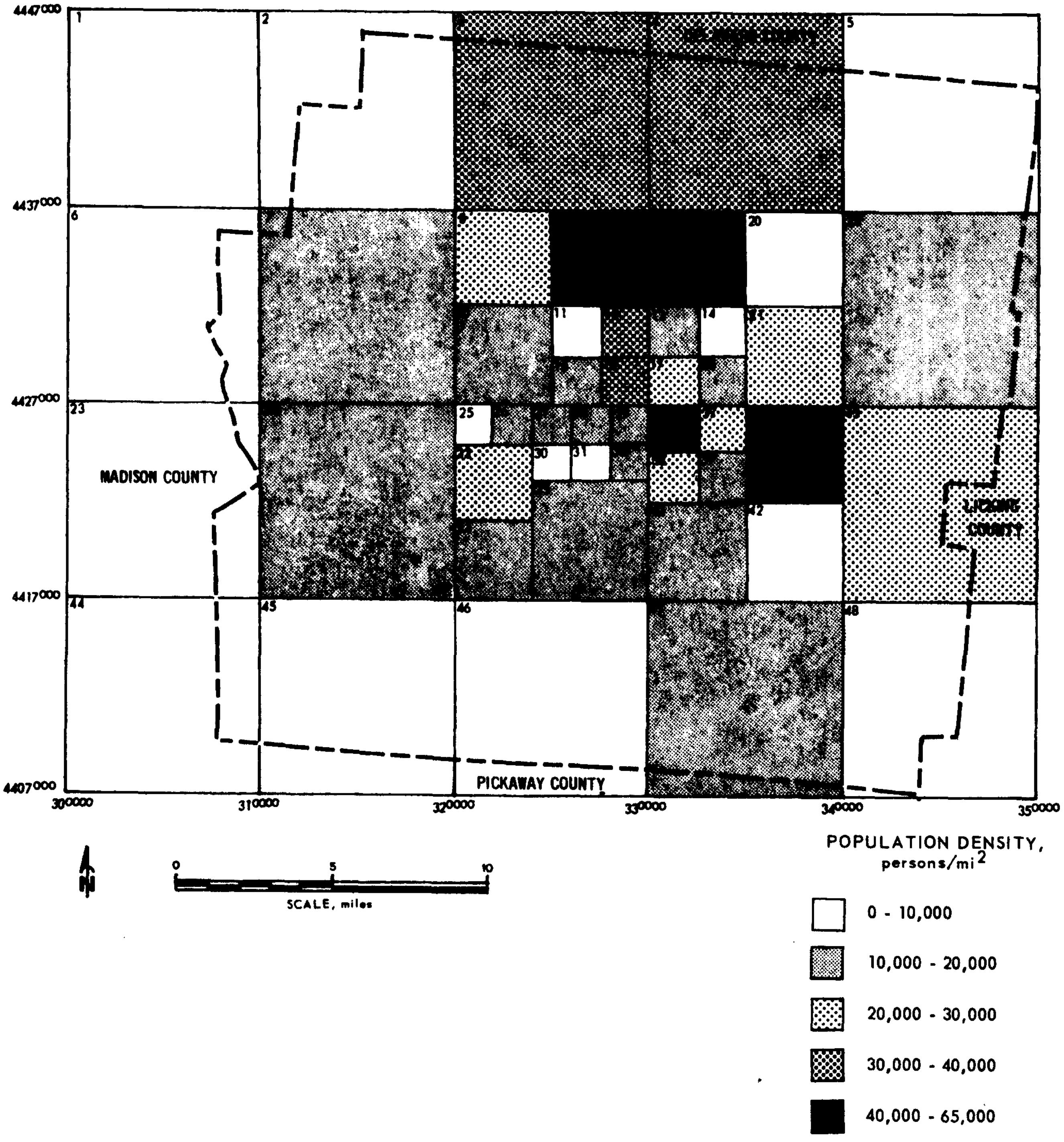

Figure 3. Population density for Franklin county study area, 1968.

landscape is conducive to air drainage to the northwest since the average wind direction is from the southwest as reported by the Weather Bureau located at the airport.

CLIMATOLOGY

Columbus has a changeable weather pattern due to its location. During the summer months tropical air masses move in from the Gulf, and during winter months air masses from central and northwest Canada are observed. During the summer months, records show calm or very low winds during the evening and early morning. Columhus has no "wet" or "dry" season as such, however the lightest rainfall occurs during the fall, which would come closest to providing a normal dry season.

MAJOR INDUSTRIAL FACTORS

Columbus, which is the Ohio state capital, is not a heavily industrialized area. There were two iron and steel fabricating plants, a fabric coating establishment, one paint blending operation, three asphalt batch plants, one chemical fertilizer company, a lime quarry, an aircraft manufacturer, and one zinc manufacturing firm. Other small industrial point sources were present but contributed an insignificant quantity of emissions compared to the larger industries mentioned.

GRID COORDINATE SYSTEM

A grid coordinate system, based on the Universal Transverse Mercator Projection (UTM) was used in the Franklin County Study Area to show the geographical distribution of emissions. A map of this grid system is presented in Figure 4.

The UTM system was chosen due to its advantages over other standard grid systems such as the Latitude-Longitude and State Plane Coordinate Systems. The major advantages of this system are that (1) it is continuous across the country and is not hindered by political subdivisions, (2) the grids are of uniform size throughout the country, (3) it has world-wide use, and (4) the grids are square in shape--a necessary feature for use in meteorological dispersion models.

The Universal Transverse Mercator Projection is based upon the metric system. Each north-south and east-west grid line, as illustrated in Figure 4, is identified by a coordinate number expressed in meters. Each point source and grid is identified by the horizontal and vertical coordinates of their geographical center to the nearest 100 meters.

As shown in Figure 4, the Study Area was divided into 48 grids of four main sizes--4, 6, 25, and 100 square kilometers. Grid zones of different sizes are used to limit the number of grid zones and yet allow a satisfactory definition of the geographical gradation of emissions. The majority of the emissions is usually concentrated in the populated and industrialized portions of a Study Area. Smaller grids are placed

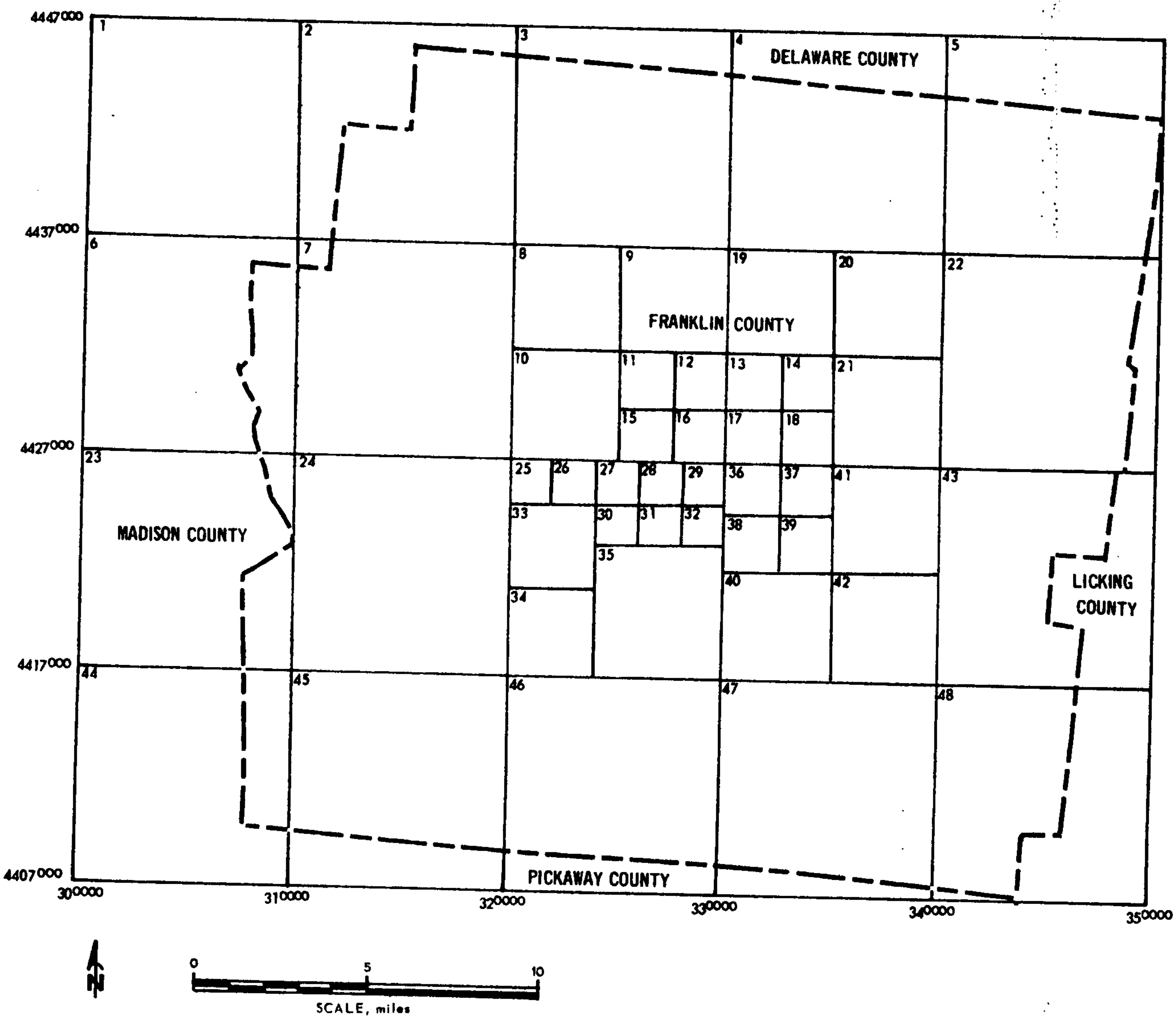

Figure 4. Grid coordinate system for the Franklin county study area.

over these areas in order to reflect abrupt changes in emissions within short distances. The use of grid zones smaller than 4 square kilometers is not warranted because of the inherent inaccuracies in the data. Since only a small percentage of the total emissions occur in rural areas, larger grid zones are normally used to show the distribution of emissions in these lightly populated portions of a Study Area.

EMISSIONS BY CATEGORY

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

1. Stationary fuel combustion
2. Transportation
3. Solid waste disposal
4. Industrial processes
5. Evaporative losses

Each of these categories is considered individually in this section where data sources are given and methods of calculation discussed.

STATIONARY FUEL COMBUSTION

The stationary fuel combustion category is concerned with any fixed source which burns fuels for either space heating or process heating. The four primary sources in this category are industrial facilities, steam-electric plants, residential housing, and commercial and institutional establishments. In the Columbus area, coal, distillate oil, and natural gas were the primary fuels used. Table 3 summarizes the types of fuels consumed and the category that they are used in, and Table 4 presents an average chemical analysis of these fuels.

Steam-Electric Utility

METHODOLOGY: Data on the three power plants in the area were acquired from the municipal plant and the Columbus and Southern Ohio

TABLE 3 ANNUAL FUEL CONSUMPTION IN COLUMBUS STUDY AREA, 1968

Category	Steam-Electric	Industrial	Residential	Commercial and Institutional	Totals
Coal (tons)	457,000	108,000	29,324	127,000	721,325
Natural Gas (million cu. ft.)	967	14,584	34,456	24,728	74,735
Distillate Oil (thousand gal.)	1,033	0	22,160	18	23,211

TABLE 4 AVERAGE CHEMICAL ANALYSIS OF FUELS CONSUMED IN THE COLUMBUS STUDY AREA, 1968

Type Fuel	Type Source	% by weight Ash Content	% by weight Sulfur Content
Coal	Steam-Electric	13.5	.8
	Industrial	10.0	3.0
	Domestic-Commercial	12.0	2.1
Residual Fuel Oil	Steam-Electric	NU	NU
	Industrial	NU	NU
	Domestic-Commercial	NU	NU
Distillate Fuel Oil	Steam-Electric	N	0.2
	Industrial	N	0.2
	Domestic-Commercial	N	0.15

N = Negligible

NU = Fuel not used by this type source

Electric Company and compared to figures presented by the National Coal Association.[5] The data included the annual fuel consumption for 1968, type and efficiency of control equipment, sulfur and ash content of the fuel and the type of furnace.

RESULTS: All three of the power plants in the area use pulverized coal-fired boilers in addition to distillate oil and natural gas units. Approximately a half million tons of coal were consumed in these boilers in 1968. Of this .46 million tons, .1 million was consumed in boilers with no control devices for particulates. The remaining .36 million tons were controlled by mechanical collectors with efficiencies ranging from 85 to 88 percent. The average weighted efficiency of the .36 million tons of coal which was controlled was 87 percent. A total of 1.03 million gallons of distillate fuel oil was also used by the three power plants. In addition the municipal power plant consumed just under a billion cubic feet of natural gas in a gas turbine generator.

Air pollutant emissions from fuel combustion at these plants as well as from all other fuel combustion sources are summarized in Table 7. The steam-electric plants were a substantial contributor of sulfur oxides, particulates and nitrogen oxides in the Study Area. Approximately 26 percent of the total sulfur oxides from stationary fuel combustion, 40 percent of the particulates, and 38 percent of the nitrogen oxides were attributed to these three plants.

Industrial

METHODOLOGY: Since in a rapid survey of industrial sources it is impossible to contact every plant, other techniques must be used to determine the contribution of industrial fuel combustion sources. In order to do this, the total quantities of the various fuels used are determined and the amounts used by the largest industries are found. The remaining sources are considered collectively as area sources and their fuel used is based on the difference between the total and the amount consumed by the largest sources.

The total quantity of distillate fuel oil consumed by industries was estimated by the Ohio Petroleum Marketer Association. These were compared to totals provided by the majority of the acknowledged agencies. Natural gas numbers were obtained from Columbia Gas of Ohio Company who provided the breakdown by user category. Total coal consumption by industrial sources was based solely on questionnaire data or personal contacts.

The quantities of all fuels used by individual industries was found by personal contacts and then subtracted from the totals to determine area source fuel use.

It should be noted that fuel combustion by industries include both fuel used for space heating, and fuel used for process heating. A national average was used to separate process heating from space heating.

RESULTS: Coal and natural gas were used by industrial sources in the Study Area.

Table 5 shows the relative contribution of each fuel to the total emissions from stationary fuel combustion. Industrial sources account

TABLE 5 AIR POLLUTANT EMISSIONS FROM THE COMBUSTION OF FUELS IN STATIONARY SOURCES IN THE STUDY AREA, 1968 (Tons/Year)

Fuel User Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Coal					
Industrial	7,000	800	200	70	1,350
Steam-Electric	7,100	14,800	100	40	4,550
Residential	1,900	400	720	150	100
Commercial and Institutional	10,900	20,100	4,200	830	700
Subtotal	26,900	36,100	5,220	1,090	6,700
Fuel Oil					
Industrial	0	0	0	0	0
Steam-Electric	20	N	0	N	50
Residential	320	100	20	30	150
Commercial and Institutional	0	0	0	0	0
Subtotal	340	100	20	30	200
Gas					
Industrial	N	130	N	0	1,600
Steam-Electric	0	10	0	0	200
Residential	5	330	5	0	2,000
Commercial and Institutional	5	230	5	0	1,400
Subtotal	10	700	10	N	5,200
GRAND TOTAL[a]	27,250	36,900	5,250	1,120	12,100

N = Negligible

a = Totals have been rounded.

for 26 percent of total sulfur oxide emissions from stationary fuel combustion, 3 percent of particulates, 4 percent of carbon monoxide, 6 percent of hydrocarbons, and 11 percent of nitrogen oxides.

Residential

METHODOLOGY: Natural gas, distillate fuel oil and coal were the primary fuels used for residential home heating. There were homes heated by other fuels, but they represent a small percentage of the total. Data on the amount of natural gas used for domestic heating was supplied by the local power companies and compared with the rapid survey technique of estimating the fuel used for home heating.[6] Distillate oil and coal consumption data were estimated based on data supplied by local agencies and on the rapid survey technique.

RESULTS: The percentage of the number of homes that use each type fuel is estimated based on utility company data with natural gas being used in 89 percent of the dwelling units, fuel oil 9 percent and coal 1 percent.

Emissions resulting from residential fuel combustion are relatively low for all pollutants. However, since coal is not burned efficiently in homes, total emissions are higher than might be expected.

Commercial-Institutional

METHODOLOGY: Commercial and institutional establishments in the Study Area used two of the previously mentioned fuels--natural gas and coal. Data on the total amounts of these fuels used in the area as well as the consumption at individual establishments were supplied by power companies and fuel associations.

RESULTS: The use of coal at commercial and institutional establishments was by far the most significant source of emissions from this category. Major sources included the Air Force base, university, and penitentiary. The percentages were--40 percent sulfur oxides, 53 percent particulates, 80 percent carbon monoxide, 74 percent hydrocarbons, and 6 percent nitrogen oxides.

TRANSPORTATION

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

Motor Vehicles

More than 4 billion miles were traveled by motor vehicles in 1968 in the Franklin County Study Area. In the process, 323 million gallons of gasoline and 25 million gallons of diesel fuel were consumed for highway purposes.

Vehicle-mile data for all of the roads in Franklin County were supplied by the Franklin County Highway Department. This data was in the form of traffic flow maps which showed average daily traffic along the roads.

The contribution to the total motor vehicle pollution by diesel-powered vehicles was determined by assuming that approximately three percent of the total vehicle miles traveled were by diesel-powered vehicles. This was checked by estimating diesel fuel consumption in the county.[7] These emissions were apportioned on a grid basis by assuming they were proportional to gasoline emissions.

Emissions from motor vehicles are a function of the speed at which the vehicle travels. Average speeds of 10-20 mph were assumed for downtown areas, 20-30 mph for the residential areas, and 30-45 mph for the rural areas to calculate vehicle emissions.

From all transportation sources, motor vehicles accounted for 85 percent of the sulfur oxides, 68 percent of the particulates, 95 percent of the carbon monoxide, 85 percent of the hydrocarbons, and 89 percent of the nitrogen oxides. Gasoline powered motor vehicles contributed a greater percent of all pollutants than diesel powered motor vehicles. Emissions from transportation sources are summarized in Table 6.

Aircraft

Table 7 shows the air traffic activity at the largest airports in the Study Area. An estimate of the number of flights by engine type was supplied by the traffic controller at each airport and summarized in Table 7.

The air pollutant emissions from aircraft include all phases of operation (taxi, take-off, climb out, approach and landing) that take place below the arbitrarily chosen altitude of 3,500 feet. Emissions at cruise altitude (above 3,500 feet) are not of concern in an emission inventory. From all transportation sources, aircraft accounted for 9 percent of the particulates, 5 percent of the carbon monoxide, 11 percent of the hydrocarbons and 4 percent of the nitrogen oxides.

TABLE 6 SUMMARY OF AIR POLLUTANT EMISSIONS FROM TRANSPORTATION SOURCES, 1968 (Tons/Year)

Source Category	Sulfur Oxides	Particulates	Carbon Monoxide	Hydrocarbons	Nitrogen Oxides
Motor Vehicles					
Gasoline	1,300	1,750	316,400	24,400	18,600
Diesel	50	150	100	200	300
Subtotal	1,350	1,900	316,500	24,600	18,900
Aircraft					
Jet	N	150	250	300	150
Piston	N	70	15,800	3,000	750
Turboprop	N	N	N	N	N
Subtotal	N	240	16,000	3,300	900
Railroads	250	660	350	800	1,300
GRAND TOTAL	1,600	2,800	333,000	28,700	21,100

TABLE 7 AIR TRAFFIC ACTIVITY AT THE LARGEST AIRPORTS IN THE COLUMBUS STUDY AREA, 1968 (Flights/Year)[a]

Type Engine	Port Columbus International	Don Scott	Lockbourne AFB
2 Engine Conventional Jet	7,300	900	1,300
3 Engine Fan-Jet	5,300	--	--
4 Engine Fan-Jet	2,700	--	2,200
2 Engine Turboprop	5,000	--	--
1 Engine Piston	88,200	80,500	700
2 Engine Piston	58,900	11,300	--
4 Engine Piston	0	--	--
TOTALS	167,400	92,700	4,200

a = Flight is defined as a combination of a landing and a takeoff.

Railroads

Railroad operations (mainly locomotive) consume about 12 million gallons of diesel fuel per year within the Study Area. This quantity is about 50 percent less than the amount of diesel fuel consumed by motor vehicles. The majority of this fuel is consumed during switching operations. Diesel fuel consumption data was obtained from state totals for railroad use and then apportioned according to population.

Railroad operations contribute about 15 percent of the sulfur oxides and 23 percent of the particulates from all transportation sources. They account for less than 6 percent of the emissions for any other pollutant.

SOLID WASTE DISPOSAL

All of the municipal solid waste disposal is carried out by landfill operations as mentioned earlier. Therefore, it is assumed that any remaining solid waste disposal is done by commercial and institutional on-site incinerators. Table 8 presents an emission summary for solid waste disposal in Franklin County.

INCINERATION

The Ohio State University incinerator was the largest on-site unit in the study area. Other units were small commercial and residential incerators and therefore were treated as area sources.

TABLE 8 AIR POLLUTANT EMISSIONS FROM SOLID WASTE DISPOSAL, 1968

(Tons/Year)

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Incineration					
Municipal	N	N	N	N	N
On-Site	40	120	620	300	150
Subtotal	40	120	620	300	150
Open Burning					
On-Site	N	N	N	N	N
Dump	N	N	N	N	N
Subtotal	N	N	N	N	N
GRAND TOTAL	40	120	620	300	150

N = None

INDUSTRIAL PROCESSES

From an air pollution standpoint, there is no large single source since the Study Area is not a highly industrialized area. In the agricultural industry the largest source was three well controlled fertilizer plant. In the mineral products industry the largest sources were 1 lime quarry and 3 asphalt batching plants. Other industries that generated air pollutant emissions from their processes included 1 gray iron foundry, 1 steel fabrication plant, 1 fabric coating plant, 1 zinc mill, and 1 aircraft manufacturing firm. The only significant emissions contributions were sulfur oxides (3% of the total) and particulate (2% of the total).

EVAPORATIVE LOSSES

Three source categories were considered for evaporative losses--automobiles, gasoline storage and handling, and the consumption of solvents. The hydrocarbon emissions from all sources by evaporative losses are shown in Table 9.

Automobiles

Automobile evaporation losses include gas tank and carburetor evaporation and engine crankcase blowby. 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 20 percent of the automobiles were not equipped with PCV valves.

The hydrocarbon emissions from automobiles were calculated from vehicle-mile data and were apportioned onto grids using the same methods

TABLE 9 HYDROCARBON EMISSIONS FROM EVAPORATIVE LOSS SOURCES IN THE COLUMBUS STUDY AREA, 1968 (Tons/Year)

Type of Source	Hydrocarbons
Gasoline Storage and Handling	6,600
Automobiles	18,400
Solvent Consumption	
Industrial	1,900
Dry Cleaning	1,200
GRAND TOTAL	28,100

as for motor vehicles discussed earlier. Evaporative losses from automobiles accounted for 65 percent of the total hydrocarbon emissions from evaporative losses in the Study Area.

Gasoline Storage and Handling

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

Approximately 500 million gallons of gasoline and diesel fuel were stored in the Study Area in 1968. The evaporative losses from this storage and the subsequent handling accounted for 23 percent of the total evaporative losses.

Consumption of Solvents

This category included the consumption of solvents at dry cleaning plants and industrial solvent usage. Organic solvents emitted from these operations were determined by assuming an emission rate of 2.7 lb/capita/year for any cleaning plants and emission rates corresponding to the amount of solvent usage obtained from industries. The consumption of solvents by these categories accounted for 10 percent of the hydrocarbon emissions from evaporative losses.

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-three point sources are identified individually with respect to location and emissions. The majority of these point sources emitted more than .1 tons per average annual day of any pollutant.

CONTRIBUTIONS OF POINT AND AREA SOURCES

Figure 5 shows the location of all point sources in the area. Collectively the 23 point sources account for 84 percent of the sulfur oxides, 89 percent of the particulates, 23 percent of the nitrogen oxides, and only 4 percent of the carbon monoxide and 3 percent of the hydrocarbons. The percentage contribution to carbon monoxide emissions is low because motor vehicles, which are area sources, contribute 95 percent of the total carbon monoxide emissions. Similarly, the contribution to total hydrocarbon emissions is low since two groups of area sources, motor vehicles and evaporative losses are the major sources. Table 10 presents the emissions of point sources. Each source is identified by source category, grid number and horizontal and vertical coordinates. The emissions of sulfur oxides, particulates, carbon monoxide, hydrocarbons, and nitrogen oxides are shown for an average annual day, average winter day (December, January, February), and

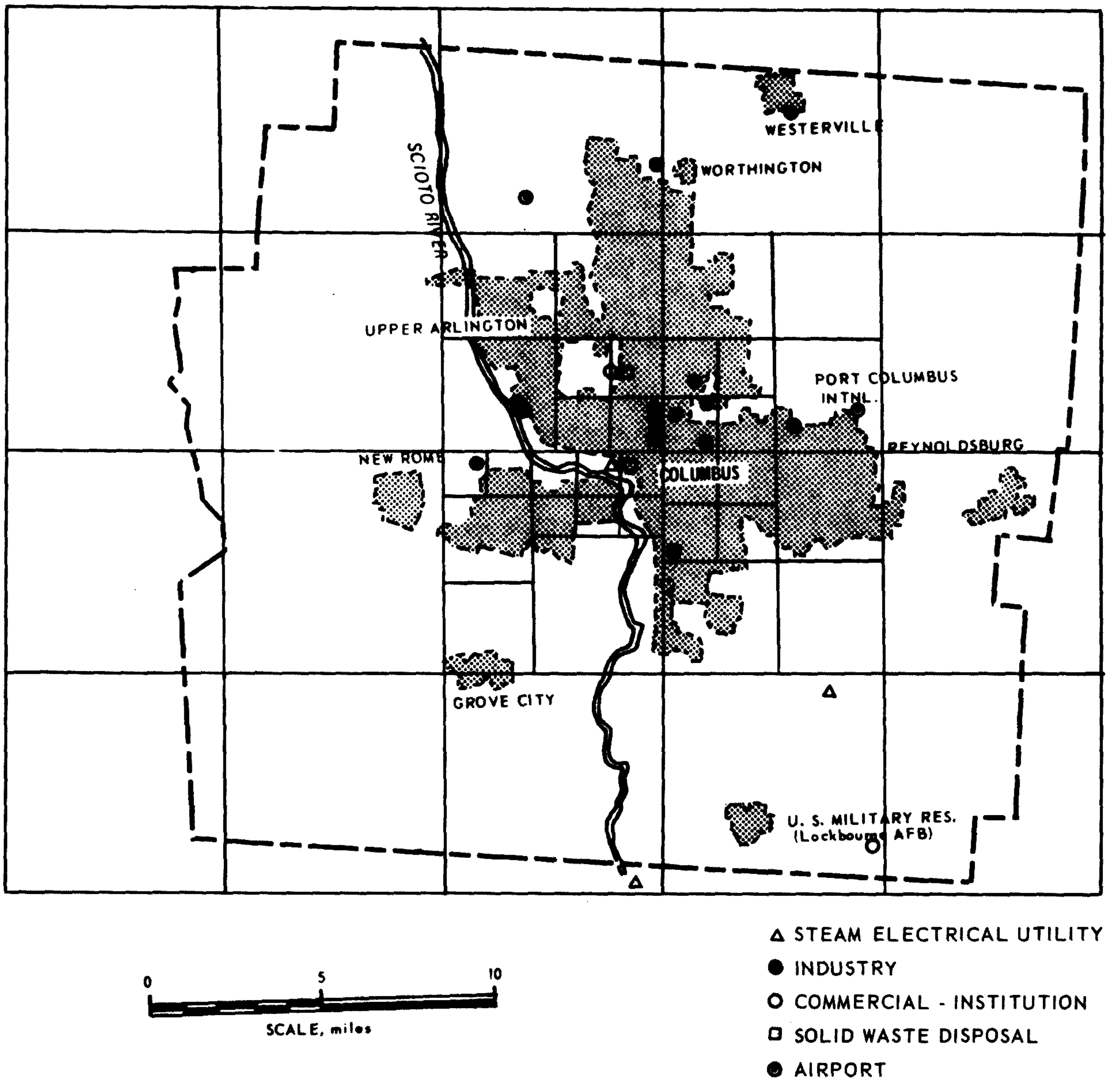

Figure 5. Point source locations for Franklin county study area.

TABLE 10 **SUMMARY OF AIR POLLUTANT EMISSIONS FROM POINT SOURCES** IN THE COLUMBUS STUDY AREA, 1968

TONS/DAY

				SOX			PART			CO			HC			NOX		
ID	GR	HC	VC	S	W	A	S	W	A	S	W	A	S	W	A	S	W	A
2	3	3300	444 0	0.0	0.0	0.0	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	3	3235	44395	0.0	0.0	0.0	0.06	0.06	0.06	12.54	12.54	12.54	2.44	2.44	2.44	0.58	0.58	0.58
2	4	3350	44410	0.0	0.0	0.0	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	10	3220	44290	1.3	1.3	1.3	0.40	0.40	0.40	0.10	0.10	0.10	0.03	0.03	0.03	0.71	0.71	0.71
2	10	3220	44290	0.0	0.0	0.0	0.10	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	11	3275	443 5	21.5	21.5	21.5	35.31	35.31	35.31	6.30	6.30	6.30	1.26	1.26	1.26	1.15	1.15	1.15
6	12	3280	443 5	0.0	0.0	0.0	0.00	0.00	0.00	0.62	0.62	0.62	0.77	0.77	0.77	0.18	0.18	0.18
2	13	3318	44295	3.7	3.7	3.7	0.41	0.41	0.41	0.12	0.12	0.12	0.04	0.04	0.04	0.82	0.82	0.82
2	16	3298	44290	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.30	0.30	0.00	0.00	0.00
2	16	3298	44285	0.0	0.0	0.0	0.88	0.88	0.88	0.47	0.47	0.47	0.00	0.00	0.00	0.00	0.00	0.00
2	16	3298	44275	2.8	3.2	3.0	0.80	0.90	0.84	0.10	0.12	0.11	5.06	5.07	5.06	0.71	0.80	0.75
2	17	3310	44290	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	21	3360	44282	0.0	32.9	13.5	0.00	1.66	0.68	0.00	0.52	0.21	0.00	0.17	0.07	0.00	3.46	1.42
7	21	3375	44290	0.0	0.0	0.0	0.48	0.48	0.48	31.39	31.39	31.39	6.52	6.52	6.52	1.76	1.76	1.76
2	25	3208	44262	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	8.36	8.36	8.36	0.00	0.00	0.00
4	28	3278	44262	4.8	4.1	3.9	5.11	4.43	4.20	0.07	0.06	0.06	0.03	0.03	0.02	3.88	3.36	3.19
3	29	3282	44262	3.8	3.8	3.8	9.20	9.20	9.20	2.39	2.39	2.39	0.47	0.47	0.47	0.38	0.38	0.38
2	38	3305	44230	0.0	0.0	0.0	0.53	0.53	0.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	46	3280	44072	13.8	12.0	11.3	11.79	10.22	9.69	0.22	0.19	0.18	0.09	0.08	0.07	9.15	7.93	7.52
1	47	3397	44095	4.3	4.3	4.3	10.63	10.63	10.63	2.83	2.83	2.83	0.59	0.59	0.59	0.50	0.50	0.50
4	47	3370	44160	5.1	4.4	4.2	32.40	28.08	26.63	0.07	0.06	0.06	0.02	0.02	0.02	3.00	2.60	2.46

average summer day (June, July, August). The appendix presents the method of calculating these three averages.

Area sources are sources of emissions that are significant by themselves, but as a group may emit a large portion of the areas total pollution. 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 from all sources by grid, as shown in Table 11. The emissions from all sources are also shown for an annual average, winter and summer day.

EMISSIONS DENSITIES

In order to provide a visual representation of the emissions of pollutants by grids, emission density maps have been prepared. Emission densities were obtained by summarizing the annual area and point source emissions for each grid and dividing this total by the land area of the grid. Figures six to ten show the variation on emission densitites for the respective grids throughout the Study Area. As expected the emissions generally follow the pattern and degree of urbanization. Emission densities for CO and HC are higher in the grids with the higher populations and corresponding higher vehicular activity.

Sulfur oxides, particulates, and nitrogen oxide emission densities are highest in the grids of higher populations and industry, corresponding to greater stationary fuel combustion and vehicular activity.

TABLE 11 SUMMARY OF AIR POLLUTANT EMISSIONS FROM ALL SOURCES IN THE COLUMBUS STUDY AREA, 1968
TONS/DAY

GRID	AREA	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	38.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	38.6	0.1	0.1	0.1	0.1	0.1	0.1	9.7	9.6	10.0	1.7	1.7	1.7	0.9	1.0	0.9
3	38.6	0.2	0.9	0.5	0.5	0.7	0.6	47.0	46.9	48.2	8.5	8.4	8.6	3.5	4.5	4.0
4	38.6	0.2	0.9	0.5	0.4	0.7	0.5	41.7	41.5	43.1	7.1	7.1	7.3	3.4	4.4	3.9
5	38.6	0.0	0.1	0.1	0.1	0.1	0.1	6.5	6.5	6.7	1.1	1.1	1.2	0.6	0.7	0.6
6	38.6	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.1	0.1	0.1	0.0	0.0	0.0
7	38.6	0.1	0.4	0.2	0.2	0.3	0.3	11.8	11.8	12.2	2.3	2.3	2.4	1.3	1.7	1.5
8	9.6	0.1	0.5	0.2	0.1	0.3	0.2	12.5	12.5	13.0	2.1	2.1	2.1	0.9	1.5	1.2
9	9.6	0.1	1.1	0.5	0.3	0.7	0.4	29.7	29.7	30.8	4.9	4.9	5.0	2.1	3.5	2.8
10	9.6	1.5	1.8	1.6	0.8	0.9	0.8	20.9	20.8	21.5	3.4	3.4	3.5	2.4	2.8	2.6
11	2.4	21.6	21.7	21.6	35.4	35.4	35.4	18.6	18.5	19.0	2.9	2.9	3.0	1.8	2.0	1.9
12	2.4	0.1	0.7	0.3	0.2	0.4	0.3	21.0	20.9	21.7	3.9	3.9	4.0	1.5	2.4	1.9
13	2.4	3.8	4.1	3.9	0.5	0.7	0.6	14.5	14.5	15.0	2.2	2.2	2.2	1.7	2.2	2.0
14	2.4	0.0	0.2	0.1	0.0	0.1	0.1	5.0	5.0	5.1	0.8	0.8	0.8	0.3	0.6	0.5
15	2.4	0.1	0.3	0.2	0.1	0.2	0.2	15.1	15.1	15.6	2.2	2.2	2.2	0.9	1.3	1.1
16	2.4	3.0	4.0	3.4	1.9	2.3	2.0	21.8	21.8	22.6	8.6	8.7	8.7	2.1	3.2	2.6
17	2.4	0.1	0.5	0.2	0.2	0.3	0.2	16.6	16.6	17.2	2.5	2.5	2.6	1.1	1.7	1.4
18	2.4	0.1	0.3	0.2	0.1	0.3	0.2	15.6	15.5	16.1	2.4	2.4	2.5	1.1	1.5	1.3
19	9.6	0.1	0.9	0.5	0.2	0.6	0.4	28.2	28.2	29.2	4.6	4.6	4.7	2.0	3.2	2.6
20	9.6	0.0	0.2	0.1	0.1	0.1	0.1	8.9	8.9	9.2	1.5	1.5	1.5	0.7	0.9	0.8
21	9.6	0.1	33.5	13.8	0.7	2.5	1.4	47.5	48.0	48.2	9.3	9.5	9.5	3.1	7.3	4.8
22	38.6	0.1	0.5	0.3	0.2	0.4	0.3	20.1	20.0	20.8	3.7	3.6	3.8	1.9	2.4	2.1
23	38.6	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
24	38.6	0.1	0.3	0.2	0.2	0.3	0.3	10.4	10.4	10.8	2.0	2.0	2.0	1.1	1.5	1.3
25	1.5	0.0	0.1	0.1	0.1	0.1	0.1	8.3	8.3	8.6	9.5	9.5	9.5	0.5	0.6	0.6
26	1.5	0.0	0.3	0.1	0.1	0.2	0.1	6.7	6.7	6.9	1.1	1.1	1.1	0.5	0.9	0.7
27	1.5	0.0	0.3	0.1	0.1	0.2	0.1	9.6	9.6	9.9	1.3	1.3	1.4	0.6	0.9	0.7

TABLE 11 SUMMARY OF AIR POLLUTANT EMISSIONS FROM ALL SOURCES (cont.)

28	1.5	4.9	4.5	4.1	5.2	4.7	4.4	22.3	22.2	23.0	2.6	2.6	2.6	4.8	4.6	4.3
29	1.5	4.1	4.4	4.2	9.7	9.8	9.7	124.3	123.1	128.1	13.2	13.1	13.6	4.7	5.0	5.0
30	1.5	0.0	0.2	0.1	0.0	0.1	0.1	0.7	0.7	0.7	0.2	0.2	0.2	0.1	0.3	0.2
31	1.5	0.0	0.1	0.1	0.0	0.1	0.1	7.9	7.9	8.2	1.1	1.0	1.1	0.4	0.5	0.5
32	1.5	0.0	0.3	0.2	0.1	0.2	0.1	13.7	13.6	14.2	1.7	1.7	1.7	0.6	1.0	0.8
33	6.1	0.1	0.6	0.3	0.1	0.4	0.2	18.5	18.4	19.1	2.8	2.8	2.8	1.1	1.9	1.5
34	13.8	0.1	0.3	0.2	0.1	0.2	0.2	6.7	6.7	6.9	1.3	1.3	1.4	0.7	1.1	0.9
35	2.4	0.2	0.5	0.3	0.3	0.4	0.4	26.5	26.4	27.4	4.7	4.7	4.9	2.4	2.9	2.7
36	2.4	0.1	0.9	0.4	0.1	0.5	0.3	32.0	32.0	33.1	3.9	4.0	4.1	1.3	2.5	1.9
37	2.4	0.1	0.4	0.2	0.1	0.3	0.2	17.3	17.3	17.9	2.5	2.5	2.6	1.0	1.6	1.3
38	2.4	0.0	0.5	0.2	0.6	0.8	0.7	10.3	10.3	10.7	1.5	1.5	1.5	0.5	1.2	0.8
39	2.4	0.1	0.2	0.1	0.1	0.2	0.1	13.7	13.6	14.1	1.9	1.9	2.0	0.8	1.1	0.9
40	9.6	0.1	0.4	0.2	0.2	0.3	0.2	7.0	7.0	7.3	1.5	1.5	1.5	0.9	1.4	1.1
41	9.6	0.2	1.3	0.7	0.4	0.9	0.6	35.2	35.2	36.4	6.5	6.5	6.7	3.1	4.8	3.9
42	9.6	0.1	0.1	0.1	0.1	0.2	0.1	14.8	14.7	15.3	2.4	2.4	2.4	1.2	1.2	1.2
43	38.6	0.2	0.7	0.4	0.3	0.5	0.4	31.7	31.6	32.8	5.4	5.4	5.6	2.7	3.4	3.1
44	38.6	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
45	38.6	0.1	0.1	0.1	0.2	0.2	0.2	8.4	8.3	8.7	1.5	1.5	1.6	0.9	1.0	0.9
46	38.6	14.0	12.3	11.6	12.0	10.5	10.0	28.2	28.0	29.1	4.9	4.8	5.0	11.5	10.5	10.1
47	38.6	9.7	9.3	8.9	43.5	39.3	37.8	29.7	29.5	30.6	5.5	5.5	5.7	6.3	6.2	5.9
48	38.6	0.0	0.1	0.1	0.1	0.1	0.1	3.3	3.3	3.4	0.7	0.7	0.7	0.4	0.5	0.5
TOTAL		68.2	113.5	84.0	118.2	120.1	113.1	902.9	899.8	931.2	157.6	157.8	161.7	83.9	108.2	93.7

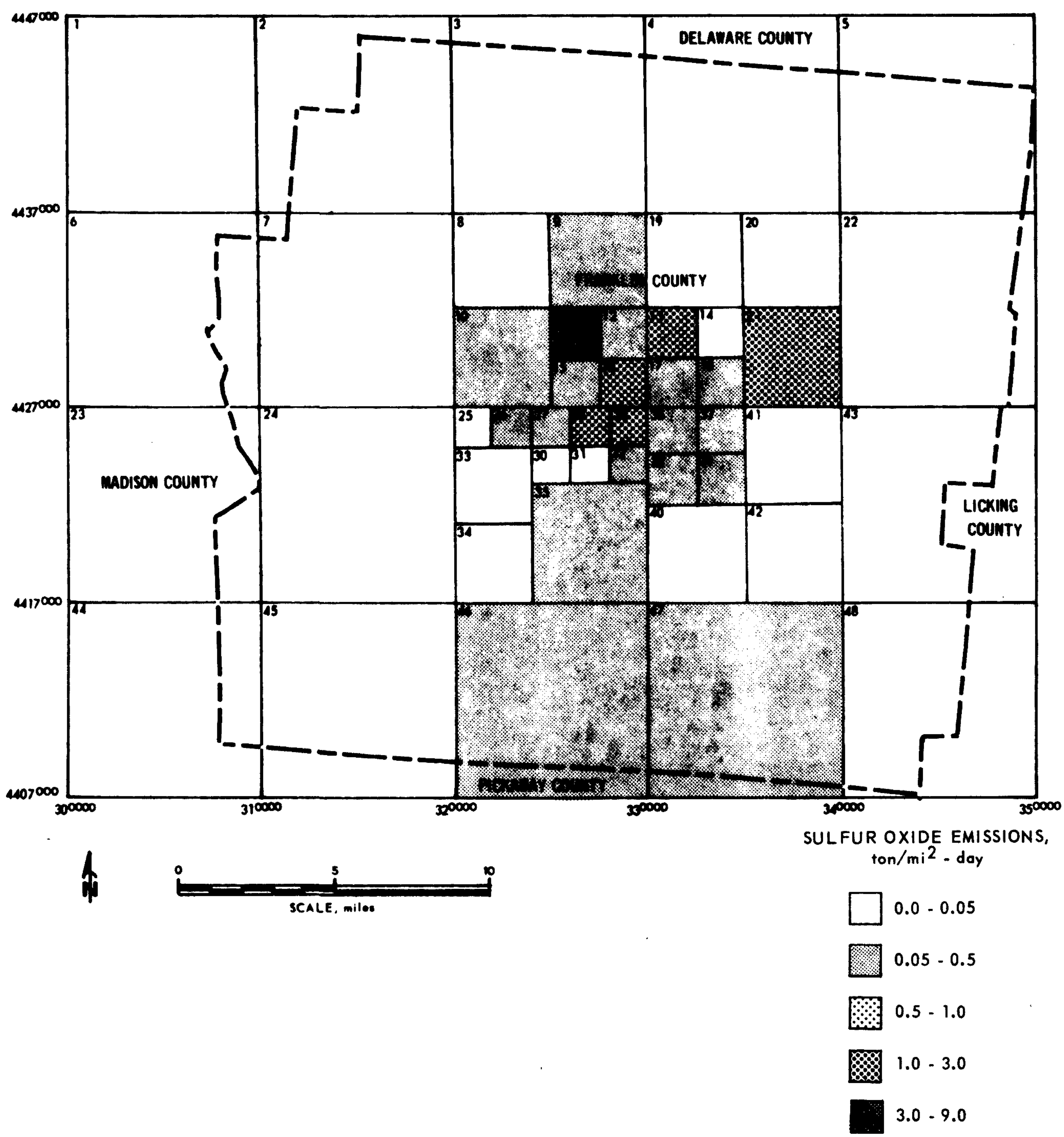

Figure 6. Sulfur oxide emission density from all sources in the Franklin county study area.

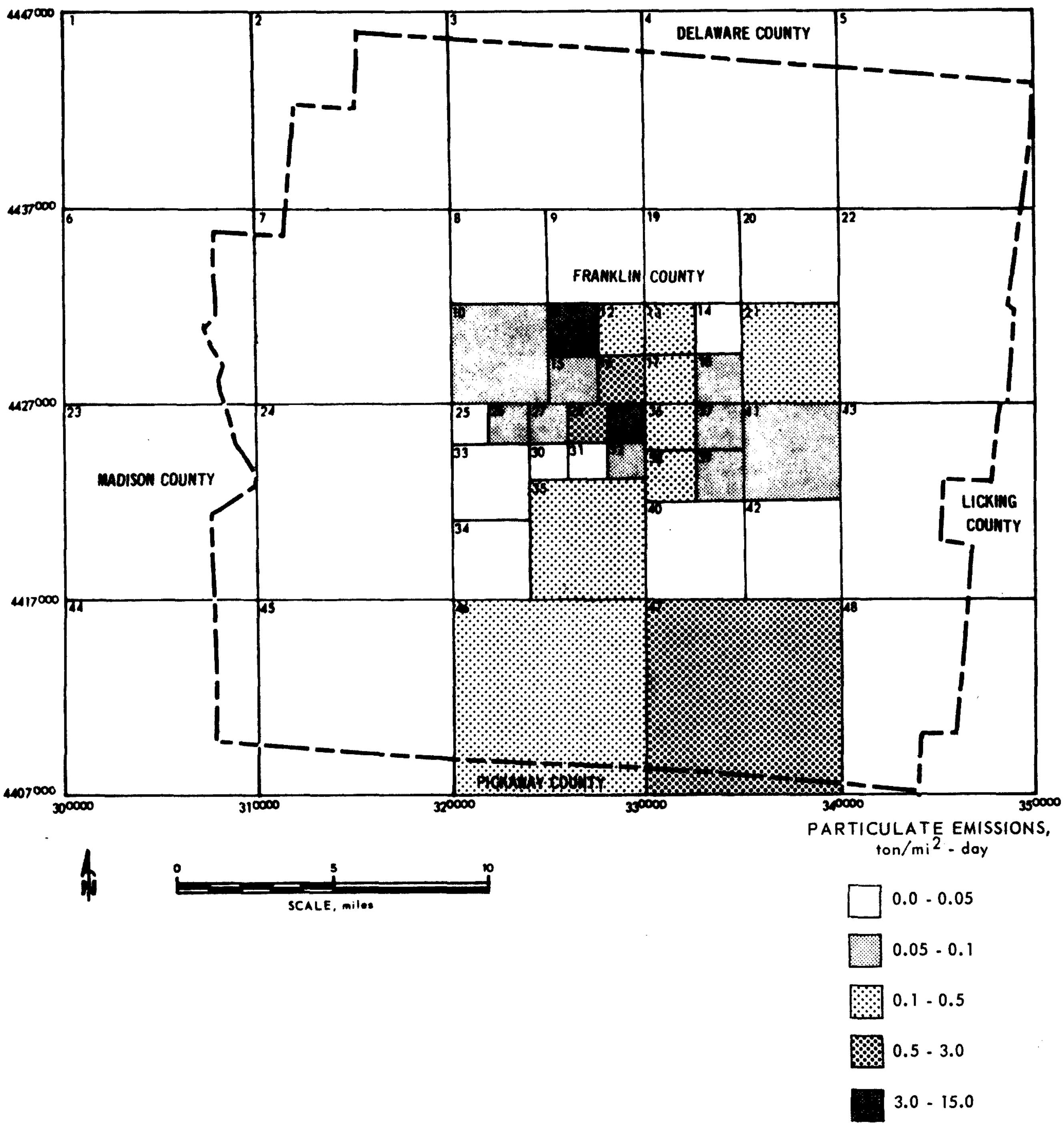

Figure 7. Particulate emission density from all sources in the Franklin county study area.

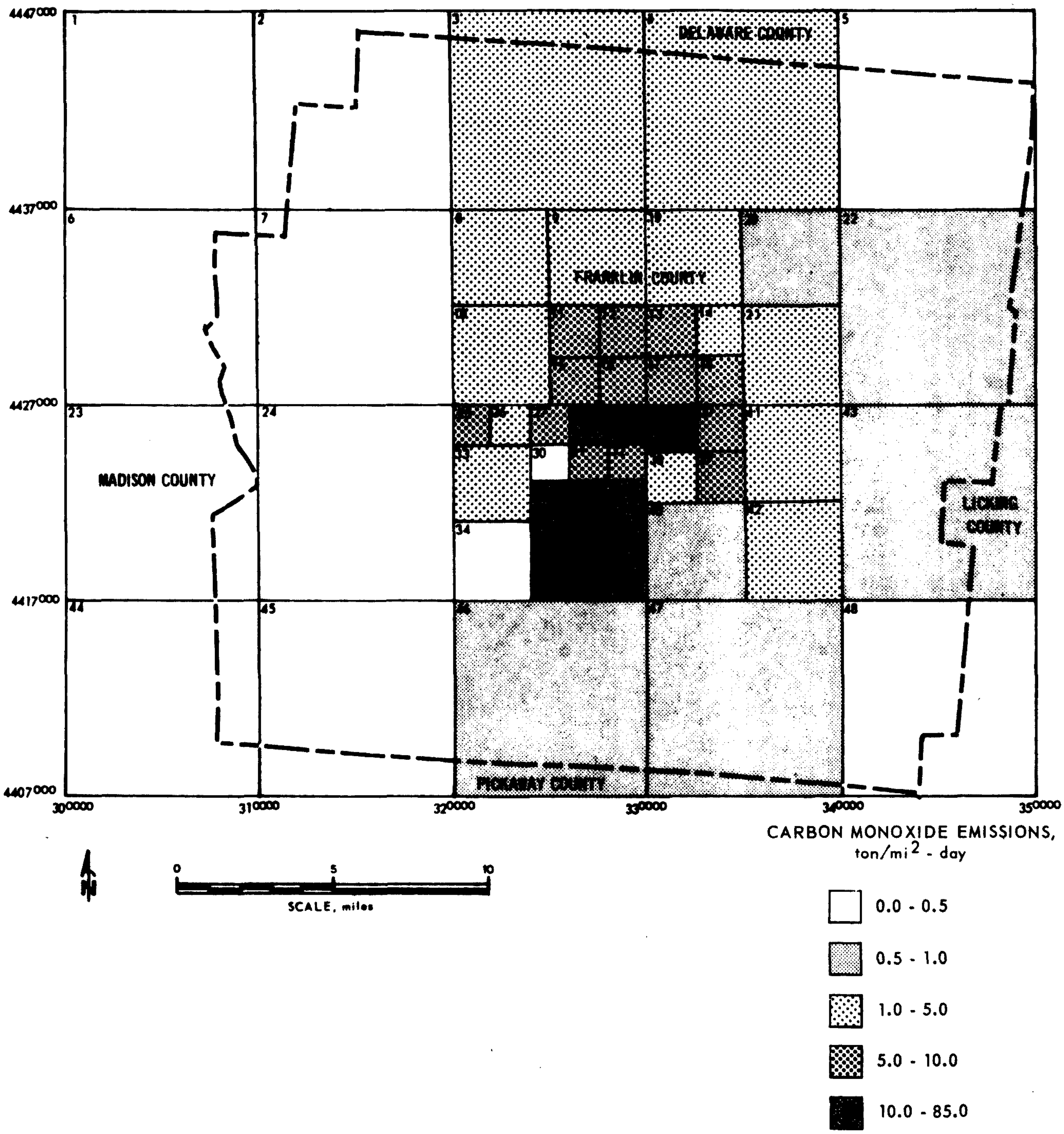

Figure 8. Carbon monoxide emission density from all sources in the Franklin county study area.

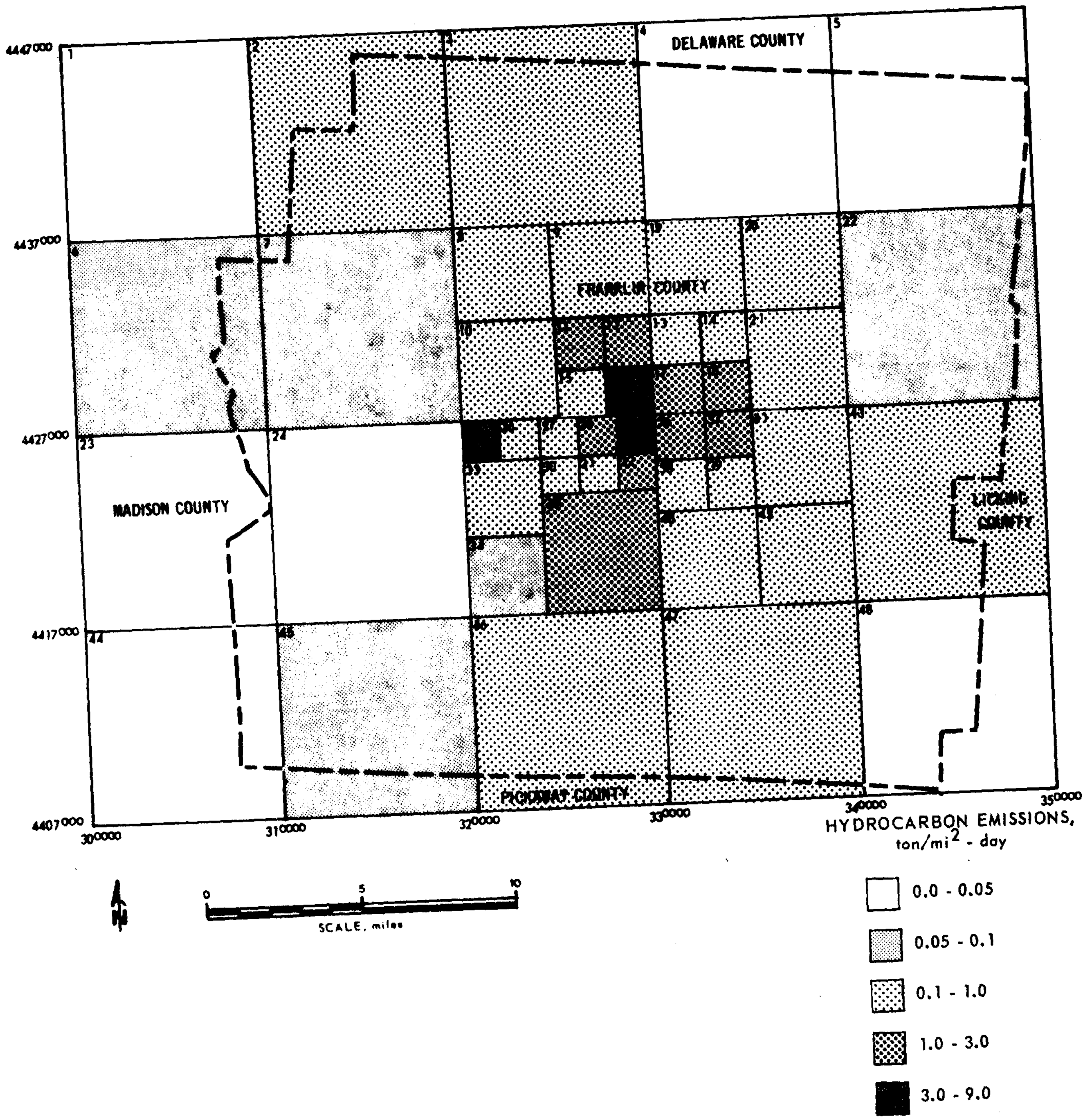

Figure 9. Hydrocarbon emission density from all sources in the Franklin county study area.

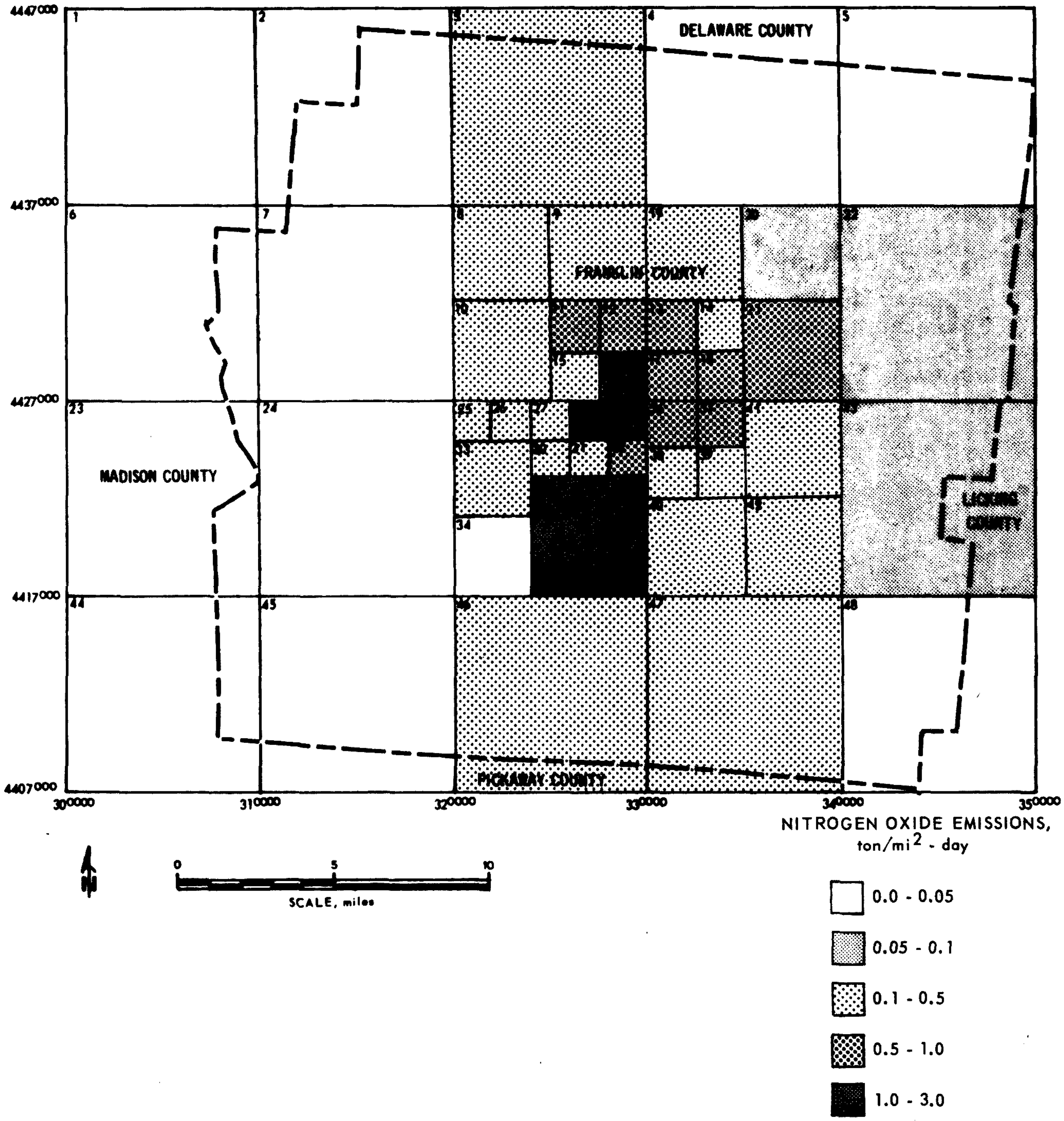

Figure 10. Nitrogen oxide emission density from all sources in the Franklin county study area.

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1. Ozolins, Guntis and Raymond Smith, Rapid Survey Techniques for Estimating Community Air Pollution Emissions. DHEW, PHS, October 1966.

2. Duprey, R. L., Compilation of Air Pollutant Emission Factors, United States, DHEW, PHS, 1968.

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6. Ozolins, op. cit., pp. 43-45.

7. Highway Statistics/1967, United States Department of Transportation, Federal Highway Administration, Bureau of Public Roads.

8. Duprey, op. cit., p. 46.

APPENDIX A

METHOD FOR CALCULATING SUMMER, WINTER AND ANNUAL AVERAGE EMISSIONS FOR FUEL CONSUMPTION IN STATIONARY SOURCES

YEARLY AVERAGE (A)

$$A = \frac{\text{Fuel Consumed} \times \text{Emission Factor (E. F.)}}{\text{Days of Operation}}$$

e.g. A plant consumed 100,000 tons of coal in 1967 while operating 365 days. The total degree days for the area was 4,800 and 2,800 for the three winter months. The plant was estimated to use 15 percent of the fuel for space heating and 85 percent for process heating. From this information, the annual average emission for carbon monoxide would be the following:

$$A = \frac{100{,}000 \text{ Tons/year} \times 3 \text{ lbs. CO/Ton coal}}{365 \text{ Days/year} \times 2{,}000 \text{ lb./Ton}}$$

$A = 0.41$ Ton/Day

WINTER AVERAGE (W)

$$W = \frac{\text{Fuel Consumed} \times \text{E.F.}}{\text{Days of Winter Operation}} \times \frac{\text{Winter Degree Days}}{\text{Total Degree Days}} \times \text{\% Fuel Used for space heating}$$

$$+ \frac{\text{Fuel Consumed} \times \text{E.F.}}{365} \times \text{\% Fuel used for process heating}$$

$$W = \left[\frac{100{,}000 \times 2{,}800}{90 \times 4{,}800} \times 0.15 + \frac{100{,}000}{365} \times 0.85\right] \frac{3}{2{,}000}$$

$W = 0.49$ Ton/Day

SUMMER AVERAGE (S)

$$S = \frac{\text{Fuel Consumed} \times \text{E.F.}}{\text{Days of Summer Operation}} \times \frac{\text{Summer Degree Days}}{\text{Total Degree Days}} \times \text{\% Fuel Used for space heating}$$

$$+ \frac{\text{Fuel Consumed} \times \text{E.F.}}{365} \times \text{\% Fuel used for process heating}$$

$$S = \left[\frac{100{,}000}{90} \times \frac{0}{4{,}800} \times 0.15 + \frac{100{,}000}{365} \times 0.85\right] \frac{3}{2{,}000}$$

$S = 0.35$ Ton/Day

APPENDIX B

METRIC CONVERSION FACTORS

Multiply	By	To Obtain
Feet	0.3048	Meters
Miles	1609	Meters
Square Feet	0.0929	Square meters
Square Miles	2.59	Square kilometers
Pounds	453.6	Grams
Pounds	$453.6/10^4$	Tons (metric)
Tons (metric)	1.103	Tons (short)
Tons (short)	907.2	Kilograms
Tons (short)	.9072	Tons (metric)
To Obtain	By	Divide