HOUSTON-GALVESTON
AIR POLLUTION EMISSION INVENTORY

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Houston-Galveston Air Pollutant Emission Inventory

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PREFACE

This report, which presents the emission inventory of the Houston-Galveston 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 as well as 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 latter group which generally contains about fifty to one hundred sources 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. The emissions in both cases are expressed in terms of tons of pollutants for an average annual, summer, and winter day.

Emissions for the most part are estimated using various indicators of pollutant emissions and average emission factors that are related to these. This means that information and data are collected on fuel

consumptive, refuse burning rates, vehicle miles and gasoline consumption, 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 type 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.

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 January, 1969. The data obtained in this study is for the most part representative of 1967 and emission estimates presented herein should be considered as showing the conditions during 1967.

For purposes of this survey, a Study Area was set up consisting of eight counties surrounding the cities of Houston and Galveston. The entire area covers some 7800 square miles and included a 1967 population of about 2 million people. The Study Area was subdivided into 61 grid zones ranging in size from 25 aquare kilometers in the heavily populated areas to 1600 square kilometers in the outlying areas.

Any individual source which had emissions significant to the overall pollution was classified as a point source and located specifically in the aforementioned grid zones. The remaining single sources were added to the area sources and reported as grid totals.

SUMMARY OF RESULTS

An estimated 1.8 million tons of the five major pollutants are emitted anually in the Study Area. The breakdown of these emissions by type of pollutant and source category are summarized in Table 1. The following is a brief summary of pollutant emissions as presented in Table 1.

Sulfur Oxides	1967 Total = 143,900 tons	
	Industrial Process	93%
	Transportation	6%
	Other	1%
Particulates	1967 Total = 155,800 tons	
	Industrial Process	84%
	Refuse Disposal	5%
	Road Vehicles	4%
	Industrial Fuel Use	4%
	Other	3%
Carbon Monoxides	1967 Total = 1,066,400 tons	
	Road Vehicles	76%
	Industrial Process	20%
	Refuse Disposal	3%
	Other	1%
Hydrocarbons	1967 Total = 291,700 tons	
	Industrial Process	62%
	Road Vehicles	22%
	Evaporation	14%
	Other	2%

Nitrogen Oxides

1967 Total = 213,300 tons

Industrial Fuel Use	32%
Road Vehicles	21%
Industrial Process	21%
Steam Electric	21%
Other	5%

Emissions by Point Sources

Oxides of Sulfur	93%
Particulates	89%
Carbon Monoxide	21%
Hydrocarbons	64%
Oxides of Nitrogen	59%

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

Source Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation	9,200	8,500	821,500	107,300	49,500
Road Vehicles	3,700	6,000	810,200	63,600	45,500
Evaporation	--	--	--	40,700	--
Other	5,500	2,500	11,300	3,000	4,000
Combustion of Fuels Stationary Sources	200	7,800	100	Neg.	114,100
Industry	100	5,700	100	Neg.	67,500
Steam-Electric	100	1,700	Neg.	Neg.	44,000
Residential	Neg.	200	Neg.	Neg.	1,500
Commercial	Neg.	100	Neg.	Neg.	700
Refuse Disposal	300	8,400	39,000	3,000	4,800
Incineration	300	2,100	5,600	1,000	500
Open Burning	--	6,300	33,400	2,000	4,300
Industrial Process Emissions	134,200	131,100	205,800	181,400	44,900
TOTAL EMISSIONS	143,900	155,900	1,066,400	291,700	212,900

STUDY AREA

The Study Area for the emission survey of the Houston-Galveston Metropolitan Area consists of eight counties-Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery and Waller. The eight county area is located in the south-eastern region of the State of Texas. Figure 1 shows the location of the Houston-Galveston Study Area relative to other cities in its vicinity. Figure 2 represents a more detailed drawing of the Study Area.

The climate of the Study Area is predominately marine. The terrain includes numerous small steams and bayous which, together with the Gulf of Mexico and Galvestin Bay, favor the development of both ground and advective fog. Prevailing winds are from the southeast and south, except in January, when frequent passages of high pressure areas bring invasions of polar air and prevailing northerly winds.

Although the total area is slightly over 7800 square miles, only some 200 square miles are at present urbanized. Over 80 percent of the Study Area's 2 million people reside in Harris County, and 7 percent live in Galveston County. The other six counties are mostly rural. The 1960 and 1967 population of each of the ten counties are presented in Table 2. Comparison of the 1960 and 1967 population for the entire United States shows an increase of 10.9 percent where as the Houston Study Area increased 27 percent in the same period.

The manufacturing industries (Table 3) in the Study Area are highly diversified but with a lot of chemically orientated facilities. In addition to the eight major oil refineries, there are petrochemical plants, cement manufacturing, coffee roasting, grain milling, acid plants and aero-space facilities.

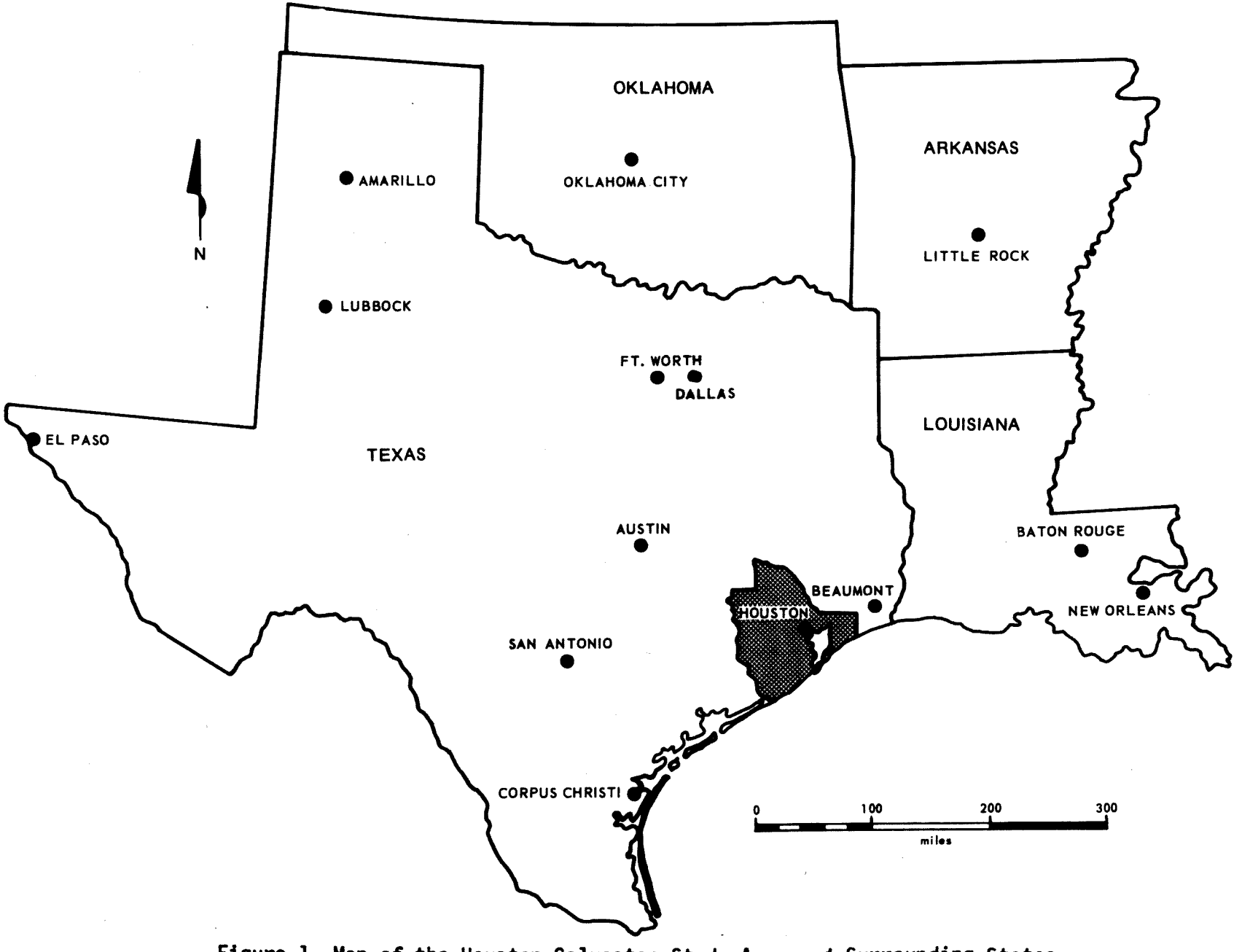

Figure 1. Map of the Houston-Galveston Study Area and Surrounding States

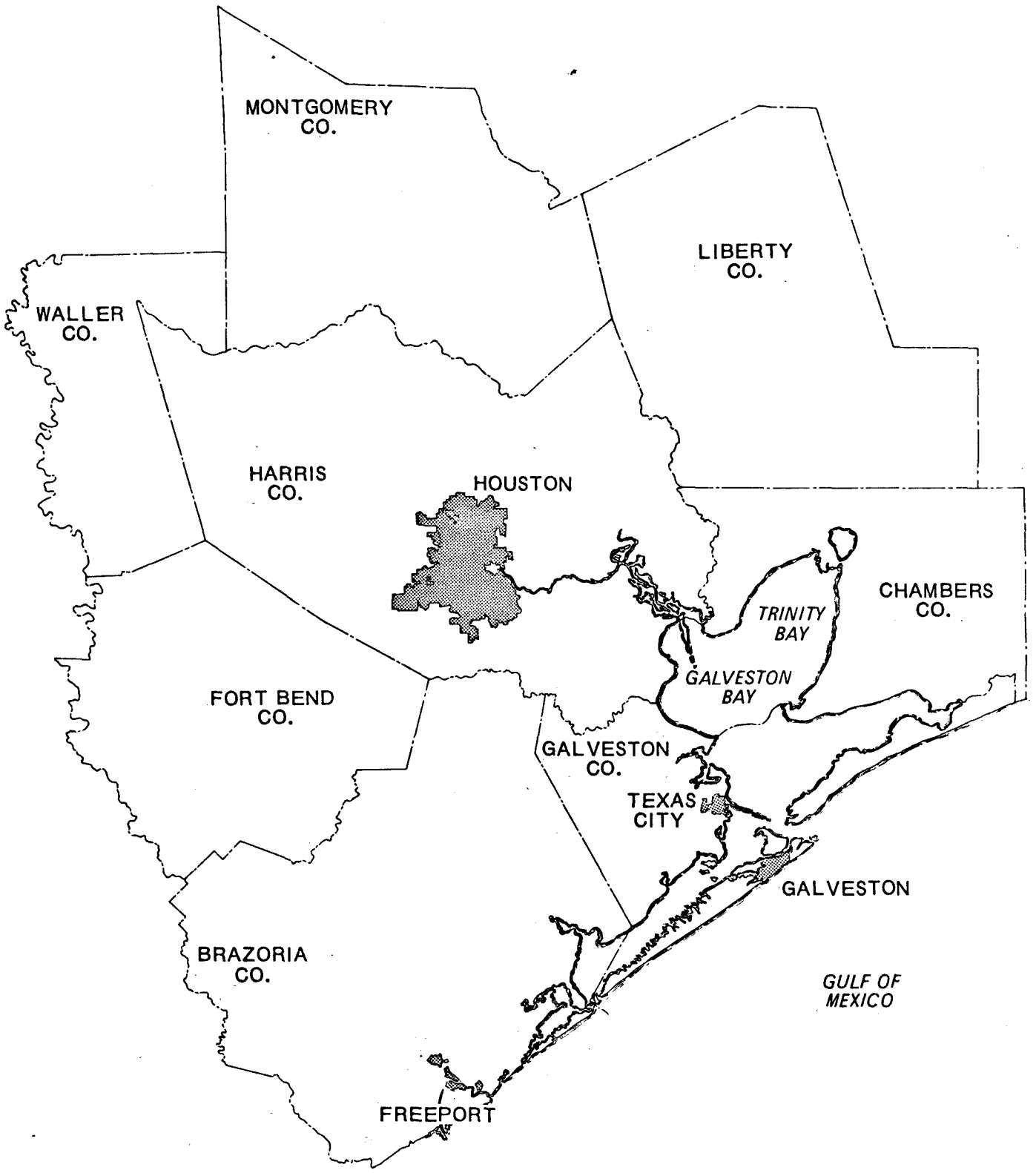

Figure 2. Detailed Map of the Houston-Galveston Study Area

Table 2 Population Figures for the
Houston-Galveston Study Area

	1960	1967	Percent Increase
Brazoria County	76,200	97,800	28
Chambers County	10,400	12,000	15
Fort Bend County	40,500	50,700	25
Galveston County (Balance)	73,200	96,700	32
City of Galveston	67,200	70,600	5
Harris County (Balance)	305,000	430,900	41
City of Houston	938,200	1,159,800	24
Liberty County	31,600	33,600	6
Montogomery County	26,300	35,700	33
Waller County	12,100	14,800	22
Grand Total	1,581,200	2,002,600	27

Table 3 Number of Establishments in the Houston and Galveston Standard Metropolitan Statistical Areas (1960)

	Houston	Galveston Texas City
Food and Tobacco	81	8
Textile Products	18	-
Paper and Printing	62	3
Chemical Products	113	8
Lumber & Wood Products	47	-
Stone and Gravel Products	53	2
Primary and Intermediate Metal Products	152	4
Electrical Machinery	126	-
Transportation and Ordinance	20	2
Instruments and Miscellaneous	17	-

GRID COORDINATE SYSTEM

Grid coordinates based on the Universal Transvere Mercator System were used in this study to show the geopraphical distribution of sources and emissions. As shown in Figure 3, the Study Area was divided into 61 grids of four different sizes - 25,100,400 and 1600 square kilometers.

Different size grids are used to limit the number of grid zones and yet allow a satisfacoty definition of geographical gradation of emissions in areas where the majority of pollution occurs. For this reason, the 25 kilometer grids are used in the downtown areas where the emission densities whould change abruptly within short distances. In areas primarily rural in nature, the use of small zones are not as important.

As illustrated in Figure 3, each grid line is identified by a coordinate number. The north-south and the east-west coordinates are expressed in meters.

The point sources in the Study Area are identified by both horizontal and vertical coordinates to the nearest 100 meters. The grids are identified by the coordinates of their geographical center.

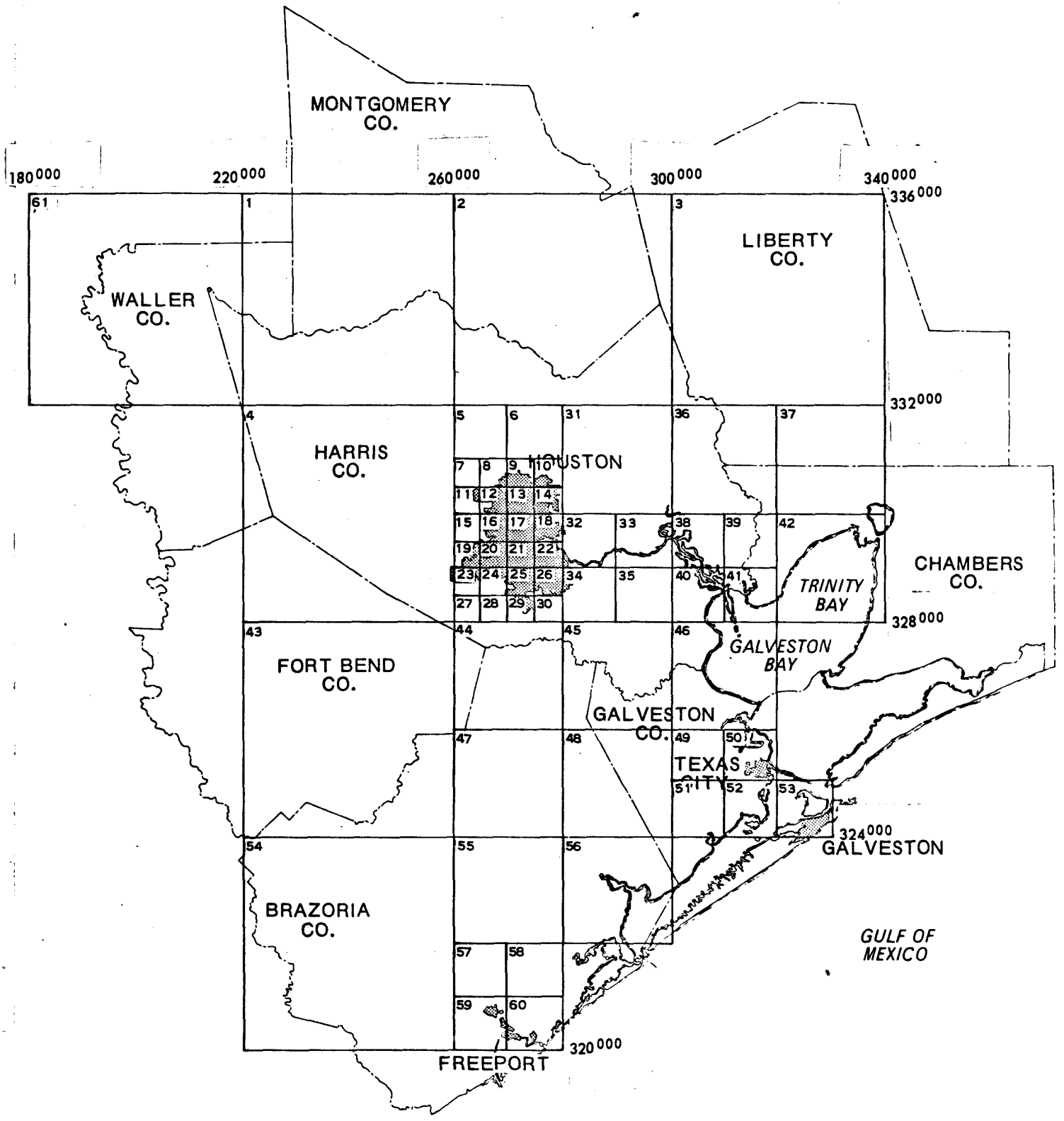

Figure 3. Grid Coordinate System for the Houston-Galveston Study Area

EMISSIONS BY CATEGORY

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

1. Fuel Consumption in stationary sources
2. Transportation
3. Solid-waste disposal
4. Industrial process losses

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

It is important to note that the estimates presented herein are estimates of partial totals. This stems from the inavailability of certain types of data. It was especially difficult to gather information on hydrocarbon emissions and natural gas consumption for the Houston Area. The results should be viewed with these limitations in mind.

Fuel Combustion in Stationary Sources

Although all the three major fuels are consumed within the Study Area, natural gas is the most significant. As shown in Tables 4 through 6, approximately one half million tons of coal, 1.6 million barrels of fuel oil, and 895 trillion cubic feet of natural gas were consumed in the Study Area. The breakdown of fuel consumption by user category and by jurisdiction is also shown in these tables.

The nine steam-electric generating plants within the Study Area consume 25 percent of the natural gas while industry uses approximately 70 percent.

All the coal used in the Study Area was made into coke and used in the production of steel.

The fuel oil was consumed by railroads and vessels in the Study Area. The railroads used about .8 million barrels of distillate while the 4000 ships per year in the ship channel burned an equal amount of residual fuel oil.

Average values for the sulfur and ash contents of the fuels may be found in Table 7.[10, 11]

Emissions From Fuel Consumption

Air pollutant emissions resulting from fuel consumption in stationary sources are listed in Table 8. The emissions are presented for industrial, steam-electric utility, residential, and commercial sources.

Emissions due to coal were not included in this section but were put in process emissions. Oil emissions were placed with transportation sources.

Natural gas accounted for approximately 100 thousand tons of pollutants. The largest portion of this being nitrogen oxides.

Data Sources

Fuel consumption data for the Study Area were obtained from a variety of sources. Natural gas numbers were gotten from natural gas companies and pipe line companies. Also some information was furnished by individual industries. The Houston Light and Power Company supplied us with the consumption of their power plants.

Coal was estimated from published coke production figures.

Distillate fuel oil estimates were obtained from five or six of the larger railroads in the Study Area. The residual fuel oil was generated by a factor recieved from the Maritime Association in Houston. It also supplied the number of ships using the ship channel yearly.

Transportation

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

Road Vehicles

The miles of travel by motor vehicles in the Study Area are summarized in Table 9. Vehicle miles data for the city of Houston was obtained from a transportation study done by the Texas A & M University. The vehicle miles for all other jurisdictions in the Study Area were estimated by gasoline consumption and proportioned into grids by population.

Travel by diesel powered vehicles was estimated from state wide fuel consumption figures. It was found approximately 2 percent of the vehicle miles in the Area are diesel. Vehicle miles by diesel were also proportioned by population.

Aircraft

Tables 11 shows the air traffic activity at the three largest airports in the Study Area. Total aircraft operations were supplied by the Federal Aviation Administration for W. P. Hobby Airport while the others were gotten from personal communications. An operation is defined as either a takeoff or a landing. Aircraft accounted for less than 25 percent of the total transportation emissions for any pollutant.

Railroads and Vessels

Railroads consume about 25 million gallons of diesel fuel. This was obtained from various railroads in the Area. River vessels consumed about 25 million gallons of residual fuel oil. Because of the sulfur content of the fuel oil, sulfur oxides from vessels are significant when compared to emissions from other transportation sources, but other pollutants emitted by vessels and railroad are small.

Solid Waste Disposal

Approximately 2 million tons of refuse were generated during 1967 in the Study Area. Table 13 presents a solid waste balance for the Houston Galveston Study Area, showing the various methods of disposal and the quantities disposed of by each method. Landfills accounted for 28 percent; municipal and on-site incineration 17 percent; dumps 32 percent; and on-site burning 23 percent of the total refuse disposed.

Table 14 shows the air pollutant emissions from solid-waste disposal. The largest single sources were a municipal incinerator in Houston and burning dumps in Galveston County.

Industrial Process Emissions

Table 3 shows selected manufacturing establishments in the Area by SMSA for 1960. The largest percentage of the industry in the Area is located along the ship channel in the city of Houston and Harris County. There are also industrial areas in Galveston County and Brazoria County. Emissions from industrial process losses are shown in Table 15.

Table 4 Summary of Coal Consumption
in Houston Study Area, 1967 (tons/year)

	Residential	Commercial	Industrial	Total
Brazoria	Neg. *	Neg.	Neg.	Neg.
Chambers	Neg.	Neg.	Neg.	Neg.
Fort Bend	Neg.	Neg.	Neg.	Neg.
Galveston	Neg.	Neg.	Neg.	Neg.
Harris	Neg.	Neg.	550,000	550,000
Liberty	Neg.	Neg.	Neg.	Neg.
Montgomery	Neg.	Neg.	Neg.	Neg.
Waller	Neg.	Neg.	Neg.	Neg.
Total	Neg.	Neg.	550,000	550,000

* Neg-Negligible

Table 5 Summary of Fuel Oil Consumption
in the Houston Study Area, 1967 (BBL/YEAR)

	Residential	Commercial	Industrial	Total
Brazoria	Neg.**	Neg.	Neg.	Neg.
Chambers	Neg.	Neg.	Neg.	Neg.
Fort Bend	Neg.	Neg.	Neg.	Neg.
Galveston	Neg.	Neg.	Neg.	Neg.
Harris	Neg.	Neg.	1,600,000*	1,600,000
Liberty	Neg.	Neg.	Neg.	Neg.
Montgomery	Neg.	Neg.	Neg.	Neg.
Waller	Neg.	Neg.	Neg.	Neg.
Total	Neg.	Neg.	1,600,000	1,600,000

*Estimated amount of fuel oil consumed by vessels and railroads.

**Neg-Negligible

TABLE 6 SUMMARY OF NATURAL GAS CONSUMPTION IN HOUSTON STUDY AREA, 1967 (10^6 cu. ft./year)

	Residential	Commercial	Industrial	Steam Electric	Total
Brazoria	1,200	400	310,000	--	311,600
Chambers	150	10	4,000	--	4,160
Fort Bend	650	150	8,000	54,550	63,350
Galveston	2,200	850	90,000	58,690	151,740
Harris (Balance)	6,200	1,830	50,000	107,690	165,720
Houston	14,100	9,400	150,000	4,740	178,240
Liberty	450	100	4,000	--	4,550
Montgomery	500	20	3,000	--	3,520
Waller	200	10	12,000	--	12,210

Table 7 Chemical Analysis of Fuels
Burned in Houston Study Area, 1967

	Sulfur Percent	Ash Percent	Volatile Percent
Coal	1.0	9.0	38.7
Natural Gas	0.0008	-	-
Residual Fuel Oil	1.97	-	-
Distillate Fuel Oil	0.18	-	-

TABLE 8 SUMMARY OF EMISSIONS FROM BURNING OF FUELS IN STATIONARY SOURCES, 1967 (TONS/YEAR)

Fuel	User Category	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro carbons	Nitrogen Oxides
Coal	Industrial					
	Steam-Electric					
	Residential					
	Commercial					
	Totals	--	--	---	--	--
Fuel Oil	Industrial					
	Steam-Electric					
	Residential					
	Commerical					
	Total	--	--	--	--	--
Gas	Industrial	130	5,680	130	Neg.	67,500
	Steam-Electric	50	1,690	Neg.	Neg.	44,800
	Residential	Neg.	200	Neg.	Neg.	1,500
	Commerical	Neg.	200	Neg.	Neg.	1,260
	Total	180	7,770	130	Neg.	115,060
Grand Total		180	7,770	130	Neg.	115,060

TABLE 9 VEHICLE-MILES TRAVELED IN HOUSTON-GALVESTON STUDY AREA 1967

10^3 VEHICLE MILES/DAY

Political Jurisdiction	Gasoline Powered	Diesel Powered
Brazoria Co.	1,332	27
Chambers Co.	147	3
Fort Bend Co.	568	11
Galveston Co.	1,969	40
Harris Co.	6,879	140
City of Houston	14,387	293
Liberty Co.	627	12
Montgomery Co.	431	8
Waller Co.	196	4
Total	26,536	538

TABLE 10 GASOLINE AND DIESEL CONSUMPTION IN HOUSTON-GALVESTON STUDY AREA, 1967 (10^6 gal./year)

Political Jurisdiction	Gasoline Consumption	Diesel Consumption
Brazoria Co.	38.9	1.9
Chambers Co.	4.3	.2
Fort Bend Co.	16.6	.8
Galveston Co.	57.5	2.9
Harris Co.	200.9	10.0
City of Houston	420.1	21.0
Liberty Co.	18.3	.9
Montgomery Co.	12.6	.6
Waller	5.7	.3
Total	774.9	38.6

Table 11 Air Activity at W. P. Hobby Airport, 1967

	Itinereant Operations	Local Operations
Air Carrier	103,976	18,335
General Aviation	149,838	
Military	1,005	
Total	254,819	18,335

Table 11A Air Quality at Ellington Air Force Base & Andrau Airport, 1967

Ellington	- 72,000 operations
Andrau	- 30,000 operations

TABLE 12 SUMMARY OF TRANSPORTATION EMISSIONS IN HOUSTON STUDY AREA, 1967 (TONS/YEAR)

	Sulfur Oxides	Particu-lates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Road Vehicles	3,670	6,010	810,170	63,600	45,500
Gasoline	2,900	3,870	809,000	60,970	41,200
Diesel	770	2,140	1,170	2,630	4,300
Aircraft	--	1,870	11,230	2,910	1,540
Jet	--	1,830	1,190	1,040	1,070
Piston	--	40	10,040	1,870	470
Vessels	5,050	380	30	30	1,180
Railroads	500	260	40	40	1,260
Totals	9,220	8,520	821,470	66,580	49,480

Table 13 Refuse Balance for the Houston-Galveston Study Area, 1967 (Tons/Year)

Political Jurisdiction	Totaled Generated	Incineration		Landfills	Dumps	On-Site Burning	Transferred
		Municipal	On-Site				
City of Houston	1,130,000	100,000	190,000	540,000*		90,000	210,000 (out)
Brazoria	105,000				87,000	18,000	
Chambers	12,000				2,000	10,000	
Fort Bend County	45,000				31,000	14,000	
Galveston County	295,000				223,000	72,000	
Harris County (Balance)	370,000		60,000	50,000	250,000	220,000	210,000 (in)
Liberty County	36,000				23,000	13,000	
Montgomery County	35,000				16,000	19,000	
Waller County	19,000				12,000	7,000	
Totals	2,047,000	100,000	250,000	590,000	644,000	463,000	

*90,000 Tons/Year of landfill figure is used by compost manufacture.

Table 14 Air Pollutant Emissions
From Solid Waste Disposal in the Houston-
Galveston Study Area, 1967 (Tons/Year)

	Sulfur Oxides	Partic-ulates	Carbon Monoxide	Hydro-Carbons	Nitrogen Oxides
Total Incineration	350	2100	5,550	130	470
Municipal	100	850	50	20	100
On-Site	250	1250	5,500	110	370
Total Open Burning	--	6280	33,370	1960	4320
Dumps	--	2580	13,690	800	1770
On-Site	--	3700	19,680	1160	2550
Total Emissions	350	8380	38,920	1290	4790

Table 15 Air Pollutant Emissions From Process Emission Sources in Houston-Galveston Study Area, 1967 (Tons/Year)

Type of Industry	Sulfur Oxides	Particu-lates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Refineries	47,570	5,840	149,000	116,800	39,420
Acid Plants	71,720	910			
Chemical Plan s	4,300	4,520	56,020	64,280	
Cement Manufacturing		14,400			
Coffee Plant		81,900			
Fertilizer	1,900	470			
Grain Milling & Handling		7,880			
Pulp & Paper		3,010			
Primary Metals	8,800	14,850	320	270	5,500
Total	134,290	133,780	205,840	181,350	**44,290**

EMISSIONS BY JURISDICTION

In order to decide the relative significance between jurisdictions from an air pollution standpoint, emissions for each of the nine jurisdictions have been summarized. Table 10 through table 24 present the summary of each of these jurisdictions.

For the purpose of the report, Harris County has been broken into two jurisdictions: City of Houston and balance of Harris County. Portions of the Ship Channel Area are being controlled by two air pollution agencies (Houston and Harris County), but for simplicity the ship channel was placed in the balance of Harris County summary.

TABLE 16 SUMMARY OF EMISSIONS IN BRAZORIA COUNTY
1967 (TONS/YEAR)

Source Category	Sulfur Oxides	Particu-lates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Road Vehicles	180	300	40,680	5,240	2,280
Other	--	--	--	--	--
Combustion of Fuels Stationary Sources					
Industry	60	2,790	60	Neg.	33,170
Steam-Electric	--	--	--	--	--
Residential	Neg.	10	Neg.	Neg.	70
Commercial	Neg.	10	Neg.	Neg.	20
Refuse Disposal					
Incineration	--	--	--	--	--
Open Burning	--	490	2,610	150	340
Industrial Process Emissions	2,110	--	18,000	58,690	--
Total Emissions	2,350	3,600	61,350	64,080	35,880

TABLE 17 SUMMARY OF EMISSIONS IN CHAMBERS COUNTY
1967 (TONS/YEAR)

Source Category	Sulfur Oxides	Particu-lates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Road Vehicles	20	30	4,490	580	250
Other	--	--	--	--	--
Combution of Fuels Stationary Sources					
Industry	Neg.	40	Neg.	Neg.	430
Steam-Electric	--	--	--	--	--
Residential	Neg.	Neg.	Neg.	Neg.	10
Commercial	Neg.	Neg.	Neg.	Neg.	Neg.
Refuse Disposal					
Incineration	--	--	--	--	--
Open Burning	--	90	470	30	60
Industrial Process Emissions	--	--	--	--	--
Total Emissions	20	160	4,960	610	750

TABLE 18 SUMMARY OF EMISSIONS IN FORT BEND COUNTY
1967 (TONS/YEAR)

Source Category	Sulfur Oxides	Particu-lates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Road Vehicles	80	130	17,350	2,230	970
Other	--	--	--	--	--
Combustion of Fuels Stationary Sources					
Industry	Neg.	70	Neg.	Neg.	860
Steam-Electric	25	410	Neg.	Neg.	10,600
Residential	Neg.	5	Neg.	Neg.	40
Commercial	Neg.	Neg.	Neg.	Neg.	Neg.
Refuse Disposal					
Incineration	--	--	--	--	--
Open Burning	--	240	1,250	70	160
Industrial Process Emissions	--	--	--	--	--
Total Emissions	105	855	18,600	2,300	12,630

TABLE 19 SUMMARY OF EMISSIONS IN GALVESTON COUNTY
1967 (TONS/YEAR)

Source Category	Sulfur Oxides	Particu-lates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Road Vehicles	270	440	60,130	7,740	3,370
Other	--	--	--	--	--
Combustion of Fuels Stationary Sources					
Industry	20	810	20	Neg.	9,630
Steam-Electric	25	440	Neg.	Neg.	11,440
Residential	Neg.	20	Neg.	Neg.	130
Commercial	Neg.	10	Neg.	Neg.	50
Refuse Disposal					
Incineration	--	--	--	--	--
Open Burning	--	1,470	7,820	460	1,010
Industrial Process Emissions	41,220	2,660	149,000	34,780	9,130
Total	41,535	5,850	216,970	42,980	34,760

TABLE 20 SUMMARY OF EMISSIONS IN BALANCE OF HARRIS COUNTY
1967 (TONS/YEAR)

Source Category	Sulfur Oxides	Particu-lates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Road Vehicles	950	1,560	210,000	27,030	11,780
Other	3,600	950	2,890	620	1,550
Combustion of Fuels Stationary Sources					
Industry	30	1,350	30	Neg.	16,050
Steam-Electric	50	810	Neg.	Neg.	21,000
Residential	Neg.	60	Neg.	Neg.	360
Commerical	Neg.	20	Neg.	Neg.	110
Refuse Disposal					
Incineration	60	300	1,320	20	90
Open Burning	--	2,760	14,660	860	1,900
Industrial Process Emissions	88,770	37,750	38,690	87,870	35,800
Total Emissions	93,460	45,560	267,590	116,400	88,640

TABLE 21 SUMMARY OF EMISSIONS IN CITY OF HOUSTON
1967 (TONS/YEAR)

Source Category	Sulfur Oxides	Particu-lates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Road Vehicles	1,990	3,260	439,200	56,530	24,650
Other	1,940	1,550	8,370	2,340	2,420
Combustion of Fuels Stationary Sources					
Industry	10	450	10	Neg.	5,350
Steam-Electric	Neg.	40	Neg.	Neg.	900
Residential	10	130	10	Neg.	820
Commercial	Neg.	90	Neg.	Neg.	550
Refuse Disposal					
Incineration	190	950	4,180	80	290
Open Burning	--	720	3,830	230	500
Industrial Process Emissions	2,190	90,610	--	--	--
Grand Total	6,330	97,800	455,600	59,180	35,480

TABLE 22 SUMMARY OF EMISSIONS IN LIBERTY COUNTY
1967 (TONS/YEAR)

Source Category	Sulfur Oxides	Particu-lates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Road Vehicles	90	140	19,150	2,460	1,070
Other	--	--	--	--	--
Combustion of Fuels Stationary Sources					
Industry	Neg.	40	Neg.	Neg.	340
Steam-Electric	--	--	--	--	--
Residential	Neg.	5	Neg.	Neg.	25
Commercial	Neg.	Neg.	Neg.	Neg.	Neg.
Refuse Disposal					
Incineration	--	--	--	--	--
Open Burning	--	200	1,040	60	130
Industrial Process Emissions	--	--	--	--	--
Total Emissions	90	385	20,190	2,520	1,655

TABLE 23 SUMMARY OF EMISSIONS IN MONTGOMERY COUNTY
1967 (TONS/YEAR)

Source Category	Sulfur Oxides	Particu-lates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Road Vehicles	60	100	13,160	1,690	740
Other	--	--	--	--	--
Combustion of Fuels Stationary Sources					
Industry	Neg.	30	Neg.	Neg.	320
Steam-Electric	--	--	--	--	--
Residential	Neg.	5	Neg.	Neg.	30
Commercial	Neg.	Neg.	Neg.	Neg.	Neg.
Refuse Disposal					
Incineration	--	--	--	--	--
Open Burning	--	220	1,150	70	150
Industrial Process Emissions	--	--	--	--	--
Total Emissions	60	355	14,310	1,760	1,240

TABLE 24 SUMMARY OF EMISSIONS IN WALLER COUNTY, 1967 (TONS/YEAR)

Source Category	Sulfur Oxides	Particu-lates	Carbon Monoxide	Hydro-carbons	Nitrogen Oxides
Transportation					
Road Vehicles	30	40	5,980	770	340
Other					
Combustion of Fuels Stationary Sources					
Industry	Neg.	110	Neg.	Neg.	1,280
Steam-Electric					
Residential	Neg.	Neg.	Neg.	Neg.	10
Commercial	Neg.	Neg.	Neg.	Neg.	Neg.
Refuse Disposal	--				
Incineration					
Open Burning	--	100	550	30	70
Industrial Process Emissions					
Total Emissions	30	250	6,530	800	1,700

EMISSION BY GRID

For the prupose of modeling the air pollutant emissions in the Study Area, the resulting emissions were apportioned on the grid reference system shown in Figure 3.

The emissions of each pollutant were divided into two source subgroups - point and area sources. The 50 point sources were identified by source category, grid number and horizontal and vertical coordinates. Figure 4 shows the location of major point sources in the Study Area. The point sources are presented in Table 25, along with emissions for the five pollutants for an average annual, winter, and summer day.

The emissions for all sources on the annual, winter and summer basis are shown in Table 21. The calculation of these averages is similar to those done for the point sources.

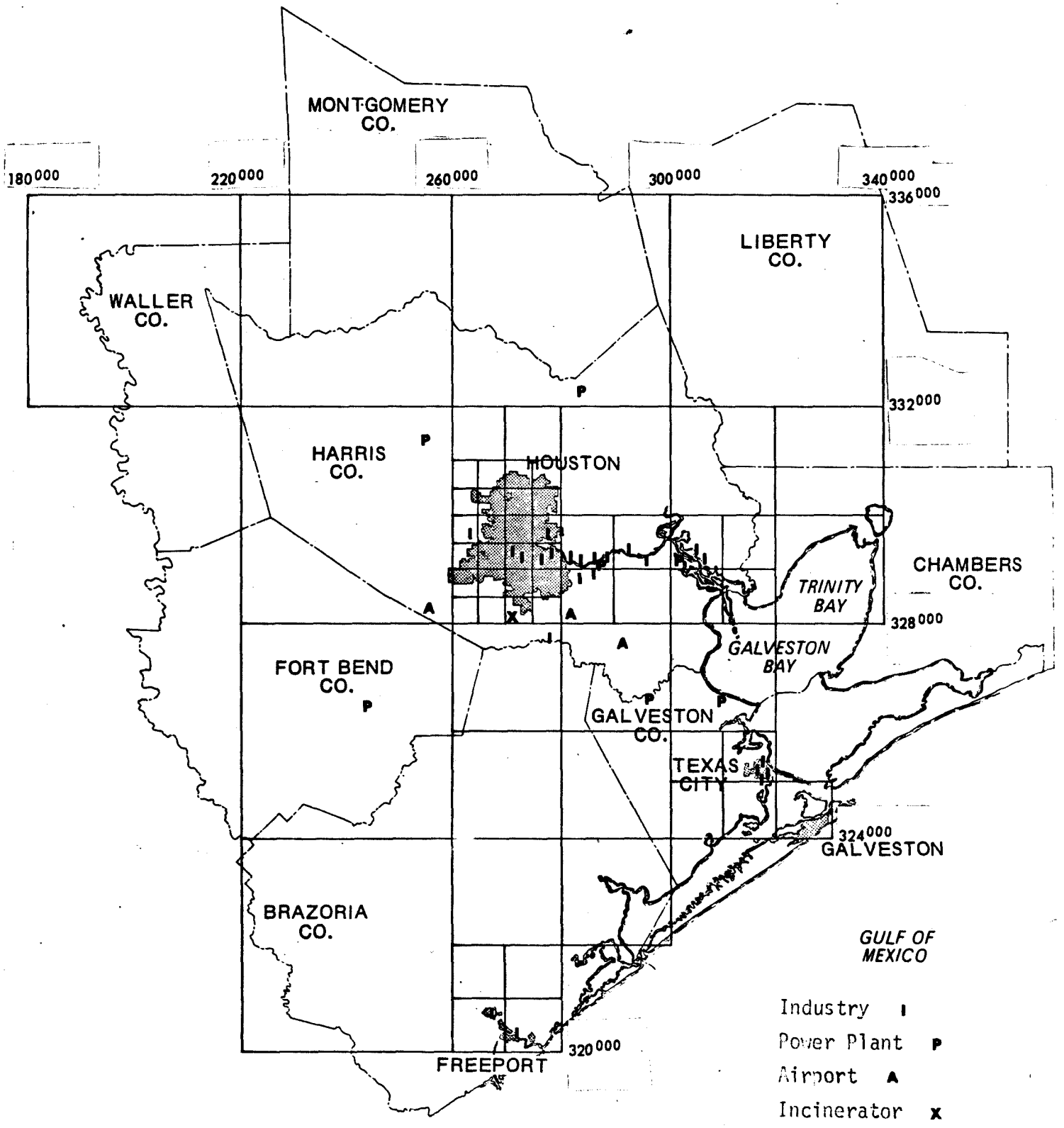

Figure 4. Point Source Location Map

TABLE 25 SUMMARY OF EMISSIONS FROM POINT SOURCES IN THE HOUSTON-GALVESTON STUDY AREA, 1967 (TONS/DAY)

Source Category	Grid	Hor. Coor. (100m)	Vert. Coor. (100m)	SO_x SUM	SO_x WIN	SO_x AVG	PART. SUM	PART. WIN	PART. AVG	CO SUM	CO WIN	CO AVG	HC SUM	HC WIN	HC AVG	NO_x SUM	NO_x WIN	NO_x AVG
Airport	34	2800	32820	--	--	--	3.34	3.34	3.34	18.72	18.72	18.72	5.58	5.58	5.58	2.55	2.55	2.55
Airport	4	2500	32910	--	--	--	0.02	0.02	0.02	4.11	4.11	4.11	0.76	0.76	0.76	0.19	0.19	0.19
Airport	45	2910	32770	--	--	--	1.78	1.78	1.78	7.85	7.85	7.85	1.63	1.63	1.63	1.48	1.48	1.48
Industry	38	3065	32910	10.00	10.00	10.00	4.00	4.00	4.00	--	--	--	100.00	100.00	100.00	35.00	35.00	35.00
Industry	38	3070	32900	6.00	6.00	6.00	--	--	--	--	--	--	--	--	--	--	--	--
Industry	33	2945	32900	10.00	10.00	10.00	2.00	2.00	2.00	--	--	--	50.00	50.00	50.00	17.00	17.00	17.00
Industry	34	2835	32900	50.00	50.00	50.00	2.50	2.50	2.50	--	--	--						
Industry	31	2970	33100	--	--	--	2.25	2.25	2.25	--	--	--						
Industry	32	2870	32910	18.00	18.00	18.00	--	--	--	--	--	--	--	--	--	--	--	--
Industry	32	2815	32900	5.10	5.10	5.10	--	--	--	--	--	--						
Industry	32	2825	32910	--	--	--	10.60	10.60	10.60	--	--	--						
Industry	34	2810	32890	--	--	--	9.80	9.80	9.80	--	--	--						
Industry	33	2900	32935	3.50	3.50	3.50	--	--	--	--	--	--						
Industry	32	2825	32900	10.00	10.00	10.00	1.00	1.00	1.00	--	--	--	25.00	25.00	25.00	8.00	8.00	8.00
Industry	34	2840	32890	8.00	8.00	8.00	2.00	2.00	2.00	--	--	--	50.00	50.00	50.00	17.00	17.00	17.00
Industry	34	2810	32890	94.50	94.50	94.50	--	--	--	--	--	--						
Industry	34	2860	32900	--	--	--	6.00	6.00	6.00	--	--	--						
Industry	34	2870	32900	4.00	4.00	4.00	1.00	1.00	1.00	--	--	--	15.00	15.00	15.00	6.00	6.00	6.00
Industry	32	2890	32825	--	--	--	--	--	--	45.00	45.00	45.00						

TABLE 25 SUMMARY OF EMISSIONS FROM POINT SOURCES IN THE HOUSTON-GALVESTON STUDY AREA, 1967 (TONS/DAY)

Source Category	Grid	Hor. Coor. (100m)	Vert. Coor. (100m)	SO_x SUM	SO_x WIN	SO_x AVG	PART. SUM	PART. WIN	PART. AVG	CO SUM	CO WIN	CO AVG	HC SUM	HC WIN	HC AVG	NO_x SUM	NO_x WIN	NO_x AVG
Industry	33	2920	32900	--	--	--	--	--	--	59.00	59.00	59.00						
Industry	21	2745	32940	--	--	--	12.70	12.70	12.70	--	--	--						
Industry	32	2880	32930	24.10	24.10	24.10	40.69	40.69	40.69	2.26	2.26	2.26	0.75	0.75	0.75	15.07	15.07	15.07
Incinerator	29	2700	32835	0.20	0.20	0.20	1.72	1.72	1.72	0.10	0.10	0.10	0.03	0.03	0.03	0.20	0.20	0.20
Dump	30	3050	32630	--	--	--	0.82	0.82	0.82	4.36	4.36	4.36	0.26	0.26	0.26	0.57	0.57	0.57
Dump	50	3160	32560	--	--	--	0.78	0.78	0.78	4.13	4.13	4.13	0.24	0.24	0.24	0.54	0.54	0.54
Dump	51	3030	32480	--	--	--	0.44	0.44	0.44	2.33	2.33	2.33	0.13	0.13	0.13	0.30	0.30	0.30
Industry	44	2790	32750	6.00	6.00	6.00	4.80	4.80	4.80									
Industry	32	2835	32900				1.25	1.25	1.25									
Industry	22	2760	32940				70.00	70.00	70.00									
Industry	21	2735	32940				70.00	70.00	70.00									
Industry	22	2760	32940				1.25	1.25	1.25									
Industry	15	2635	32985				84.40	84.40	84.40									
Industry	50	3130	32505	72.33	72.33	72.33	4.00	4.00	4.00	408.22	408.22	408.22	50.00	50.00	50.00	17.00	17.00	17.00
Industry	50	3150	32510	--	--	--	--	--	--	--	--	--	15.30	15.30	15.30	--	--	--
Industry	50	3145	32505	8.00	8.00	8.00	1.00	1.00	1.00				15.00	15.00	15.00	4.00	4.00	4.00
Industry	50	3130	32505	5.20	5.20	5.20	1.30	1.30	1.30	--	--	--	--	--	--	--	--	--
Industry	50	3115	32508	19.40	19.40	19.40												
Power Plant	32	2860	32905	0.01	0.01	0.01	0.49	0.27	0.32	--	--	--	--	--	--	12.66	7.00	8.22

TABLE 25 SUMMARY OF EMISSIONS FROM POINT SOURCES IN THE HOUSTON-GALVESTON STUDY AREA, 1967 (TONS/DAY)

Source Category	Grid	Hor. Coor. (100m)	Vert. Coor. (100m)	SO_x SUM	SO_x WIN	SO_x AVG	PART. SUM	PART. WIN	PART. AVG	CO SUM	CO WIN	CO AVG	HC SUM	HC WIN	HC AVG	NO_x SUM	NO_x WIN	NO_x AVG
Industry	50	3160	32505	8.00	8.00	8.00	1.00	1.00	1.00	--	--	--	15.00	15.00	15.00	4.00	4.00	4.00
Power Plant	32	2650	32830	--	--	--	0.14	0.08	0.09	--	--	--	--	--	--	3.70	2.04	2.40
Power Plant	2	2860	33210	0.01	--	--	0.23	0.13	0.15	--	--	--	--	--	--	5.95	3.29	3.86
Power Plant	45	2950	32605	0.02	0.01	0.01	0.82	0.45	0.53	--	--	--	--	--	--	21.30	11.77	13.82
Power Plant	38	3000	32920	0.04	0.02	0.03	1.42	.79	.92	--	--	--	--	--	--	36.93	20.41	23.97
Power Plant	43	2450	32670	0.05	0.03	0.03	1.73	0.95	1.12	--	--	--	--	--	--	44.92	24.82	29.15
Power Plant	4	2570	33170	0.01	0.01	0.01	0.45	0.35	0.30	--	--	--	--	--	--	11.83	6.54	7.67
Power Plant	46	3100	32670	0.05	0.03	0.03	1.86	1.03	1.21	--	--	--	--	--	--	48.32	26.70	31.35
Industry	33	2975	32915	--	--	--	13.56	13.56	13.56	--	--	--	--	--	--	--	--	--
Industry	32	2850	32900	--	--	--	6.78	6.78	6.78	--	--	--	--	--	--	--	--	--
Industry	59	2670	32090	--	--	--	--	--	--	49.32	49.32	49.32	40.30	40.30	40.30	--	--	--
Industry	60	2740	32040	5.79	5.79	5.79	7.59	7.59	7.59	.17	.17	.17	120.50	120.50	120.50	90.29	90.29	90.29
Industry	18	2770	32940	--	--	--	5.10	5.10	5.10									

TABLE 26 EMISSIONS FROM TOTAL SOURCES IN HOUSTON-GALVESTON STUDY

AREA BY GRID (TONS/DAY)

Grid	Hor. Coor. (100m)	Vert. Coor. (100m)	Area (mi^2)	SO_x SUM	SO_x WIN	SO_x AVG	PART. SUM	PART. WIN	PART. AVG	CO SUM	CO WIN	CO AVG	HC SUM	HC WIN	HC AVG	NO_x SUM	NO_x WIN	NO_x AVG
1	2400	33400	617.60	.07	.07	.07	.38	.37	.37	18.53	16.39	17.38	2.29	2.02	2.14	1.02	.96	.98
2	2800	33400	617.60	.37	.32	.34	2.01	1.89	1.90	84.93	75.15	79.66	10.51	9.25	9.83	10.66	7.76	8.37
3	3200	33400	617.60	.16	.14	.14	.65	.63	.64	36.74	32.45	34.43	4.59	4.04	4.29	2.05	1.91	1.95
4	2400	33000	617.60	.76	.67	.71	4.60	4.38	4.41	180.55	160.43	169.71	22.43	19.84	21.04	21.79	16.14	17.25
5	2650	33150	38.60	.06	.05	.05	.29	.28	.28	14.44	12.78	13.55	1.78	1.77	1.67	.80	.75	.76
6	2750	33150	38.60	.14	.12	.13	.66	.65	.65	32.81	29.02	30.77	4.06	3.57	3.80	1.82	1.71	1.73
7	2625	33075	9.65	.10	.09	.09	.45	.44	.45	23.68	20.94	22.20	2.94	2.59	2.75	1.31	1.24	1.25
8	2675	33075	9.65	.12	.10	.11	.56	.56	.56	28.04	24.80	26.29	3.48	3.06	3.25	1.56	1.47	1.48
9	2725	33075	9.65	.16	.14	.15	.89	.89	.89	38.77	34.35	36.39	4.76	4.19	4.45	2.15	2.06	2.05
10	2775	33075	9.65	.09	.08	.08	.52	.52	.52	22.47	19.91	21.09	2.76	2.43	2.58	1.25	1.19	1.19
11	2625	33025	9.65	.13	.12	.12	.31	.22	.31	23.48	20.71	21.99	2.94	2.59	2.75	1.36	1.35	1.31
12	2675	33025	9.65	.26	.23	.25	.55	.54	.54	53.03	46.68	49.61	6.75	5.93	6.31	3.01	2.83	2.87
13	2725	33025	9.65	.34	.30	.32	.55	.54	.54	45.05	39.67	42.16	5.72	5.02	5.34	2.84	2.74	2.73
14	2775	33025	9.65	.22	.23	.21	.32	.33	.32	18.29	16.14	17.13	2.30	2.02	2.15	1.43	1.35	1.30
15	2625	32975	9.65	.17	.15	.16	84.75	84.74	84.74	34.65	30.49	32.41	4.41	3.87	4.12	1.96	1.84	1.87
16	2675	32975	9.65	.40	.37	.39	.73	.72	.72	56.03	48.46	52.44	7.09	6.23	6.63	3.48	3.18	3.35
17	2725	32975	9.65	.68	.64	.66	1.04	1.03	1.03	78.12	68.81	73.11	9.91	8.71	9.27	5.13	4.87	4.97
18	2775	32975	9.65	.29	.27	.28	5.57	5.57	5.57	35.73	31.49	33.35	4.51	3.96	4.21	2.31	2.24	2.24
19	2625	32925	9.65	.31	.28	.30	.60	.57	.58	64.30	56.56	60.13	8.21	7.21	7.67	3.63	3.33	3.44
20	2675	32925	9.65	.67	.61	.64	1.17	1.11	1.12	114.98	101.15	107.53	14.68	12.90	33.72	6.78	6.29	6.45
21	2725	32925	9.65	1.00	.91	.95	84.35	84.26	84.29	163.45	143.75	152.85	20.89	18.36	19.53	10.67	9.01	9.27
22	2775	32925	9.65	4.51	4.49	4.50	73.10	73.10	73.09	37.93	33.44	35.51	4.82	4.24	4.51	15.20	15.17	15.13

TABLE 26 EMISSIONS FROM TOTAL SOURCES IN HOUSTON GALVESTON STUDY AREA BY GRID (TONS/DAY)

Grid	Hor. Coor. (100m)	Vert. Coor. (100m)	Area (mi^2)	SO_x SUM	SO_x WIN	SO_x AVG	PART. SUM	PART. WIN	PART. AVG	CO SUM	CO WIN	CO AVG	HC SUM	HC WIN	HC AVG	NO_x SUM	NO_x WIN	NO_x AVG
23	2625	32875	9.65	.26	.23	.25	.56	.55	.55	50.65	44.60	47.39	6.43	5.65	6.01	2.88	2.75	2.76
24	2675	32875	9.65	.23	.20	.21	.46	.45	.45	44.74	39.38	41.85	5.68	4.99	5.31	2.53	2.39	2.42
25	2725	32875	9.65	.30	.26	.28	.62	.60	.60	58.29	51.51	54.53	8.41	6.51	6.93	3.31	3.13	3.16
26	2775	32875	9.65	.34	.33	.35	.75	.71	.71	75.11	66.11	70.25	9.58	8.41	8.95	4.25	4.95	4.04
27	2625	32825	9.65	.13	.11	.12	.29	.28	.28	24.93	21.96	23.33	3.15	2.77	2.95	1.42	1.36	1.28
28	2675	32825	9.65	.07	.06	.06	.16	.17	.16	11.81	10.42	11.06	1.48	1.30	1.39	.67	.67	.66
29	2725	32825	9.65	.34	.33	.34	2.04	2.05	2.04	26.97	23.78	25.25	3.42	3.01	3.20	1.73	1.69	1.67
30	2775	32825	9.65	.11	.10	.11	1.06	1.06	1.06	26.15	23.55	24.75	3.02	2.68	2.84	1.82	1.76	1.76
31	2900	33100	154.40	.14	.12	.13	3.08	3.08	3.07	33.64	29.83	31.59	4.11	3.62	3.84	1.85	1.79	1.78
32	2850	32950	38.60	61.96	61.92	61.84	64.26	63.95	64.01	126.03	117.11	121.23	35.40	36.25	36.78	57.02	55.14	55.53
33	2950	32950	38.60	14.36	14.34	14.35	17.31	17.30	17.31	89.82	86.31	86.93	53.77	53.32	53.53	30.60	30.50	30.53
34	2850	32850	38.60	157.42	157.32	157.37	29.76	29.69	29.70	204.58	183.33	193.13	93.42	90.69	91.99	47.32	46.71	46.75
35	2950	32850	38.60	.25	.22	.24	1.22	1.20	1.20	52.83	46.81	49.59	6.47	5.69	6.05	2.94	2.78	2.81
36	3100	33100	154.40	.11	.10	.10	.53	.53	.53	26.43	23.38	24.79	3.27	2.88	3.06	1.46	1.37	1.39
37	3300	33100	154.40	.01	.01	.01	.07	.07	.07	3.95	3.49	3.70	.49	.43	.46	.22	.21	.21
38	3050	32950	38.60	17.64	17.60	17.62	7.50	6.90	6.99	41.31	34.89	36.87	105.07	104.46	104.74	86.27	69.61	73.31
39	3150	32950	38.60	.13	.12	.12	.62	.62	.62	27.09	24.01	25.43	3.31	2.91	3.10	1.50	1.43	1.44
40	3050	32850	38.60	2.23	2.21	2.22	.86	.85	.86	31.09	27.55	29.19	3.82	3.36	3.57	2.21	2.11	2.13
41	3150	32850	38.60	.02	.02	.02	.15	.15	.15	6.72	5.96	6.31	.81	.72	.76	.37	.36	.35
42	3300	32900	154.40	.01	.01	.01	.05	.05	.05	2.78	2.46	2.60	.34	.30	.32	.15	.14	.14

TABLE 26 EMISSIONS FROM TOTAL SOURCES IN HOUSTON-GALVESTON STUDY
AREA BY GRID (TONS/DAY)

Grid	Hor. Coor. (100m)	Vert. Coor. (100m)	Area (mi^2)	SUM	SO_x WIN	AVG	SUM	PART. WIN	AVG	SUM	CO WIN	AVG	SUM	HC WIN	AVG	SUM	NO_x WIN	AVG
43	2400	32600	617.60	.23	.19	.20	2.75	1.97	2.13	44.30	39.07	41.39	5.41	4.72	5.07	47.36	27.17	31.50
44	2700	32700	154.40	6.10	6.08	6.09	5.42	5.42	5.42	24.02	21.31	22.56	2.93	2.58	2.74	1.33	1.29	1.28
45	2900	32700	154.40	.20	.17	.18	3.39	3.00	3.09	50.15	45.24	47.61	6.90	6.26	6.56	25.13	15.45	17.54
46	3100	32700	154.40	.06	.04	.04	1.94	1.11	1.29	3.78	3.34	3.54	.46	.41	.43	48.52	26.90	31.55
47	2700	32500	154.40	.01	--	.01	.04	.04	.04	2.49	2.20	2.33	.30	.26	.28	.13	.12	.12
48	2900	32500	154.40	.03	.03	.03	.16	.17	.16	8.14	7.20	7.63	1.00	.88	94	.44	.42	.42
49	3050	32550	38.60	.13	.12	.12	.72	.71	.73	32.14	28.47	30.16	3.95	3.48	3.70	1.75	1.70	1.70
50	3150	32550	38.60	113.16	113.13	113.14	10.27	10.26	10.24	459.66	454.25	456.75	101.35	100.66	100.98	41.46	41.35	41.36
51	3050	32450	38.60	.06	.05	.06	.78	.78	.77	17.46	15.73	16.53	1.99	1.77	1.87	1.13	1.10	1.10
52	3150	32450	38.60	.06	.05	.06	1.28	1.28	1.27	7.59	6.72	7.12	.93	.82	.87	13 72	13.72	13.71
53	3250	32450	38.60	.32	.28	.30	1.71	1.70	1.69	75.65	66.89	70.99	9.31	8.20	8.71	4.19	4.02	4.02
54	2400	32200	617.60	.02	.02	.02	.12	.11	.12	6.25	5.52	5.86	.77	.68	.72	.34	.32	.33
55	2700	32300	154.40	.02	.02	.02	.12	.11	.12	6.25	5.52	5.86	.77	.68	.72	.34	.32	.33
56	2900	32300	154.40	--	--	--	--	--	--	.01	.01	.01	--	--	--	--	--	--
57	2650	32150	38.60	--	--	--	.02	.02	.02	1.25	1.10	1.17	.15	.14	.14	.06	.05	.06
58	2750	32150	38.60	--	--	--	--	--	--	.01	.01	.01	--	--	--	--	--	--
59	2650	32050	38.60	.21	.19	.20	.98	.97	.97	97.34	93.55	96.22	46.51	45.61	45.11	2.78	2.62	2.65
60	2750	32050	38.60	6.24	6.22	6.23	10.08	10.07	10.05	49.90	44.71	47.38	126.71	125.97	126.31	93.07	92.91	92.94
61	2000	33400	617.60	.07	.06	.07	.42	.41	.42	18.61	16.48	17.47	2.29	2.02	2.14	1.03	.99	.98

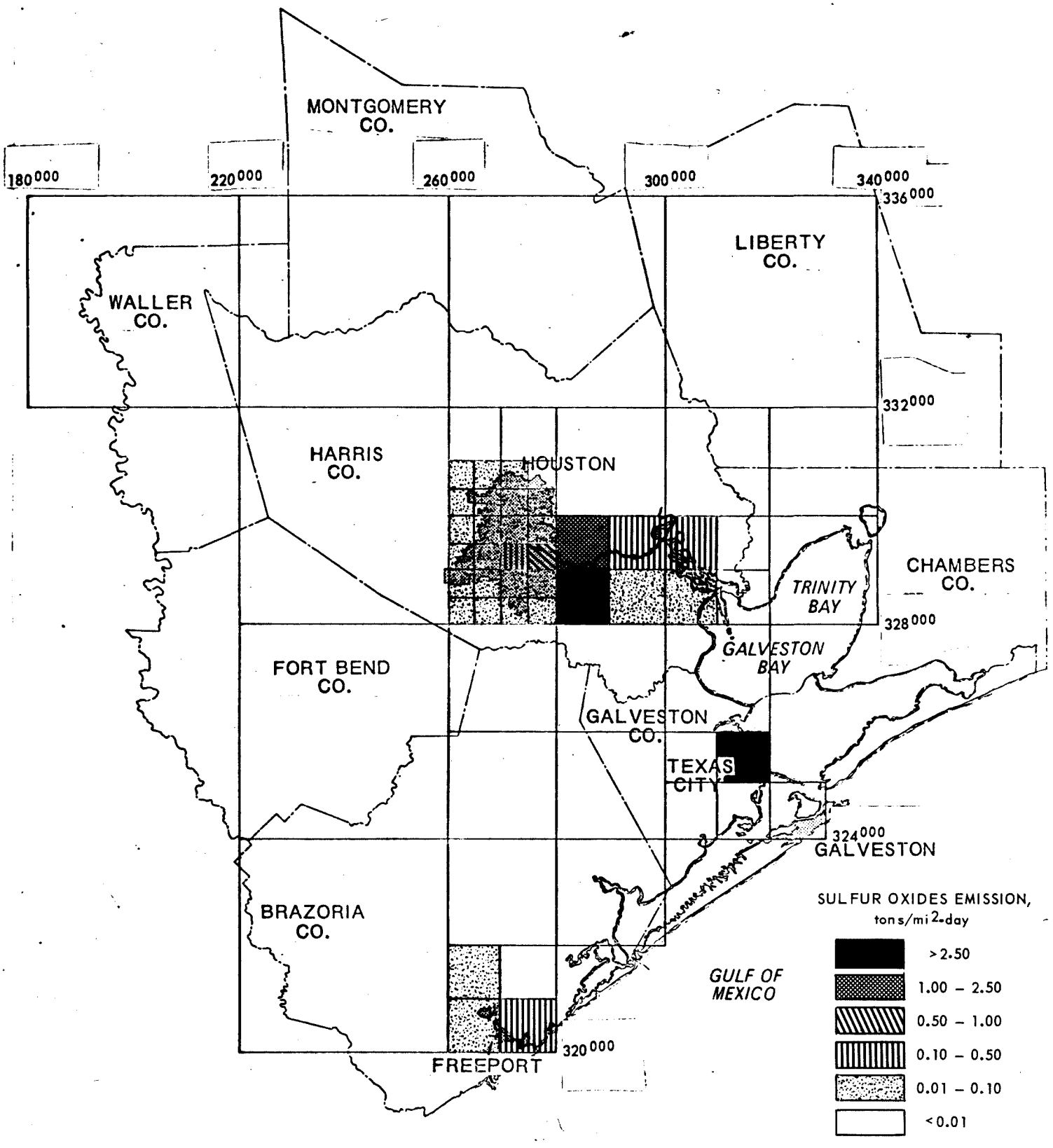

Figure 5. Sulfur oxides emission density from all sources for Houston-Galveston study area.

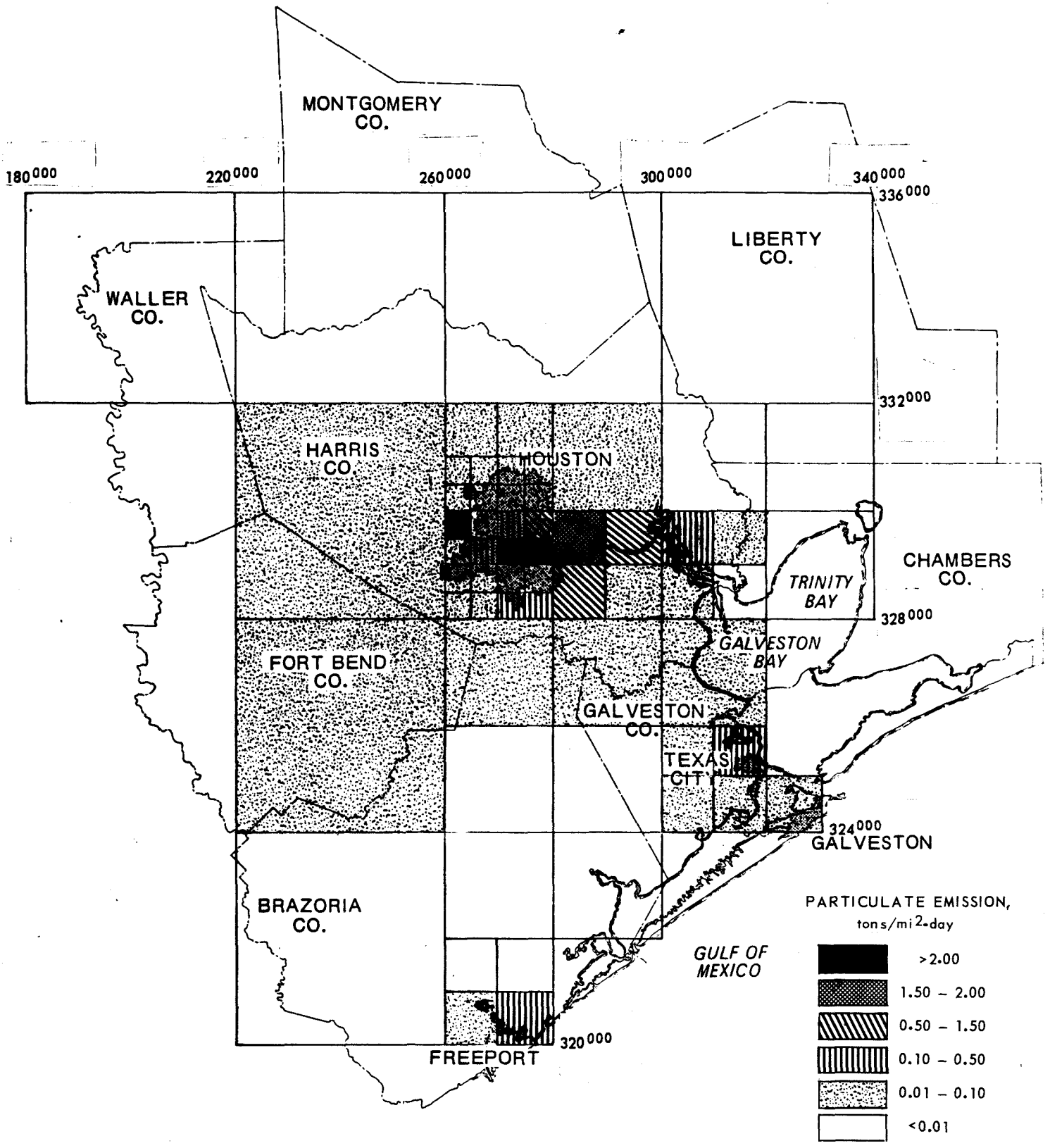

Figure 6. Particulate emission density from all sources for Houston-Galveston study area.

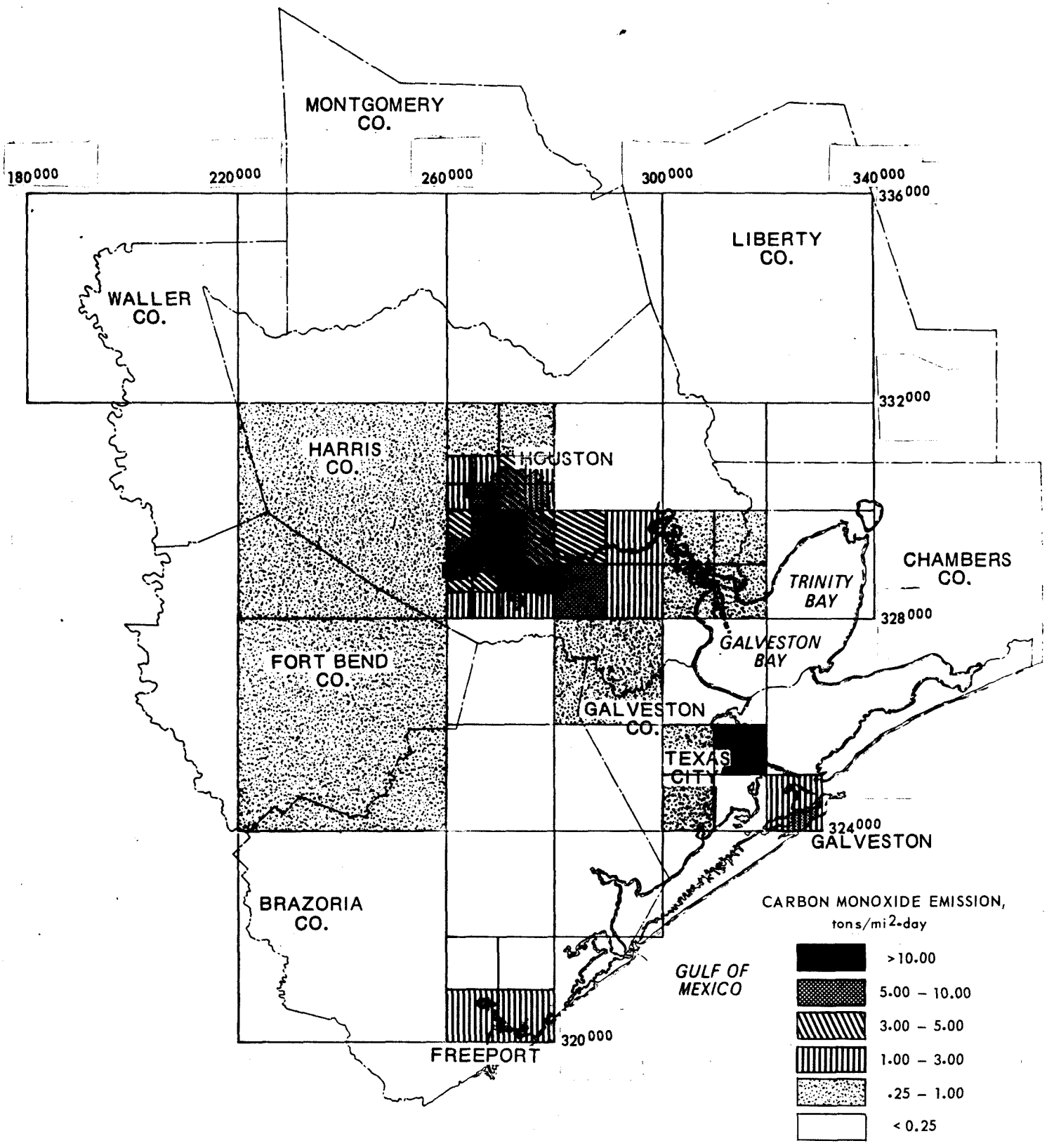

Figure 7. Carbon monoxide emission density from all sources for Houston-Galveston study area.

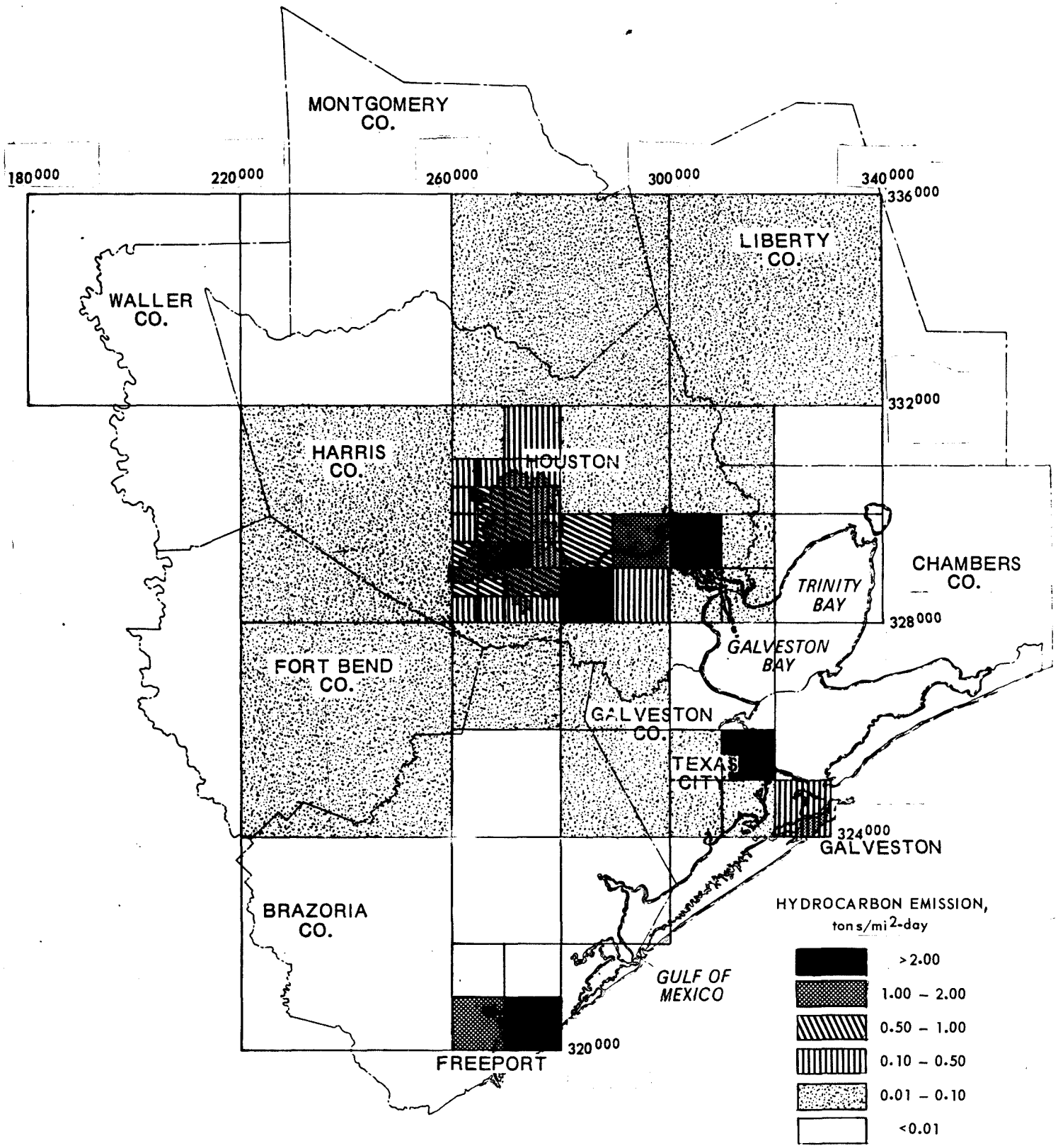

Figure 8. Hydrocarbon emission density from all sources for Houston-Galveston study area.

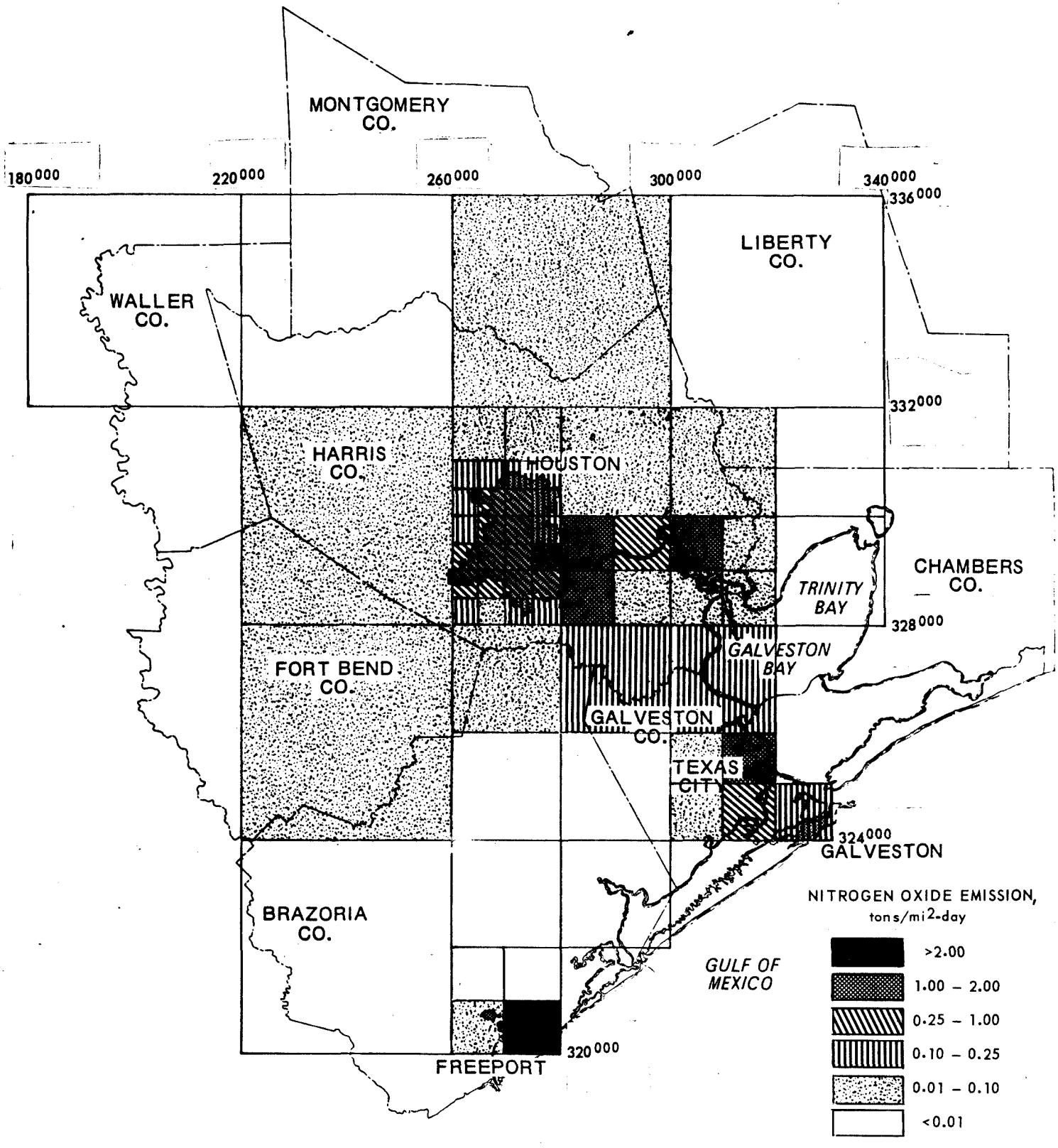

Figure 9. Nitrogen oxide emission density from all sources for Houston-Galveston study area.

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