EPA-450/3-74-028-b
May 1973

AIR POLLUTION/LAND USE PLANNING PROJECT VOLUME II. METHODS FOR PREDICTING AIR POLLUTION CONCENTRATIONS FROM LAND USE

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Water Programs
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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AIR POLLUTION/LAND USE PLANNING PROJECT VOLUME II. METHODS FOR PREDICTING AIR POLLUTION CONCENTRATIONS FROM LAND USE

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Interagency Agreement No. EPA-IAG-0159(D)

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Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Water Programs
Office of Air Quality Planning and Standards
Research Triangle Park, N. C. 27711

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Publication No. EPA-450/3-74-028-b

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ABSTRACT

In order to evaluate or rank land use plans in terms of air quality, it is necessary for planners to be able to project emission density (mass of pollutant per unit of land for any specified time period) using only planning variables, because detailed source characteristics are not available at the time alternative plans are being developed and evaluated. The objective of this study is to analyze the utility of various land use parameters in describing the air quality impacts of land use plans.

Parameters that are tested include land use by zoning class and 2-digit SIC code, employment dwelling units, and square footage of floor space. Variables that are to be explained by these parameters include air quality as represented by the Air Quality Display Model (AQDM), emissions and emission densities, process weight for industrial sources, and energy consumption.

The basic criterion for evaluating the land-use-based emission estimation methods is the ability of the estimates to reproduce regional air quality as represented by the AQDM dispersion model, using the best available point-source inventory information. When data deficiencies prohibit the application of this criterion, standard statistical measures are applied. Statistical techniques used are analysis of variance, multiple regression, and product-moment correlation analysis. Emission inventory and land use data are drawn from the Chicago metropolitan study area.

1.0 INTRODUCTION

In order to evaluate or rank land use plans in terms of air quality, it is necessary for planners to be able to project emission density (mass of pollutant per unit of land for any specified time period) using only planning variables, because detailed source characteristics are not available at the time alternative plans are being developed and evaluated. The planning parameters tested in this study include mean emission densities by zoning categories or by 2-digit SIC classification, land utilization, employment, and building size. The variables to be estimated include energy and process throughput; these, in turn, determine fuel combustion and process emissions, respectively. The objectives of the study were (1) to determine what information routinely collected or available in the planning process could be used to quantitatively estimate air quality; and (2) to determine which classification structures or additional parameters should be used in the planning process in order to carry out air quality analyses of land use plans. The tests of utility of each type of classification or each parameter are based on statistical criteria and/or the resulting air quality representation when inserted in the Air Quality Display Model (AQDM) dispersion model.[1] Statistical techniques include analysis of variance, simple correlation, and multiple regression.

It is assumed that manufacturing land is sufficiently distinct in emission characteristics to be analyzed separately from residential and commercial land. Residential and commercial land uses are grouped together due to their similar emission characteristics.

The Chicago Metropolitan Air Quality Control Region was used as a study region because of proximity, availability of data, and the large number of diverse manufacturing sources in the region. Emission inventories for the Chicago region collected by the City of Chicago Department of Environmental Control and the State of Illinois Environmental Protection Agency were used for the study. Using these inventories, we employ a number of alternative strategies to develop land-use-based emission factors. Subsequently, we apply these factors to presently available Chicago land use data to evaluate whether the use of these factors can accurately reproduce estimates of present air quality conditions in the Chicago area.

Section 2 of this report characterizes the emission patterns in the study region and analyzes the variance in manufacturing emissions. Section 3 tests various methods for explaining this variance and predicting emission patterns using the Chicago emission files as a data base. Section 4 summarizes the results of the study. Appendix A describes the Chicago region in terms of factors influencing present and future emission patterns. The remaining Appendices, B-D, contain technical detail, data, and statistical results supporting the text of Section 3.

2.0 AN ANALYSIS OF EMISSION PATTERNS

Air pollution emission patterns and their air quality effects in the Chicago region are discussed in the Report Summary, Volume I. This volume focuses on the stationary source patterns in the Chicago region and, in particular, on the sources of suspended particulate matter. This limitation is purely for convenience, and the methods discussed herein are directly applicable to other pollutant forms emitted from stationary sources.

This section presents a detailed analysis of emission patterns in the study region by zoning class and major industrial sector. The results of using mean emission-density estimators by land use classification to predict pollution concentrations are presented. These results provide the rationale for exploring other methods of estimation, as discussed in Section 3.

2.1 CURRENT AIR POLLUTION PROBLEMS IN CHICAGO STUDY REGION

Particulate emissions in an urban area result either from the combustion of fuels containing ash or from industrial plants that produce dust particles during the manufacturing process. High air pollution concentrations in the Chicago area are due primarily to the intense residential and commercial land uses surrounding the central business district (CBD or Loop area of Chicago) and the heavily concentrated industrial areas to the south and southwest of the CBD. Figure 2.1 shows the suspended particulate isopleths (lines of constant concentrations) and the concentration peaks

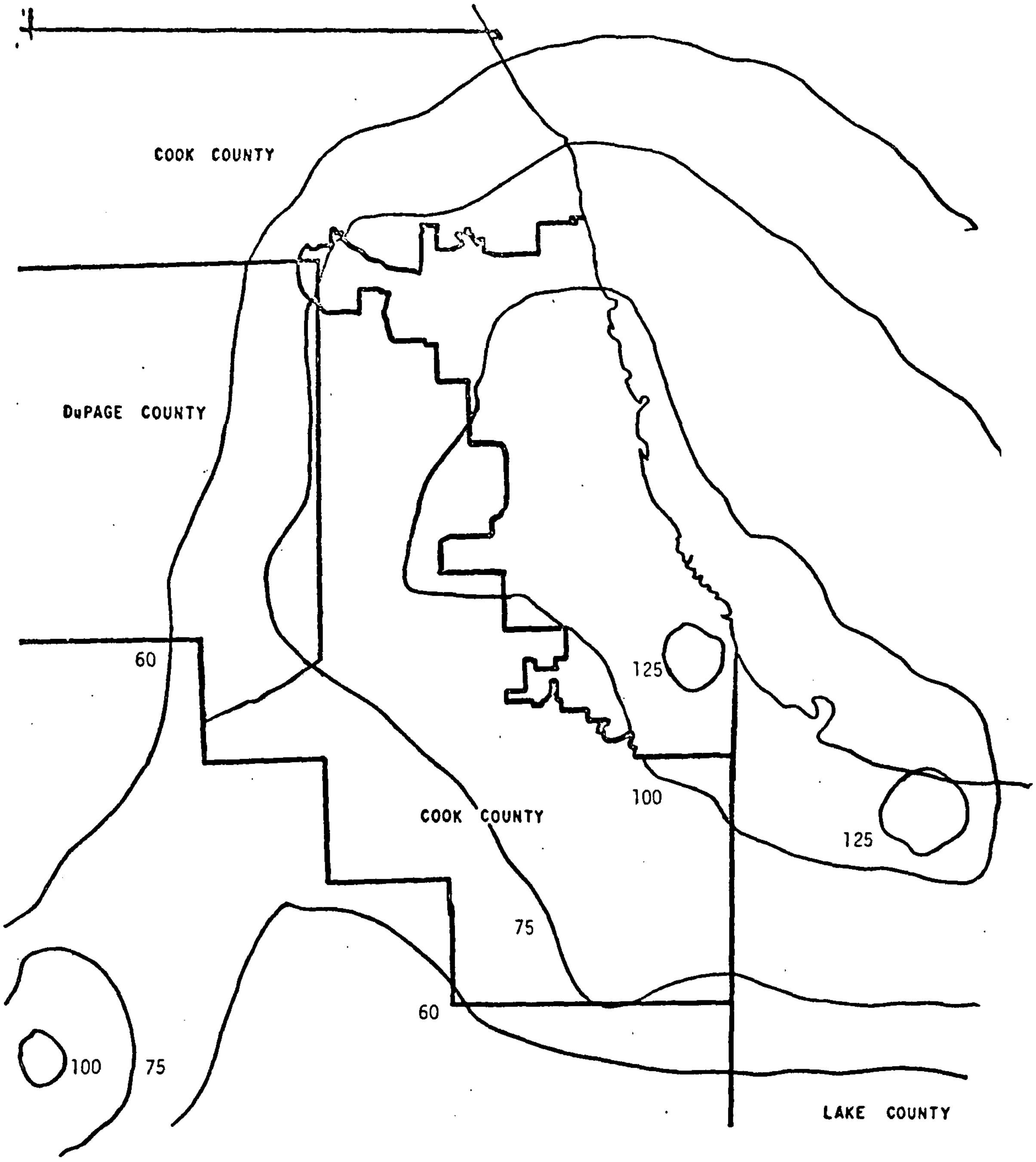


Figure 2.1. Isopleths of suspended particulates using unregulated emission inventory.

resulting from these two intensive land use clusters.

The State of Illinois has enacted emission control regulations (emission standards) designed to achieve the National Ambient Air Quality Standard (75 $\mu g/m^3$ annual geometric mean) by 1975. These regulations are described in Appendix B. Figure 2.2 shows the forecasted air quality with the control regulations in effect. Although the control regulations will have considerable effect in improving air quality, peak areas at or near the standard will exist. Growth in areas surrounding these peaks will contribute to the degradation of air quality in the area and threaten ambient air quality standards. It is for this reason that this study focuses on the three counties surrounding Chicago; namely, Cook, DuPage, and Will. This is a subregion of the 8-county Standard Metropolitan Statistical Area (six counties in Illinois and two in Indiana) and of the 9-county State of Illinois Economic Planning and Statistical Reporting Region as shown in Figure 2.3.

This study divides land use into two major categories—Manufacturing and Residential/Commercial—because of their distinct emission characteristics. Residential and commercial building emissions are a function of the energy consumed and type of fuel used. Energy consumed is, in turn, a function of area climatology, building size, and type of construction. The intense residential/commercial districts of the City of Chicago are rather unique in that a significant number of buildings are still coal heated. A rather severe restriction on the sulfur content of fuels (1% limit) has drastically increased the number of annual conversions from coal to natural gas or oil in recent years due to the large price differential between low- and high-sulfur coal in the Chicago area. This trend is expected to continue to the point where residential/commercial sources will not be

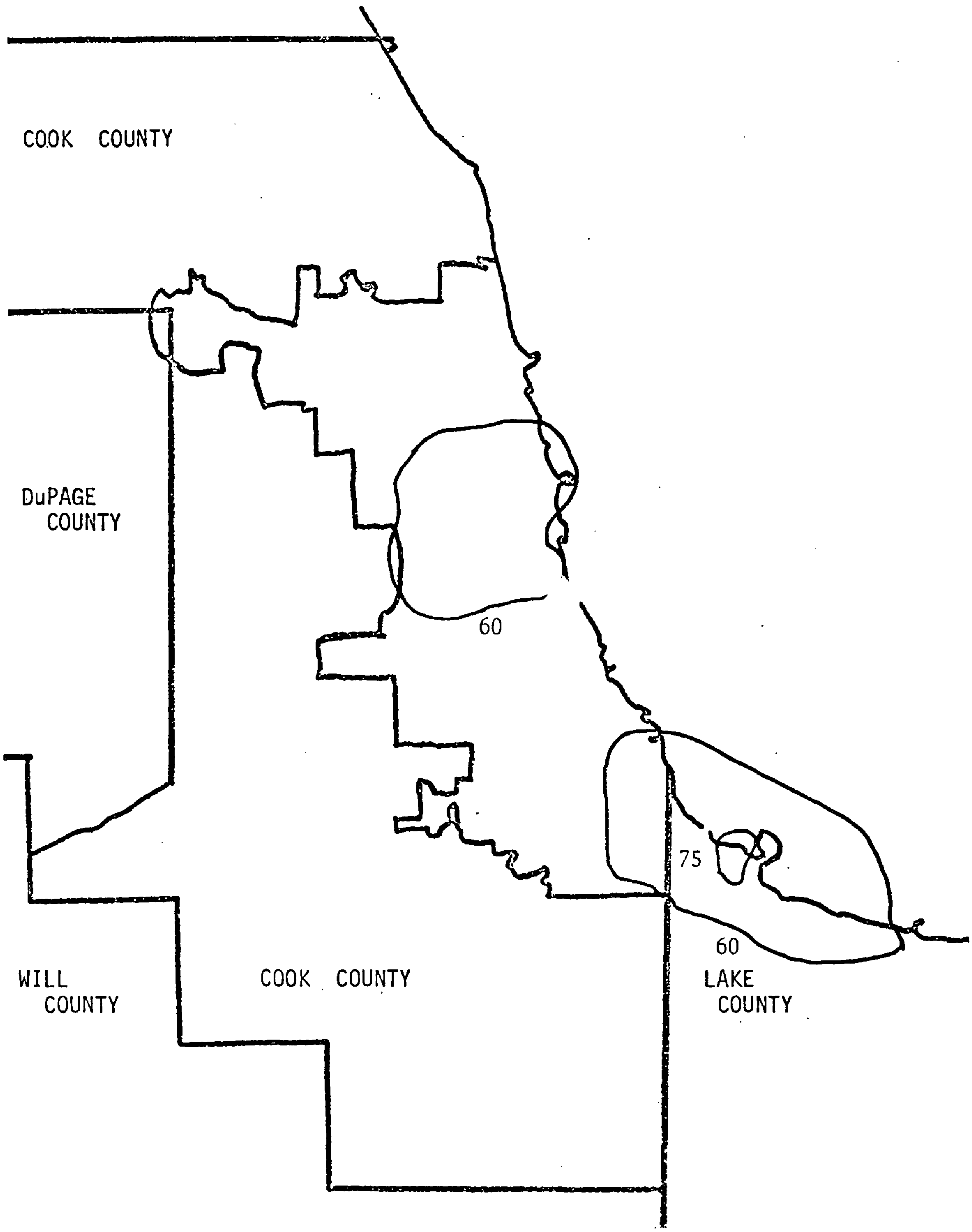


Figure 2.2. Isopleths of suspended particulates with Illinois source control regulations applied. ($\mu g/m^3$ annual geometric mean)

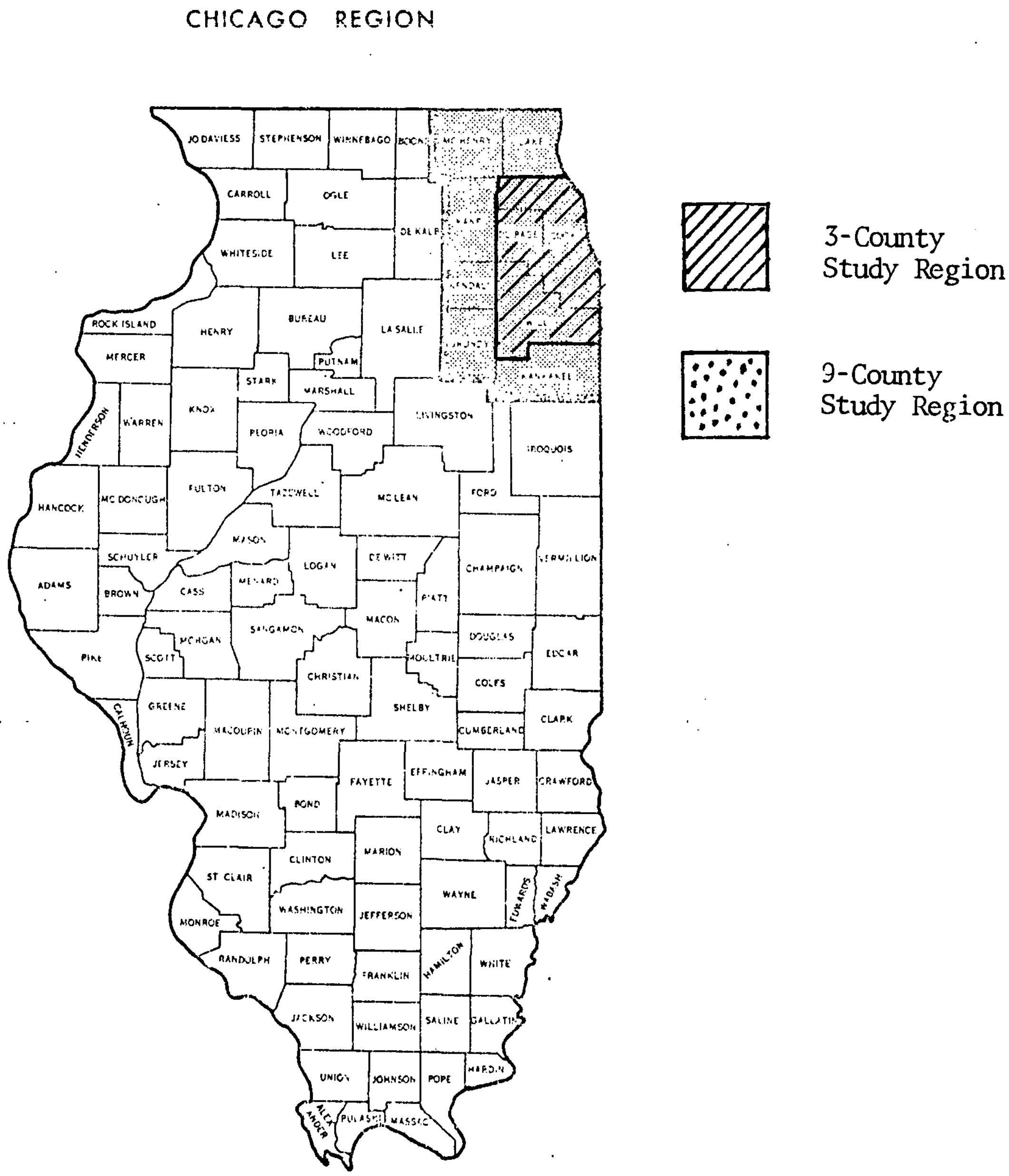


Figure 2.3. State of Illinois, Chicago economic planning and statistical reporting region.

significant contributors to the regional air pollution problem given the availability of low-sulfur fuels. Nonetheless, attempts should be made to estimate this contribution, and a method for making these estimates is discussed in Section 3 of this report.

Manufacturing processes and power plants, on the other hand, are now, and are expected to continue to be, major polluting sources, accounting for more than 83% of suspended particulate emissions after source regulation controls are enforced. Manufacturing emissions can be partitioned into emissions due to the nature of the production process itself, due to the combustion of fuels required to carry out the production process, and due to space heating. Manufacturing fuel combustion emissions will continue to be a problem because of the large quantities of fuel consumed. Manufacturers are typically on the low end of the priority list for receiving clean fuel supplies, especially natural gas. The current shortage of clean fuel resources continues to counteract the use of these fuels for manufacturing purposes, however desirable this may be from an air pollution standpoint. Coupled with this shortage of clean fuels is the fact that Illinois is rich in high-sulfur, high-ash bituminous coal reserves and considerable economic pressure exists to utilize these resources. Thus, the planning of manufacturing land use and the location of industrial parks and production facilities that include air pollution considerations are important parts of maintaining air quality standards in a region such as the Chicago Metropolitan Area. Current manufacturing activity in the study region and potential for growth in the area is further described in Appendix A.

2.2 AN ANALYSIS OF VARIANCE IN MANUFACTURING EMISSIONS

A factor that complicates the analysis of the air pollution impacts of land use plans or development projections is the disaggregated nature of the air pollution problem. Unlike water pollution, there are no centralized processing or treatment plants for which loads can be estimated on an aggregated basis. It is the existence of sources on a diverse geographic plane that constitutes the overall air pollution emission surface of the urban region. Thus, estimation of emissions on a square-mile or square-kilometer grid is required to obtain a realistic picture of air quality.

The spatial distribution of sources from the Chicago emission inventory (see Appendix A) is shown in Figure 2.4, and the resulting particulate emission pattern is shown in Figure 2.5. It is these emission patterns that give rise to the particulate concentration surfaces of Figure 2.1. As can be seen by comparing Figures 2.4 and 2.5, however, it is not the mere existence of a manufacturing source that gives rise to emissions, but also the nature and scale of the production process and space heating requirements. Although high source clusters seem to visually correlate with high emission areas, further explanation of the spatial variance in emissions is required to achieve a realistic estimation of emission patterns in the region.

The need for further analysis can also be viewed statistically as indicated in Figure 2.6 that shows the frequency distribution of industrial source emission densities in the study region. Not only is the standard deviation of this distribution quite high in relation to its average, but the skewness of the distribution causes significant estimation problems if a figure of 1.17 lb/hr/acre is used as an emission density

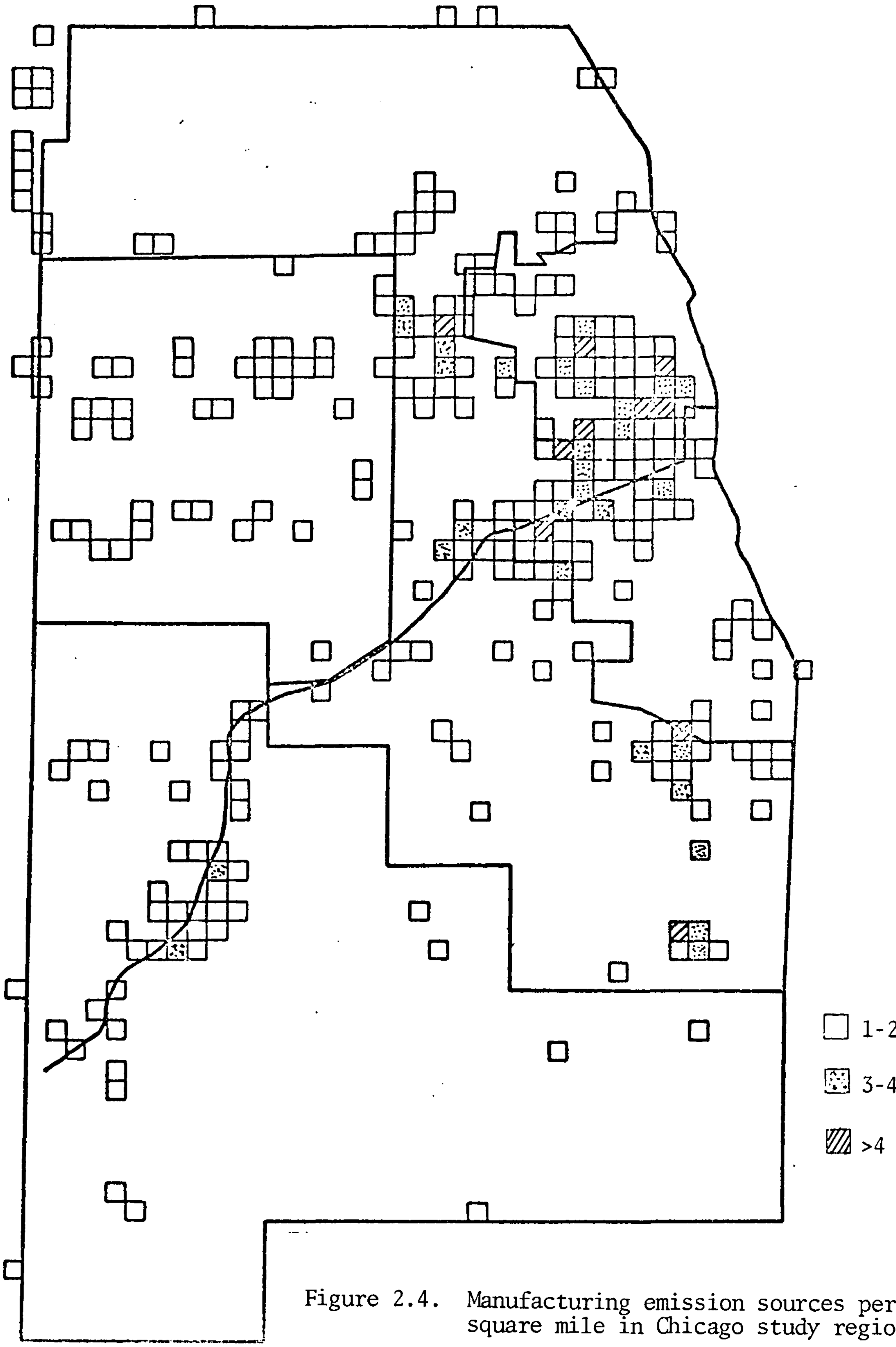


Figure 2.4. Manufacturing emission sources per square mile in Chicago study region.

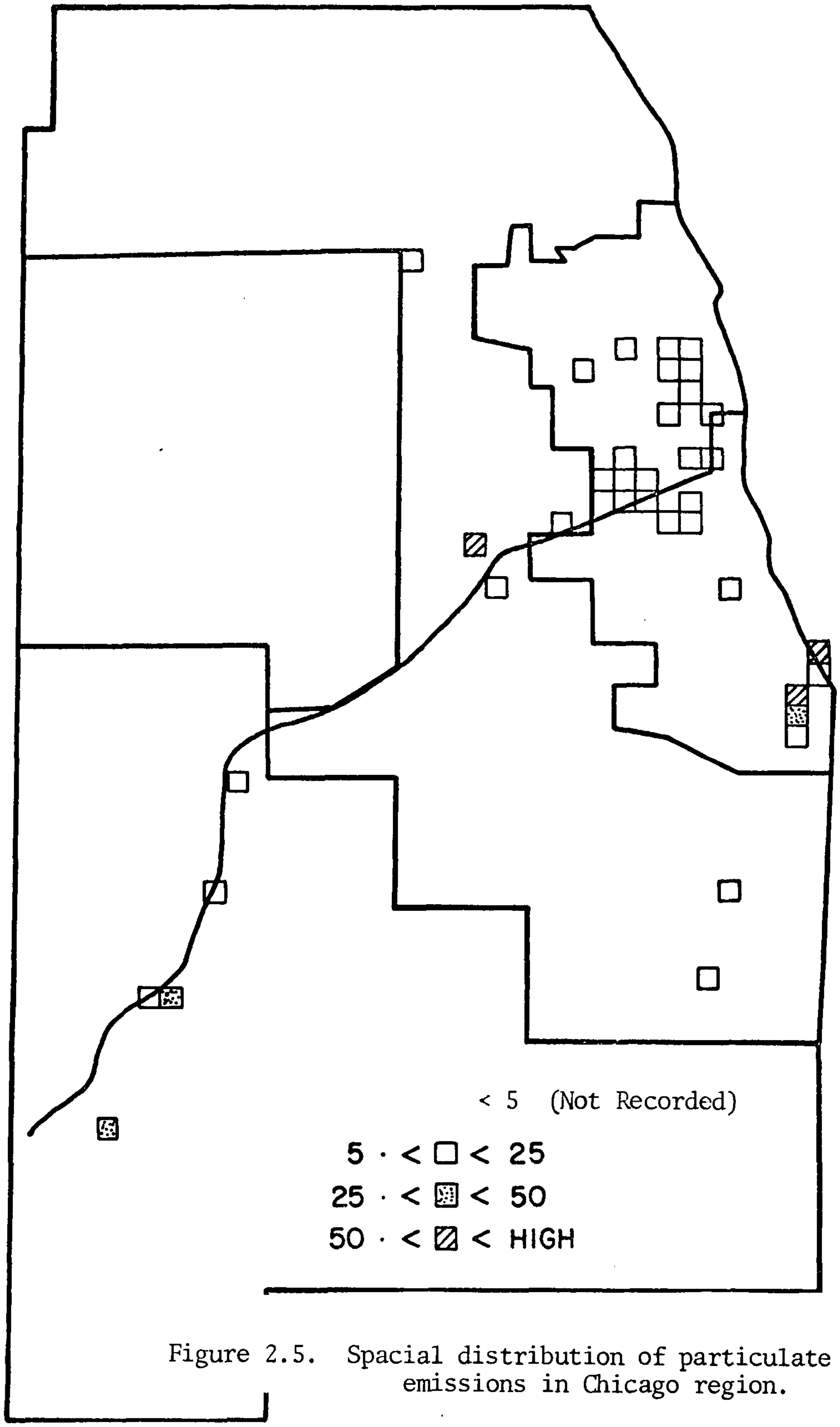
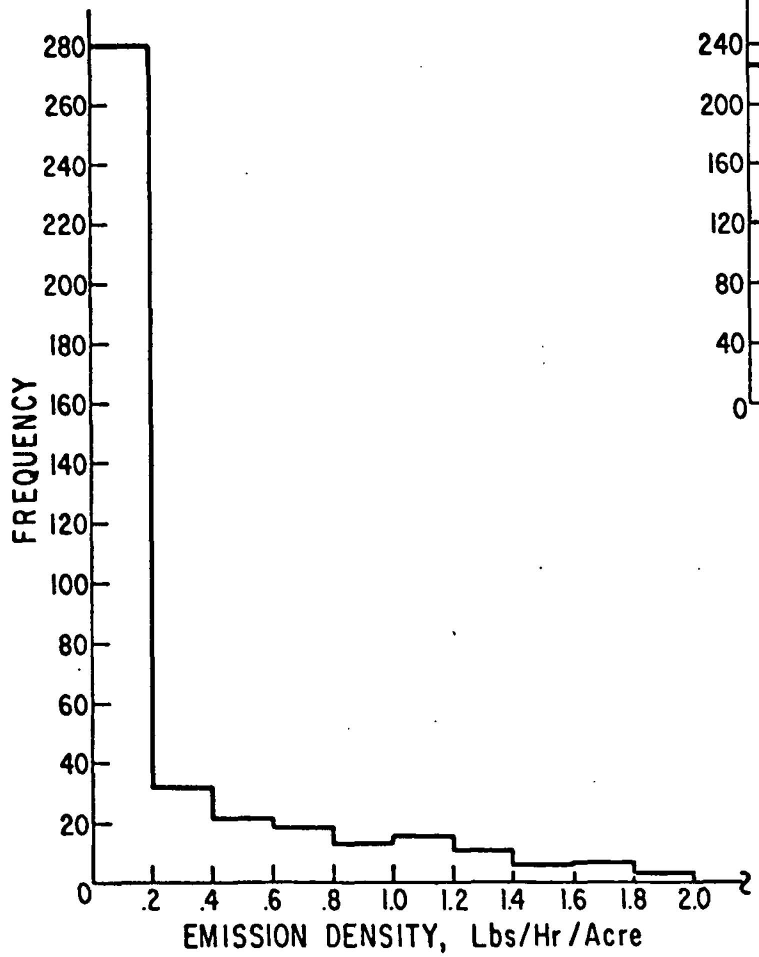


Figure 2.5. Spacial distribution of particulate emissions in Chicago region.



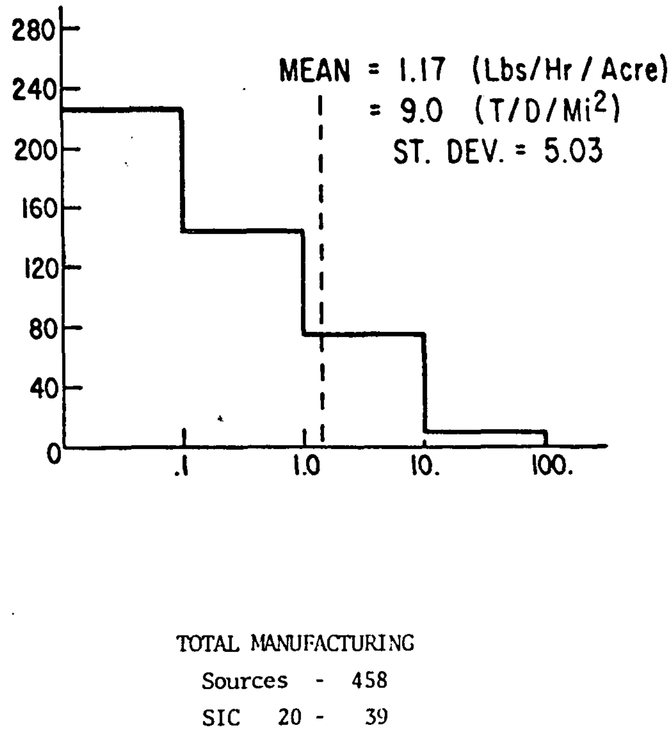


Figure 2.6. Frequency of suspended particulate emission density with Illinois point-source regulations applied.

factor in projecting future air quality. The use of this mean emission density estimate for ranking land use plans was tested by using the AQDM atmospheric dispersion model. Figure 2.7 shows the calculated air quality for suspended particulates as derived by applying a 1.17 lb/hr/acre (9.0 tons/day/mi^2) emission density factor to the present industrial land use pattern in Chicago. Figure 2.2 indicates suspended particulate air quality estimates based, on the other hand, directly upon the application of standard emission factors to the Chicago Emission Inventory with Illinois source control regulations applied. Comparison of these two figures shows that use of the average emission density factor for industrial lands does produce average air quality estimates that approximate the average air quality over the entire region. However, due to the bias in the estimation of the average emission density factor and the intense clusters of manufacturing land use in the area, pockets of very high concentrations appear in the air quality estimates based upon these factors, as opposed to those based upon the standard emission factors. Thus, if these estimates were used in ranking alternative land use plans, or in trying to identify future potential source clusters in the Chicago area, these average emission density air quality estimates would lead to the belief that air quality standards would not be met under the present conditions of Chicago land use patterns and air quality regulations.

This does not mean that the projections of air quality using these estimators are not a useful tool in ranking the air quality effects of alternative land use plans. Due to the bias of the land use emission density factor estimates, those plans containing a larger percentage of industrial zoned land will, in all probability, be ranked as being likely to produce

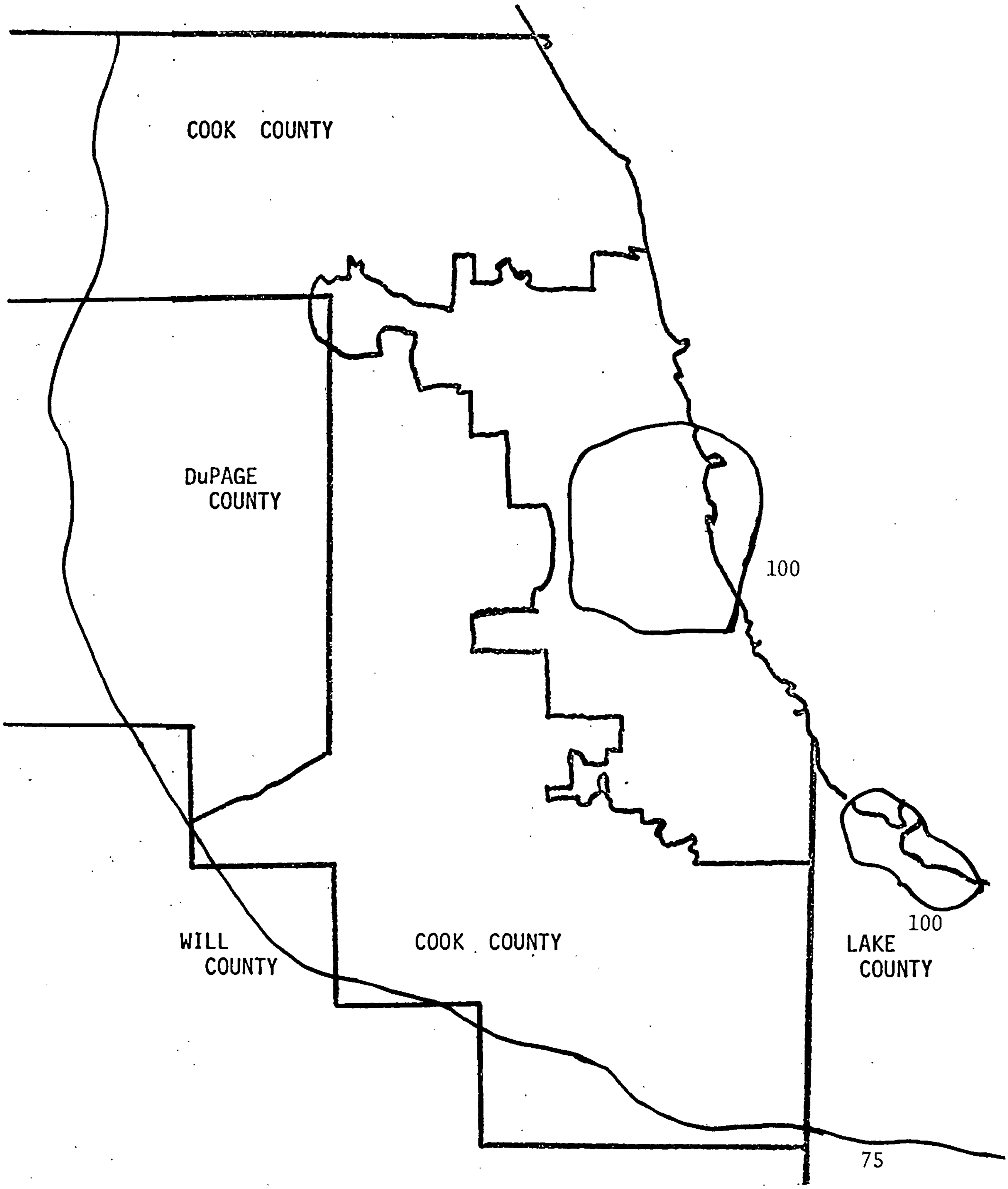


Figure 2.7. Isopleths of suspended particulates* using mean emission density estimates for manufacturing land (mean = 9.0 T/D/Mi^2 = 1.17 lb/hr/acre) (*$\mu g/m^3$ - annual geometric mean)

more significant degradation of air quality than might be justified. We conclude, therefore, that in using the mean estimators for land-use-based emission densities, some further methods must be developed to specifically take into account the skewness and variance of these distributions in projecting future air quality.

One way to estimate variance is to classify manufacturing sources as process or fuel combustion, as is currently done for control purposes. The dominance of process emissions over fuel combustion emissions is shown by the frequency distributions in Figures 2.8 and 2.9. Examination of the standard deviation of these distributions, compared with the standard deviation of the frequency distribution of the emission densities for the industrial sector as a whole, indicates that almost the entire variance in the emission density estimate is due to the variance of emissions in process sources. Thus, it can be anticipated, that if present industrial land use projections could be disaggregated into process and fuel combustion sources the projected air quality estimates would be somewhat improved. This does not alleviate the need, however, to specifically account for the wide variation in emission densities for industrial process sources.

We conclude that if mean estimators are to be used, a new process of classification must be attempted; the process may require planners to obtain more specific information in order to gain in explanatory power.

A further explanation using mean estimators was attempted; it groups digit SICs into typical "heavy" and "light" manufacturing land use. A survey[2] of zoning administrators in the Chicago region indicated the following groupings as predominant:

G_A^1 : Heavy SIC 26 - 33

G_A^2 : Light SIC 20 - 25, 34 - 39.

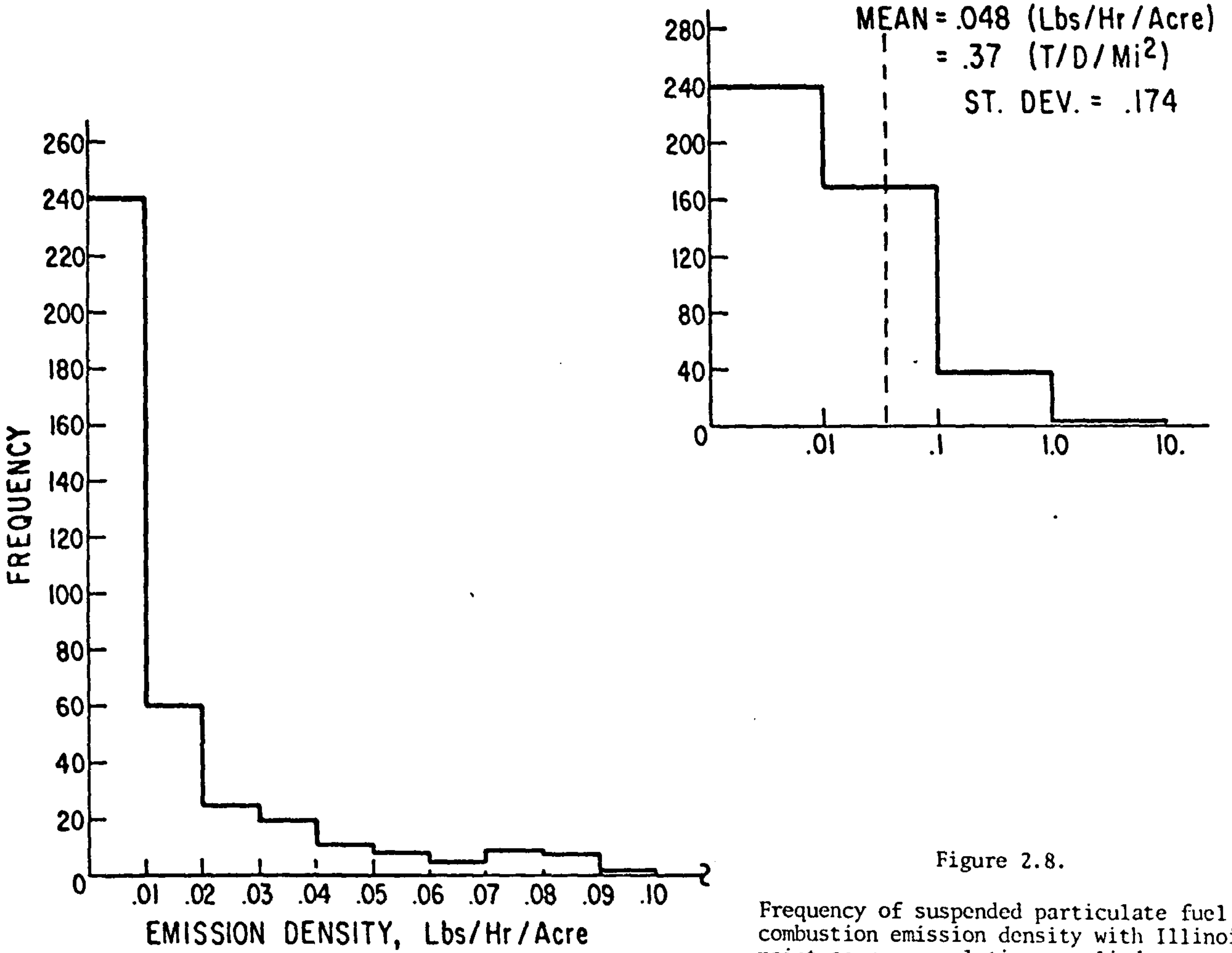
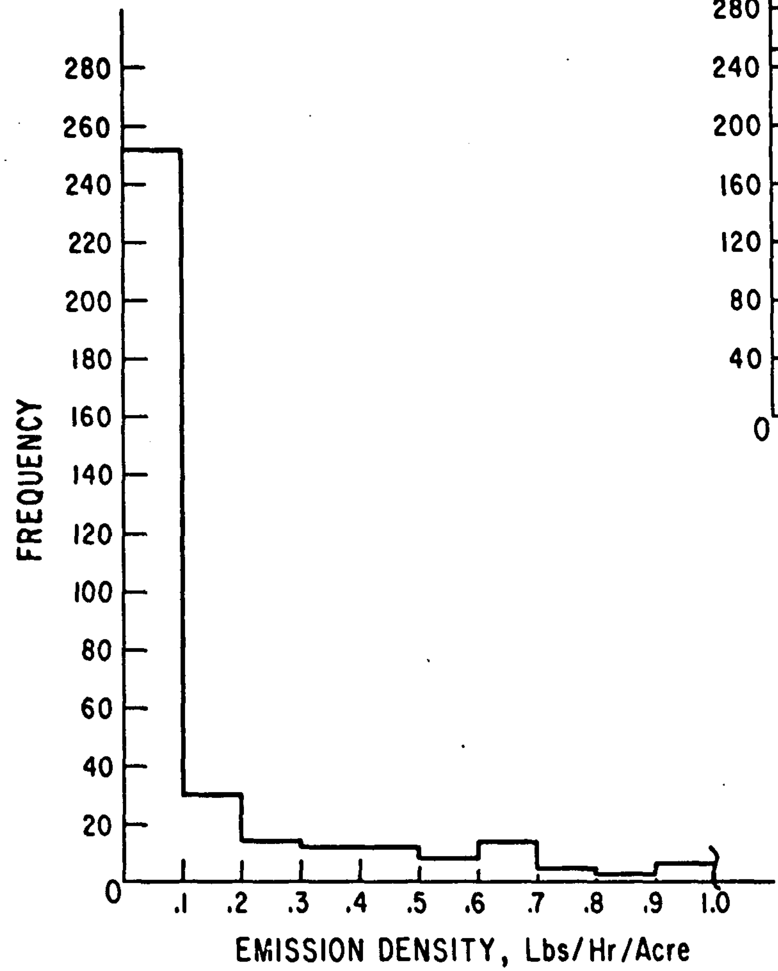


Figure 2.8.

Frequency of suspended particulate fuel combustion emission density with Illinois point-source regulations applied.



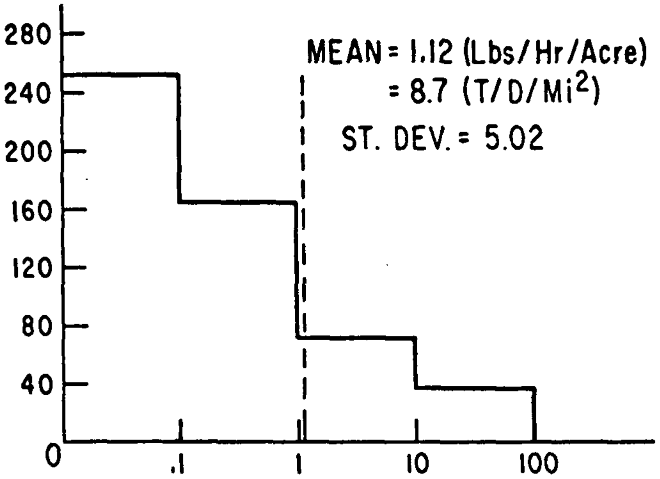


Figure 2.9.

Frequency of suspended particulate process emission density with Illinois point-source regulations applied.

The relevant statistics for this grouping are shown in Tables 2.1, 2.2, and 2.3 for suspended particulate fuel combustion, process, and total manufacturing emission densities, respectively. Again, the dominance of process emission is evident. An analysis of variance between groups indicates that mean process emission densities are significant at the .05 level, but fuel combustion emission densities are not. The significance of process emission densities carries over to total mean emission densities for the two groups.

When the mean estimates are applied to light and heavy manufacturing land use in the Chicago area, a slightly better air quality representation is obtained, as shown in Figure 2.10. A comparison with Figure 2.1 indicates that the peak areas are well represented, but the magnitudes of the peaks remain much too high, indicating a further need for refinement.

A final attempt at mean estimation for manufacturing land was attempted by using the 2-digit SIC classification. Tables 2.4, 2.5, and 2.6 contain the relevant statistics for suspended particulate fuel combustion, process, and manufacturing emission densities, respectively. An analysis of variance between 2-digit SICs shows no significant explanatory power for the emission-density variables. From this result, we are tempted to conclude that knowledge of mean emission densities by 2-digit SIC is of little assistance in predicting emissions and, hence resultant air quality. Land use data by 2-digit SIC was not available to test the resulting air quality representation.

Table 2.1. SUSPENDED PARTICULATE EMISSION DENSITY†
(lbs/hr/acre)

G_A^1 {26-33} G_A^2 {20-25, 24-39}	Unregulated Source Inventory				Regulated Source Inventory			
	Mean	Median	Std. Dev.	Skewness	Mean	Median	Std. Dev.	Skewness
G_A^1 (255)	47.60	.717	472.65	15.48	1.67	.21	6.29	7.63
G_A^2 (203)	27.24	1.04	164.76	9.63	.54	.04	2.62	8.35
TOTAL	38.57	.92	369.14	18.476	1.17	.104	5.03	9.01
ANOV					F* = 5.65	DF* = (1, 454)		S*(.05)

*F - F ratio

DF - Degrees of freedom (DFB - Between, DFW - Within)

S - Significance level

†(by Heavy and Light Industrial Zoning Class)

Table 2.2. SUSPENDED PARTICULATE FUEL COMBUSTION †
EMISSION DENSITY
(lbs/hr/acre)

G_A^1 {26-33} G_A^2 {20-25, 24-39}	Unregulated Source Inventory				Regulated Source Inventory			
	Mean	Median	Std. Dev.	Skewness	Mean	Median	Std. Dev.	Skewness
G_A^1 (255)	.604	.008	6.64	14.13	.058	.005	.208	8.53
G_A^2 (203)	.075	.005	.239	5.20	.034	.003	.120	9.53
TOTAL (458)	.370	.006	4.96	18.97	.048	.005	.174	9.44
ANOV					F* =1.34	(DF*= 1/454)		NS

*F - F ratio
DF - Degrees of freedom (DFB - Between, DFW - Within)
NS - Not significant

† (by Heavy and Light Industrial Zoning Class)

Table 2.3. SUSPENDED PARTICULATE PROCESS[†] EMISSION DENSITY (lbs/hr/acre)

G_A^1 (26-33) G_A^2 (20-25, 34-39)	Unregulated Source Inventory				Regulated Source Inventory			
	Mean	Median	Std. Dev.	Skewness	Mean	Median	Std. Dev.	Skewness
G_A^1 (255)	46.99	.666	472.64	15.48	1.61	.129	6.23	7.63
G_A^2 (203)	27.16	.998	164.76	9.63	.508	.012	2.61	8.39
TOTAL	38.20	.773	369.12	18.48	1.121	.040	5.02	9.008
ANOV					F* = 5.34	DF* = (1, 454)		S* (.05)

*F - F ratio

DF - Degrees of freedom (DFB - Between, DFW - Within)

S - Significance level

† (by Heavy and Light Industrial Zoning Class)

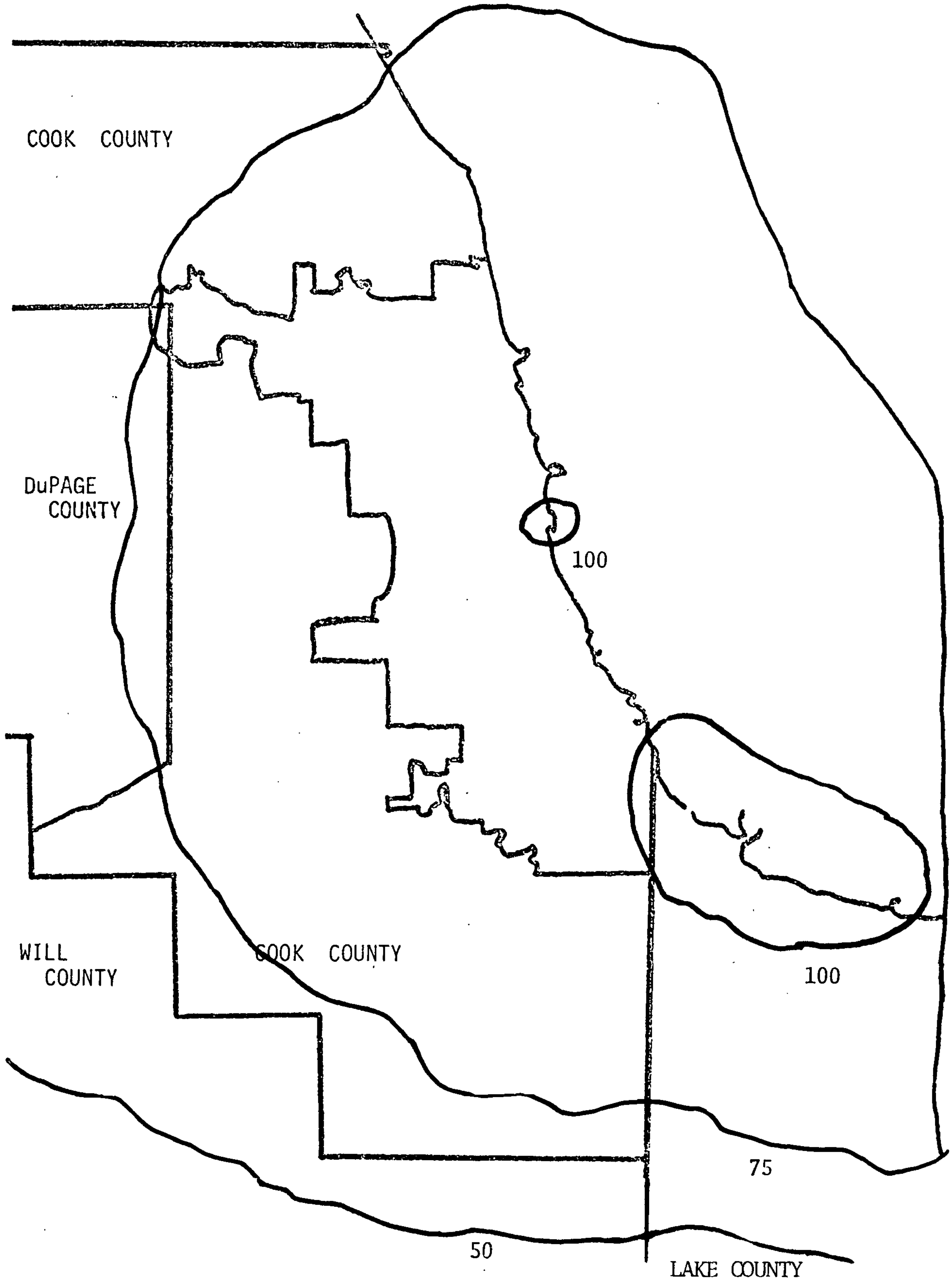


Figure 2.10. Isopleths of suspended particulates* using mean emission density estimates by manufacturing zoning classification:
Heavy industry = 13.1 T/D/mi^2 = 1.70 lb/hr/acre
Light industry = 4.2 T/D/mi^2 = .55 lb/hr/acre

*μg/m^3 annual geometric mean

Table 2.4. SUSPENDED PARTICULATE EMISSION DENSITY †
(lbs/hr/acre)

2- Digit SIC (N)	Unregulated Source Inventory				Regulated Source Inventory			
	Mean	Median	Std. Dev.	Skewness	Mean	Median	Std. Dev.	Skewness
20 (17)	.74	.09	1.4	2.5	.48	.09	.85	2.4
24 (14)	20.5	3.8	39.5	2.4	.13	.04	.29	3.2
25 (14)	8.4	2.0	13.0	1.6	.08	.04	.08	.62
26 (20)	29.6	2.4	60.2	2.0	.80	.11	1.88	3.49
27 (9)	50.6	6.4	106.7	2.1	.27	.10	.44	2.15
28 (67)	8.4	.45	29.9	5.66	.95	.11	2.74	6.28
29 (35)	17.8	.82	50.6	3.3	4.13	.25	14.12	3.85
30 (13)	2.5	.23	5.3	1.9	.51	.02	1.2	2.54
32 (43)	196.5	1.81	1141.8	6.3	2.35	.61	5.7	4.2
33 (67)	21.2	.65	87.7	6.9	1.36	.35	3.9	6.59
34 (39)	95.7	1.02	362.5	4.2	.63	.16	2.2	5.8
35 (49)	7.8	1.00	34.9	6.5	.88	.04	4.1	6.3
36 (29)	1.7	.80	2.5	1.9	.21	.02	.39	1.9
37 (12)	51.7	1.6	113.9	2.3	1.72	.02	5.7	3.0
38 (6)	3.5	.26	5.2	.74	.08	.04	.12	1.3
39 (18)	13.1	3.3	21.7	2.1	.14	.03	.27	1.9
TOTAL (458)	38.57	.92	369.14	18.48	1.17	.10	5.03	9.01
ANOV					F=1.229	16 DF=439		NS(.05)

† (by 2-digit SIC Code)

Table 2.5 SUSPENDED PARTICULATE FUEL COMBUSTION EMISSION DENSITY †
(lbs/hr/acre)

2-Digit SIC	Unregulated Source Inventory				Regulated Source Inventory			
	Mean	Median	Std. Dev.	Skewness	Mean	Median	Std. Dev.	Skewness
20 (17)	.142	.022	.447	3.7	.049	.016	.095	3.20
24 (14)	.004	0.	.009	2.02	.003	0.	.008	2.27
25 (14)	.016	0.	.026	1.61	.010	0.	.016	1.81
26 (20)	1.64	.01	7.15	4.13	.073	.010	.170	3.44
27 (9)	.036	0.	.088	2.39	.036	0.	.008	2.39
28 (67)	.083	.011	.263	4.99	.044	.009	.213	6.50
29 (35)	.111	.023	.224	2.77	.099	.019	.213	2.99
30 (13)	.012	.002	.022	2.40	.011	.002	.002	2.63
32 (43)	2.39	0.	15.42	6.33	.019		.050	4.32
33 (67)	.128	.006	.540	5.59	.082		.327	6.92
34 (39)	.067	.003	.242	5.53	.064	.003	.242	5.58
35 (49)	.101	.004	.301	3.63	.026	.004	.065	4.15
36 (29)	.065	.007	.128	2.23	.042	.003	.080	1.87
37 (12)	.200	.065	.255	1.008	.046	.014	.065	1.337
38 (6)	.049	.036	.055	.115	.030	0.	.047	.9
39 (18)	.020	0.	.057	3.57	.008	0.	.014	1.38
TOTAL (458)	.370	.006	4.96	18.97	.048	.005	.174	9.44
ANOV					.473	16 DF=439		NS(.05)

† (by 2-digit SIC Code)

Table 2.6. SUSPENDED PARTICULATE PROCESS EMISSION DENSITY†
(lbs/hr/acre)

2-Digit SIC (N)	Unregulated Source Inventory				Regulated Source Inventory			
	Mean	Median	Std. Dev.	Skewness	Mean	Median	Std. Dev.	Skewness
20 (17)	.601	0.	1.39	3.03	.43	0.	.86	2.50
24 (14)	20.46	3.82	39.53	2.42	.125	.035	.29	3.15
25 (14)	8.38	2.02	13.02	1.62	.071	.021	.083	.69
26 (20)	27.96	2.41	60.41	2.08	.72	.021	1.88	3.55
27 (9)	50.54	6.42	106.7	2.15	.235	.072	.448	2.20
28 (67)	8.30	.30	29.9	5.67	.906	.024	2.745	6.27
29 (35)	17.7	.75	50.6	3.30	4.032	.173	14.102	3.85
30 (13)	2.55	.22	5.27	1.96	.500	.005	1.183	2.58
32 (43)	194.12	1.81	1142.1	6.30	2.33		5.62	4.16
33 (67)	21.1	.62	87.74	6.90	1.27		3.04	6.66
34 (39)	95.61	.883	362.5	4.25	.564	.126	2.166	5.83
35 (49)	7.67	.871	34.93	6.46	.851	.010	4.055	6.28
36 (29)	1.64	.615	2.49	1.915	.166	.004	.367	2.16
37 (12)	51.45	1.182	113.87	2.25	1.676	0.	5.66	3.01
38 (6)	3.49	.26	5.24	.74	.054	0.	.126	1.78
39 (18)	13.08	3.18	21.66	2.05	.134	.006	.276	1.92
TOTAL (458)	38.20	.773	369.13	18.48	1.121	.040	5.021	9.01
ANOV					F=1.21	16 DF=439		NS(.05)

†(by 2-digit SIC Code)

3.0 METHODS FOR ESTIMATING EMISSIONS FROM LAND USE

The analysis of emission density variance described in the preceding section provides the rationale for further investigation into processes and methods for estimating emissions from land use. The description of the current state and potential growth of the Chicago region in Appendix A gives an indication of the parameters that are customarily used and reported in the planning process for forecasting the rate of urbanization and change of settlement patterns of the region. These parameters include rates of change in land use, employment, and productivity for major manufacturing sectors; changes in housing stock and population for residential land; and square footage of floor space for commercial development. This section analyzes and tests the utility of certain of these parameters in predicting regional emission and air quality patterns and residential/commercial land uses. Two criteria were used in evaluating these parameters: (1) the accuracy of the representation of regional air quality produced when the parameter estimates were inserted into the AQDM atmospheric dispersion model, and (2) the reliability of the representation when submitted to standard statistical analyses such as analysis of variance, product-moment correlation, and multiple linear regression.

3.1 UNIFORM EMISSION-DENSITY ESTIMATION BY MANUFACTURING ZONING CLASS

The previous section indicated some of the difficulties encountered in using mean emission density estimates by land use class or major industrial sector. The major difficulty stems from the skewness of the emission-density distribution as shown in Figure 2.6. Some improvement is realized if mean emission densities by heavy (HI) and light (LI) industry are used.

In order to obtain a direct comparison between the emission-density approach and the point-source emission factors approach, the AQDM results for each were compared in the uncalibrated model. This merely means that results, before fitting to actual air quality data and adding background concentrations, are to be compared, assuming that the point-source representation is the best attainable with current information. The mean relative error and the standard deviation in the error between air quality concentrations calculated using the point-source representation and those using the emission-density representation are then used to measure the "goodness" of the emission-density representation. Thus:

$$\mu_R = \frac{1}{N} \sum_i \frac{\Delta\chi_i}{\chi_i^{PS}} \quad (3.1)$$

$$\sigma_R = \left[\sum \frac{(\Delta\chi_i)^2}{N} - \mu_R^2 \right]^{1/2} \quad (3.2)$$

where

$\Delta\chi_i = \chi_i^{PS} - \chi_i^{ED}$,

μ_R = the mean relative error ,

σ_R = the standard deviation about the mean relative error ,

χ_i^{PS} = the arithmetic mean air quality concentration calculated at receptor point i using the point-source file ,

χ_i^{ED} = the arithmetic mean air quality concentration calculated at receptor i using the emission-density representation ,

i = an index of receptor points ,

N = the total number of receptor points.

Using this criterion and the means for heavy and light industry based on the 90% largest source sample (see Appendix A, Section A.4), which are:

$$\bar{ED}^{HI} = 18.0 \text{ T/D/mi}^2 , \quad \text{(means of sample)}$$

$$\bar{ED}^{LI} = 6.0 \text{ T/D/mi}^2$$

The following are obtained:

$$\mu_R = -5.86$$

$$\sigma_R = 1.48$$

this indicates a severe bias to overprediction. A visual comparison of the resulting air quality is provided in Figures 3.1 and 3.2.

The skewness of the distributions involved would ordinarily argue for using the median as an estimation instead of the mean. For this sample:

$$\hat{ED}^{HI} = 1.3 \text{ T/D/mi}^2 \quad \text{(medians of sample)}$$

$$\hat{ED}^{LI} = .23 \text{ T/D/mi}^2$$

and

$$\mu_R = .61$$

$$\sigma_R = .08$$

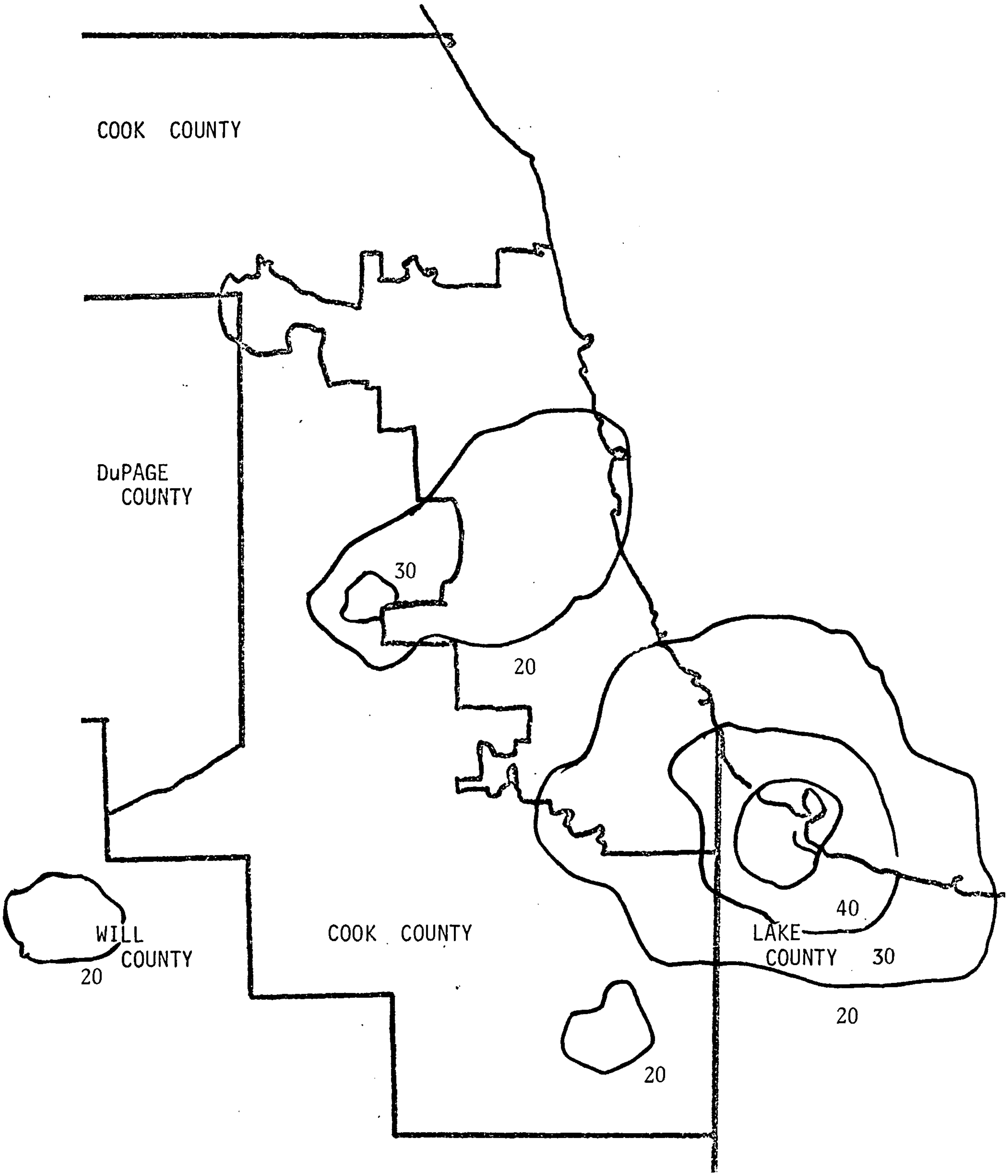


Figure 3.1. Isopleths of suspended particulates* using point-source representation.

*($\mu g/m^3$ - annual arithmetic mean - uncalbirated model)

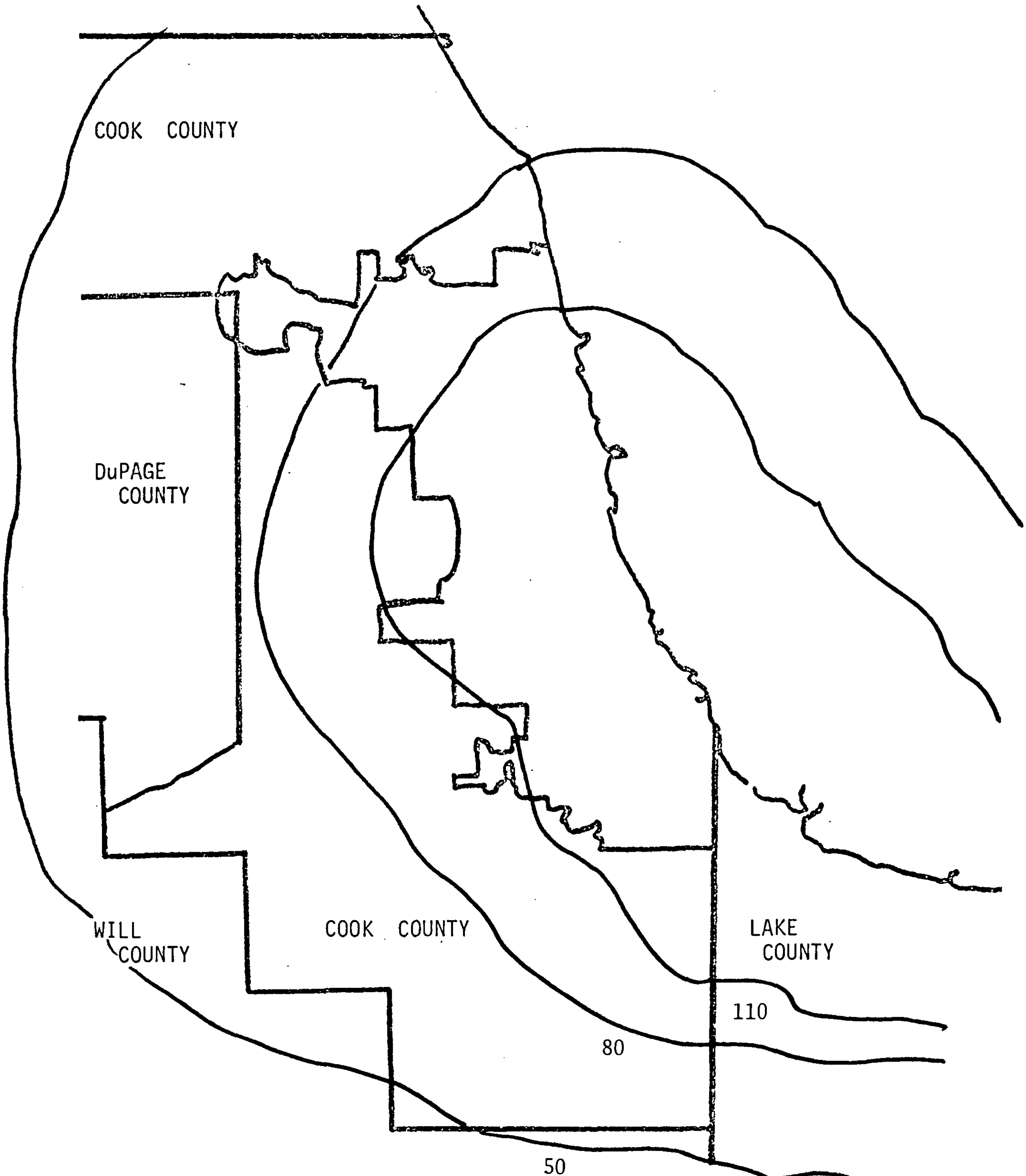


Figure 3.2. Isopleths of suspended particulates* using mean emission density representation. ($\bar{ED}^{HI}$ = 18.0 T/D/mi^2 - $\bar{ED}^{LI}$ = 6.0 T/D/mi^2)

*(μg/m^3 - annual arithemetic mean - uncalibrated model)

indicating a substantial bias to underprediction. A visual comparison can be made by simultaneously viewing Figures 3.1 and 3.3.

At this point, it is reasonable to ask if a reasonable estimate of air quality concentrations can be made using some emission-density estimates for heavy and light industry. To answer this question, assume that emission-density estimates are free parameters to be chosen so as to achieve a "best fit" in the sense that:

$$\min \sigma_R \, (ED^{HI}, ED^{LI}) \qquad (3.3)$$

$$\text{subject to} \quad \mu_R \, (ED^{HI}, ED^{LI}) = 0 \; .$$

That is, emission density estimates, $\overset{*}{ED}{}^{HI}$ and $\overset{*}{ED}{}^{LI}$, are sought which yield the best (least standard deviation), unbiased ($\mu_R = 0$) comparison with air quality concentrations as modeled using the point-source information. The analytic solution to this problem is easily worked out (Appendix C), and the results yield:

$$\overset{*}{ED}{}^{HI} = 3.53 \text{ T/D/mi}^2 \; ,$$

$$\overset{*}{ED}{}^{LI} = .53 \text{ T/D/mi}^2 \; ,$$

and

$$\mu_R = 0 \qquad \text{(by constraint)} \; ,$$

$$\sigma_R = .20$$

The resulting concentration isopleth map is shown in Figure 3.4. Thus, the best fit emission-density representation still leaves a 20% standard deviation in the relative error.

A closer look at the seriousness of this error can be taken if it is assumed that a large relative error in the lower concentration ranges can be tolerated, but, hopefully, the peak concentrations are well represented.

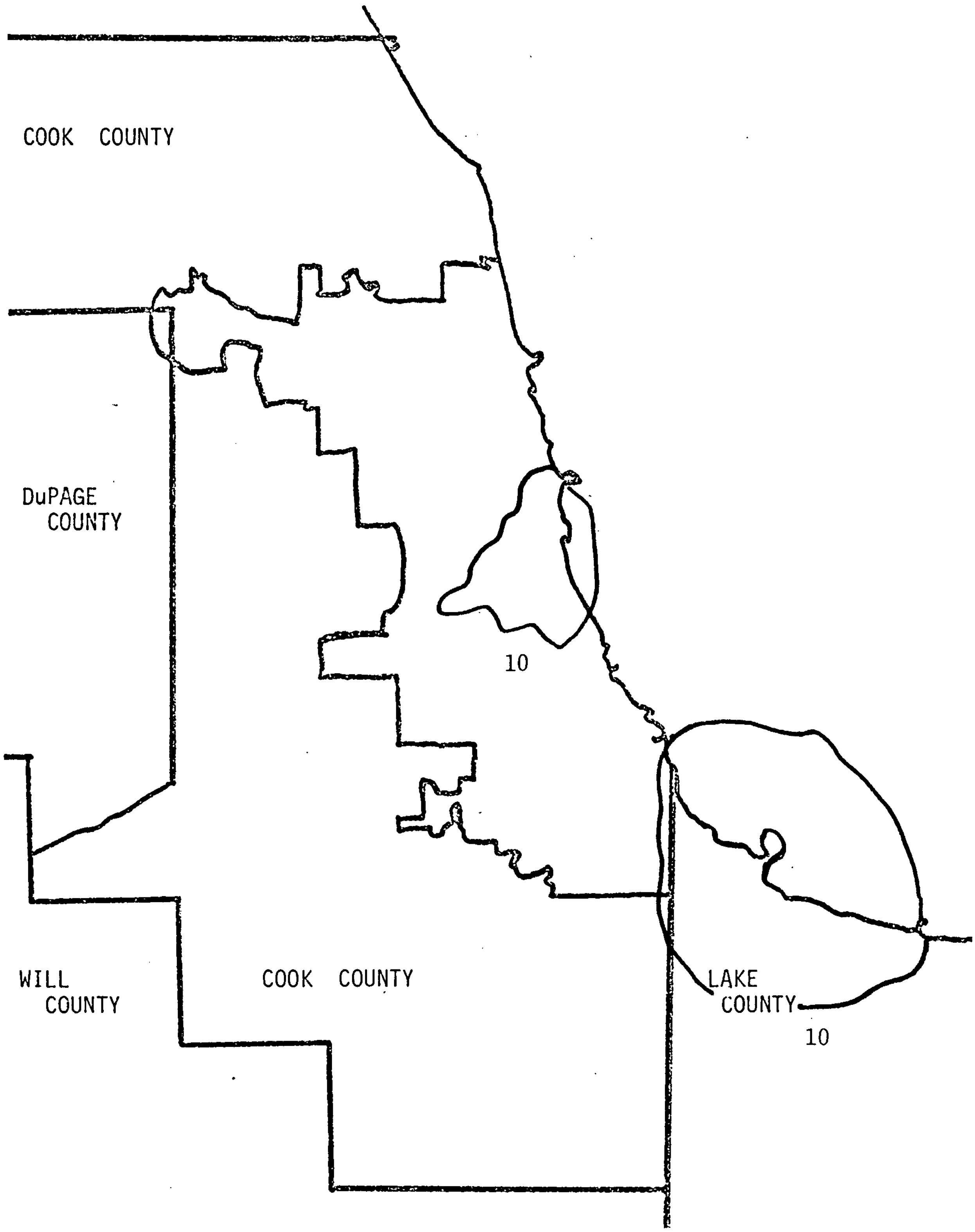


Figure 3.3. Isopleths of suspended particulates* using median emission density representation. ($\hat{ED}^{HI} = 1.3$ T/D/mi^2 - $\hat{ED}^{LI} = .23$ T/D/mi^2)

*(μg/m^3 - annual arithmetic mean - uncalibrated model)

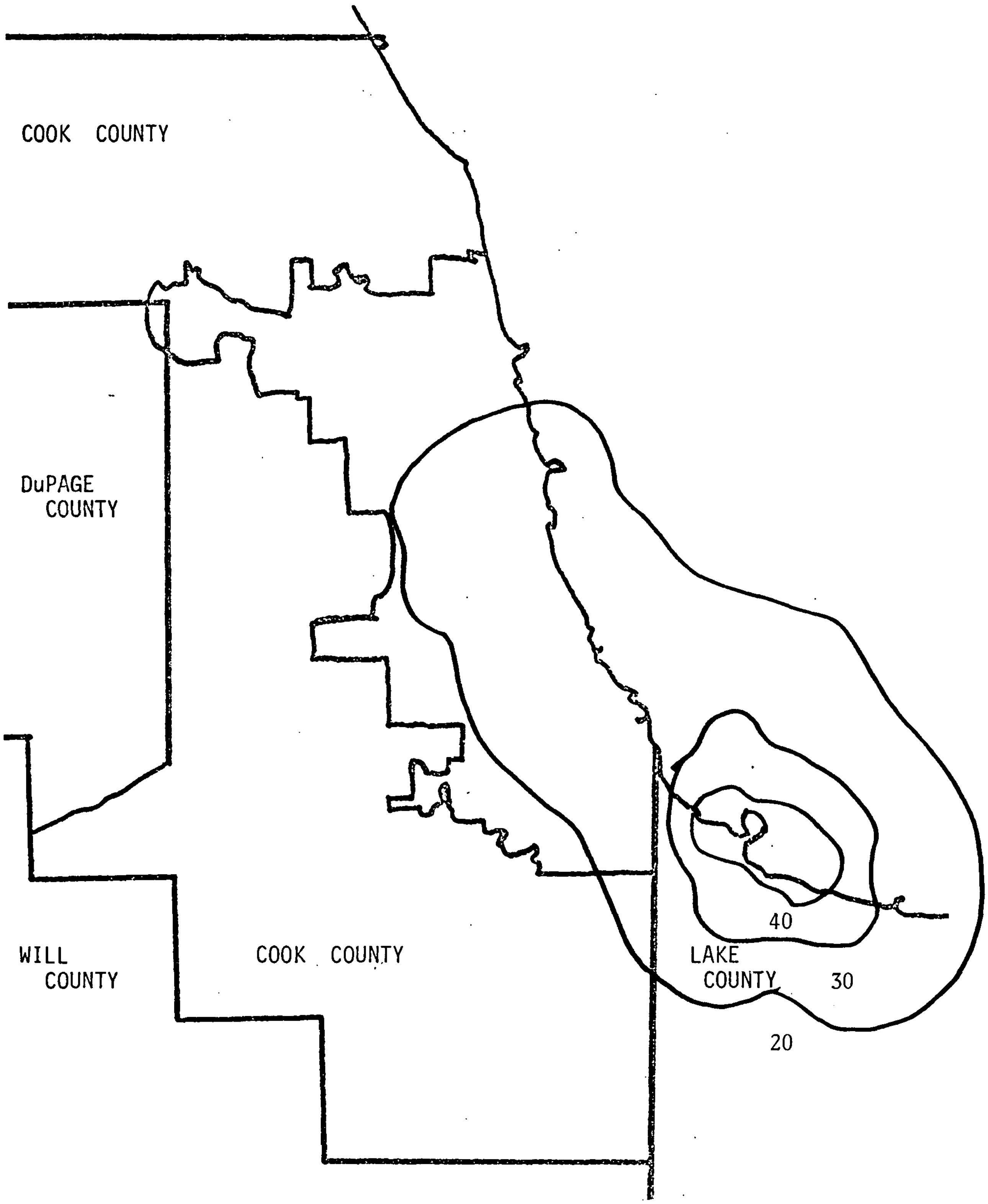


Figure 3.4. Isopleths of suspended particulates* using "best fit" emission density representation. ($\overset{*}{ED}^{HI}$ = 3.53 T/D/mi^2 - $\overset{*}{ED}^{LI}$ = .53 T/D/mi^2)

*(μgm/m^3 - annual arithmetic mean - uncalibrated model)

Nine receptor points are above 30 $\mu g/m^3$; this, when coupled with the normal rural background of 40 $\mu g/m^3$, can be considered in the critical area of the standard (75 $\mu g/m^3$). Using the "best fit" emission-density estimates applied to only these nine points yields:

$$\mu_R = .22 \quad ,$$

$$\sigma_R = .33 \quad ,$$

indicating a strong bias to underprediction, with a large standard deviation of relative error. Thus, it can be concluded that the best fit estimates actually do worse in predicting the higher peak concentrations than lower concentration levels; further, the standard deviation of bias is to underprediction, an undesirable result for estimating peak levels.

Finally, if "best fit" emission density estimates are generated using these nine highest receptor points alone, the results are:

$$\overset{*}{ED}^{HI} = 2.43 \text{ T/D/mi}^2 ,$$

$$\overset{*}{ED}^{LI} = 2.74 \text{ T/D/mi}^2 ,$$

where, for the nine highest receptor points,

$$\mu_R = 0 \quad \text{(by constraint).}$$

$$\sigma_R = .33 \quad ,$$

and for all receptor points,

$$\mu_R = .86 \quad ,$$

$$\sigma_R = .56,$$

From these results, it can be concluded that several high receptor points are being influenced by clustered light industrial land use, and even when these nine points are used to determine best-fit emission-density values, no improvement is observed in the standard deviation of relative error. All this is at the expense of a substantial bias to overprediction in the remaining receptor points.

It must be concluded, therefore, that (1) either the land use data used for this study is severely in error, or (2) that further explanation is required; e.g., further disaggregation of land use categories, or using intensity measures such as employment density. The land use data was collected from best available sources and is assumed to be sufficiently reliable for purposes of this study. Therefore, the results of this section are assumed to provide the rationale for further investigations as discussed in the next section.

3.2 ANALYSIS OF MANUFACTURING EMISSIONS BY MAJOR INDUSTRIAL SECTOR (2-digit SIC code)

The previous section indicated the need, based on the criteria of air quality representation, for further explanation of manufacturing emissions. Manufacturing land use by heavy and light industry failed to give adequate air quality representation, even when "best fit" emission density estimators were used. The next level of disaggregation is by 2-digit SIC code; however, land use data by 2-digit SIC code was not available in the Chicago area. Therefore, the analysis of this section uses statistical measures to test the utility of various parameters in predicting emissions.

Even if land use were known by 2-digit SIC, the analysis of variance of Section 2 yields discouraging results regarding the use of mean emission-density estimates by the 2-digit classification. This result is reproduced for a subset of major polluting sectors in the Chicago region as shown in

Table 3.1. The variance at the 5% significance level in average emission densities of industries classified by the 2-digit scheme differs only marginally, which, in turn, is due to the large variance of emission density within each 2-digit class. Note, however, that it is the variance in the land variable that is causing this result, since emissions by 2-digit class are significantly different. Thus, justification is provided for attempting to estimate emissions within each 2-digit classification through the use of certain planning parameters. Average employment levels, process weight, and energy are particularly important because they vary significantly among the 2-digit groupings.

In the remainder of this section, the major polluting sectors are investigated in order, as ranked by total controlled emissions. Each sector is characterized with respect to its major contribution to air pollution, process and fuel combustion emission contributions, reductions in emissions achieved by Illinois source control regulations, and the degree of explanation of controlled emissions by employment, land use, process weight, and energy consumption. Descriptions and material presented in the Standard Industrial Classification Manual[3] and the Compilation of Air Pollutant Emission Factors[4] are used when necessary to complete the discussion of each 2-digit classification.

Appendix D contains the results of applying correlation and regression analysis to the Chicago emission inventory by 2-digit SIC. In addition to product-moment correlation, four linear regression models are tested for each 2-digit category; these are:

Table 3.1. ANALYSIS OF VARIANCE TEST FOR DIFFERENCE OF MEANS BETWEEN 12 LARGEST POLLUTING SECTORS

Variable	F Value DFB 11 DFW 476	Significance Level
Land	.54	NS
Employment	4.6	.001
Process Weight	5.2	.001
Energy	2.7	.001
Controlled Emissions	7.2	.001
Controlled Emission Density	1.4	NS

General Emission Model

$$E^{CT} = A \cdot Pw + B \cdot En + C \cdot Sp + D \cdot Em + E \qquad (3.4)$$

Restricted Emission Model

$$E^{CT} = A \cdot Sp + B \cdot Em + C \qquad (3.5)$$

Restricted Process Weight Model

$$Pw = A \cdot Sp + B \cdot Em + C \qquad (3.6)$$

Restricted Energy Model

$$En = A \cdot Sp + B \cdot Em + C \qquad (3.7)$$

where

E^{CT} = controlled emissions (lb/hr)
Pw = process weight flow (t/hr)
En = energy consumption (MBtu/hr)
Sp = space (acres)
Em = employment

and A, B, C, D, and E are linear regression coefficients.

Results of these models are summarized in Table 3.2; the details for the five major polluting sectors are discussed in the remainder of the section. These five sectors account for 272, or 50%, of the sources in the emission inventory file; 76% of the manufacturing land use; 34% of employment; 96.2% of process material flow; 79.9% of energy consumed; and 85% of controlled emissions.

3.2.1 SIC 32 Stone, Clay, and Glass Products

Industries in this category manufacture products from materials taken principally from the earth in the form of stone, clay, and sand; such as glass products, cement, structural clay products, pottery; and concrete,

Table 3.2. MULTIPLE REGRESSION R^2 AND INDIVIDUAL VARIABLE CONTRIBUTIONS

	General Emission Model					Restricted Emission Model			Restricted Process Weight Model			Restricted Energy Model			% of Total Emissions	% due to Process	% due to Fuel Combustion
SIC	R^2	Pw	En	Sp	Em	R^2	Sp	Em	R^2	Sp	Em	R^2	Sp	Em			
32	.57	.55	--	.02	--	.35	.34	.01	.47	.43	.03	.82	.01	.81	29	97	3
29	.61	.08	.53	--	--	.30	.28	.02	--	--	--	.68	.64	.04	17	70	30
33	.61	.52	.03	--	.06	.13	--	.13	.03	--	.03	.03	--	.03	16	90	10
28	.73	.60	.01	.12	--	.13	.12	.01	--	--	--	.40	.01	.39	16	82	18
20	.95	.05	.90	--	--	.80	.77	.03	.19	--	.19	.81	.78	.03	7	53	47
35	.93	.69	.23	--	.01	.17	--	.17	.01	.01	--	.88	.07	.81	4	65	35
34	.89	.74	.15	--	--	.46	.46	--	.71	.71	--	.05	.05	--	3	63	37
26	.87	.81	.06	--	--	.55	.01	.54	.51	--	.51	.17	.01	.16	3	80	20
30	.87	--	.44	.42	.01	.02	--	.02	.08	--	.08	.43	.40	.03	1.3	89	11
37	.999	.88	.12	--	--	.02	.02	--	.08	.02	.06	.27	--	.27	1.1	70	30
39	.999	.999	--	--	--	.05	.05	--	.06	.06	--	.30	.30	--	1.1	82	18
36	.75	.02	.72	--	.01	.06	--	.06	.04	.02	.02	.46	--	.46	1.0	71	29

gypsum, abrasive and asbestos products. This category accounts for 29% of controlled particulate emissions in the source file; 97% of these emissions are due to the manufacturing processes themselves, while only 3% are due to fuel combustion. This category utilizes 5.5% of the energy consumed or 920 MBtu/hr; of which 833 MBtu/hr are due to the combustion of natural gas. Thus, process emissions are the major air pollution problem in this category.

Estimated uncontrolled process emission factors for various sub-categories are shown below:

SIC	Description	Suspended Particulate Emission Factors (lb/ton of finished product)
32	Stone, Glass and Clay	
3211	Flat Glass	2.0
3229	Blown Glass	60.0
3241	Cement	54.0
3251	Brick	180.0
3273	Ready Mix Concrete	0.2
3274	Lime	200.0
3275	Gypsum	132.0
3281	Cut Stone	31.0
3291	Abrasive Products	31.0
3295	Minerals & Earth	77.0
3295	Perlite	21.0
3296	Mineral Wool	50.0
3297	Non-Clay Refractory	225.0

Source: Compilation of Air Pollutant Emission Factors (Revised). U.S. EPA, Office of Air Programs, February 1972.

This category accounts for 61% of process weight flow, amounting to 17,337 tons of material moved per hour. Application of the Illinois control regulations will achieve a reduction in emissions from 88,556 lb/hr to 1330 lb/hr, or 98%. Emissions per ton of process weight will then be .08 lb/T/hr.

Correlation results for this category indicate that controlled emissions are highly correlated (r = .74) with process weight as expected. Since process weight and land are correlated (r = .66), a high correlation (r = .58) between emissions and land is also obtained. Energy and employment are also highly correlated (r = .90).

The general emission model R^2 of .57 is obtained with all five variables entering the equation. However, process weight dominates the explanation contributing an R^2 of .55, while the remaining variables contribute the remaining .02. In the restricted emission model, a multiple R^2 of .35 is obtained primarily from the land variable. For the restricted process weight model, an R^2 of .43 is obtained, again primarily due to the land variable. On the other hand, employment accounts for most of the R^2 of .82 in the restricted energy model. These results indicate that space is the most useful planning variable in predicting controlled emissions in this category.

3.2.2 SIC 29 Petroleum Refining and Related Industries

Industries in this category are engaged in petroleum refining, manufacturing of paving and roofing materials, and compounding lubricating oils and greases from purchased materials. This category accounts for 17% of controlled particulate emissions; 70% are due to the manufacturing processes themselves, while 30% are due to fuel combustion. This category utilizes 36% of the energy consumed, or 6036 MBtu/hr; of which 5115 MBtu/hr are due to the combustion of natural gas. Thus, process emissions are the major problem, although fuel combustion must also be considered a problem due to the high volume of fuel consumed.

Estimated uncontrolled process emission factors for the various subcategories are shown below:

SIC	Description	Suspended Particulate Emission Factors (lb/ton of finished product)
29	Petroleum and Coal	
2911	Petroleum Refining	5.5
2951	Paving	45.0
2952	Asphalt Coating	8.5
Source: Op cit		

This category accounts for 17% of the process weight flow amounting to 4755 t/hr. Application of the Illinois control regulations will achieve a reduction in emissions from 5110 lb/hr to 767 lb/hr, or 85%. Emissions per ton of material moved will then be .16 lb/t/hr.

Correlation results for this category indicate that controlled emissions are correlated with energy (r = .73), process weight (r = .44), employment (r = .49), and space (r = .52). Energy is correlated with space (r = .80) and employment (r = .74), but process weight is not correlated with either variable.

The general emission model R^2 is .61, with energy contributing .53 and process weight contributing .08 to the explanation. The restricted energy model R^2 is .68 with space contributing .64 to the explanation. Neither land nor employment contribute to the explanation of process weight. In the restricted emission model, the R^2 is .30 with space contributing .28 to the explanation. Thus, space appears to be the most useful planning variable in explaining emissions from this category.

3.2.3 SIC 33 Primary Metal Industries

Industries in this category engage in the smelting and refining of metals from ore, pig, or scrap; in the rolling, drawing, or alloying of metals; and in the manufacture of castings, forgings, and other basic metal products. This category accounts for 16% of controlled particulate emissions; 90% are due to the manufacturing processes themselves, while 10% are due to fuel combustion. This category utilizes 15.3% of the energy consumed, or 2575 MBtu/hr, of which 2365 Mbtu/hr are due to the combustion of natural gas. Thus, process emissions are the major air pollution problem in this category.

Estimated uncontrolled process emission factors for the various subcategories are shown below:

SIC	Description	Suspended Particulate Emission Factors (lb/ton of finished product)
33	Primary Metal Industries	
3312	Blast Furnace	200.35
3313	Electrometallurgical	1180.0
3321	Gray Iron Foundries	17.0
3323	Steel Foundries	66.0
3331	Copper Smelting	135.0
3332	Lead Smelting	162.0
3333	Zinc Smelting	530.0
3334	Aluminum Smelting	295.0
3341	Brass and Bronze Smelting	50.0
3341	Aluminum	1025.0
3341	Lead	110.0
3341	Zinc	103.0
3341	Magnesium	4.0
3352	Rolling Aluminum	135.0

Source: Op cit

This category accounts for 3.6% of the process weight flow amounting to 1010 tons of material moved per hour. Application of the Illinois control regulations will achieve a reduction in emissions from 9007 lb/hr to 733 lb/hr or 92%. Emissions per ton of process weight will then be .73 lb/T/hr.

Correlation results for this category indicated that controlled emissions are correlated with process weight (r = .73), and somewhat with employment (r = .35) and energy (.27). However, process weight is poorly correlated with land (r = .05) and employment (r = .17). Energy is somewhat correlated with space (r = .28) but poorly correlated with employment (r = .16).

The general emission model R^2 if .61 with process weight contributing .52 to the explanation, the remainder being due to employment (.06) and energy (.03). Unfortunately, the results for the restricted models show that neither land nor employment is a good predictor of emissions, process weight, or energy. Some other means for estimating these parameters, particularly process weight, is required for this category.

3.2.4 SIC 28 Chemicals and Allied Products

Industries in this category produce basic chemicals or products manufactured predominantly from chemical processes. Establishments in this group manufacture three classes of products: (1) basic chemicals; (2) chemical products to be used in further manufacturing processes; and (3) finished chemical products to be used in final consumption. This category accounts for 16% of controlled particulate emissions; 82% are due to the manufacturing processes themselves, while 18% are due to fuel combustion. This category utilizes 11.4% of the energy consumed or 1908 MBtu/hr; 758 MBtu/hr are due to coal use, 146 MBtu/hr are due to the consumption of natural gas. Thus, both process and fuel combustion emissions pose air pollution problems for this category.

Estimated uncontrolled process emission factors for the various subcategories are shown below:

SIC	Description	Suspended Particulate Emission Factors (lb/ton of finished product)
28	Chemicals and Allied	
2812	Alkalis	6.0
2815	Dyes	0.0
2819	Industrial Inorganic Chemicals	20.0
2821	Plastics	35.0
2822	Synthetic Rubber	15.0
2841	Soap	90.0
2842	Detergents	90.0
2843	Surface Acting Agents	90.0
2851	Paints	2.0
2871	Nitrate Fertilizers	12.9
2871	Phosphate Fertilizers	80.0
2892	Explosives	36.0
2893	Printing Ink	2.0
2895	Carbon Black	2300.0
2899	Chemicals	16.0

Source: Op cit

This category accounts for 12.6% of process weight flow amounting to 3569 tons of material moved per hour. Application of the Illinois control regulations will achieve a reduction in emission from 5200 lb/hr to 702 lb/hr, or 86%. Emission per ton of process weight will then be .2 lb/t/hr.

Correlation results for this category indicate that controlled emissions are correlated with process weight (r = .78) and energy (r = .54), and somewhat with space (r = .35) and employment (r = .33). However, process weight is poorly correlated with land (r = 0) and employment (r = .01).

Energy, on the other hand, is correlated with both space (r = .52) and employment (r = .63), although employment and space are also correlated (r = .72).

The general emission model R^2 is .73, with process weight contributing .60 and space .12. Since space and process weight are unrelated, a poor R^2 of .13 is obtained in the restricted emission mode. No explanation of process weight is achieved in the restricted process weight model, but energy is somewhat predictable from employment in the restricted energy model. These results indicate that some other means of predicting process weight is required, but employment may be useful in predicting fuel combustion emissions if fuel use can be estimated.

3.2.5 SIC 20 Food and Kindred Products

Industries in this category manufacture foods and beverages for human consumption, other food related products such as vegetable and animal fats and oils, and prepared feeds for animals and fowls. This category accounts for 7% of controlled particulate emissions; 53% of these emissions are due to the manufacturing processes, while 47% are due to fuel combustion. This category utilizes 7% of the energy consumed or 1945 MBtu/hr; 1084 MBtu/hr are due to coal use, 66 MBtu/hr due to oil consumption, and 776 MBtu/hr due to the combustion of natural gas. Thus, both process and fuel combustion emissions pose air pollution problems for this category.

Estimated uncontrolled process emission factors for the various subcategories are shown below:

SIC	Description	Suspended Particulate Emission Factors (lb/ton of finished product)
20	Food and Kindred	
2011	Meat Packing Plants	0.3
2013	Sausages	0.3
2015	Poultry	0.3
2036	Fresh Fish	0.1
2041	Flour	23.0
2042	Animal Feed	60.0
2046	Wet Corn Milling	8.0
2061	Cane Sugar	225.0
2085	Distilled Liquors	8.0
2095	Animal Fats	9.0

Source: Op cit

This category accounts for 11.6% of process weight flow, amounting to 524 tons of material moved per hour. Application of the Illinois control regulations will achieve a reduction in emissions from 841 lb/hr to 315 lb/hr or 63%. Emissions per ton of process weight will then be .6 lb/t/hr.

Correlation results for this category indicate that controlled emissions are correlated highly with energy (r = .92) and employment (r = .83); however, energy and employment are related (r = .58), as are space and employment (r = .85). Process weight is somewhat related to employment (r = .44) and space (r = .38).

The general emission model R^2 is .95 with energy contributing .90 and process weight only .05. The restricted emission model R^2 is .80, with space contributing .77, while employment contributes only .03. The restricted process weight model R^2 is only .19, with employment contributing the entire share of explanation. The restricted energy model R^2 is .81, with space contributing .78, while employment contributes only .03. These results indicate that space is the most useful planning parameter in estimating energy and hence emissions for this category.

3.2.6 Summary of Analysis of Manufacturing Emissions

The previous sections have analyzed the five largest polluting sectors in the Chicago study region to determine those parameters best explaining controlled particulate emissions. Contributions to controlled emissions were assumed functions of process weight and energy. This assumption is especially true if the Illinois process regulations constrain both process emissions and emissions due to fuel combustion as described in Appendix B. In the former case, a non-linear (exponential) relationship holds, while the latter relationship is indeed linear. Thus, not only were the parameters of land use and employment tested in a multiple linear model, predicting emissions along with process weight and energy, but these parameters were also tested for power in predicting the process weight and energy variables themselves.

For the five major polluting sectors analyzed in detail, the results are sporadically encouraging. SICs 32, 33, and 28 are dominated by process emissions and SICs 29 and 20 are dominated by fuel combustion emissions. Space is a useful predictor of process weight for SIC 32, and a useful predictor of energy for SICs 29 and 20. Employment is a useful predictor of energy for SICs 32 and 28. Unfortunately, neither land nor employment is a consistently good predictor of process weight flow and further investigations are required beyond the scope of this study.

Similar results for the remaining seven sectors are left to the reader to pursue in Table 3.2 and Appendix D.

3.3 ESTIMATION OF EMISSIONS FROM RESIDENTIAL/COMMERCIAL LAND

Emissions from residential and commercial (R/C) land are due primarily to fuel combustion for space heating. Therefore, the variance in emissions can be expected to relate directly to the size and construction of the building, as well as to the efficiency of the heating unit and the type of fuel burned. In this study, the size of the building as measured in total square footage is used to classify commercial buildings, and the number of dwelling units (DU) is used for residential buildings. The distribution of commercial buildings in Chicago by floor space is shown in Figure 3.5. Note that the skewness in this distribution is similar to that which occurred in the scale of manufacturing sources.

Buildings were classified in two ways for analysis purposes:

1) Light R/C (LRC)

   <20 DUs for Residential
   <20000 square feet for Commercial
   (Data aggregated on a square mile basis.)

2) Heavy R/C (HRC)

   >20 DUs for Residential
   >20000 square feet for Commercial
   (Data retained as point sources.)

Heavy R/C is further divided into intervals of 100 dwelling units or 100,000 sq ft.

It is desirable for planning purposes to know if mean energy use per DU or 10^3 ft^2 is a predictor of energy (and hence emissions, given fuel use) in each of the classes indicated. To test this hypothesis for HRC, a sample was drawn from the data for each of the heavy residential (HR) classes, as shown in Table 3.3. The sample was selected so as to achieve a uniform sample size in each of the heavy residential building size classes.

Analysis of variance was used to test the significance of variation in

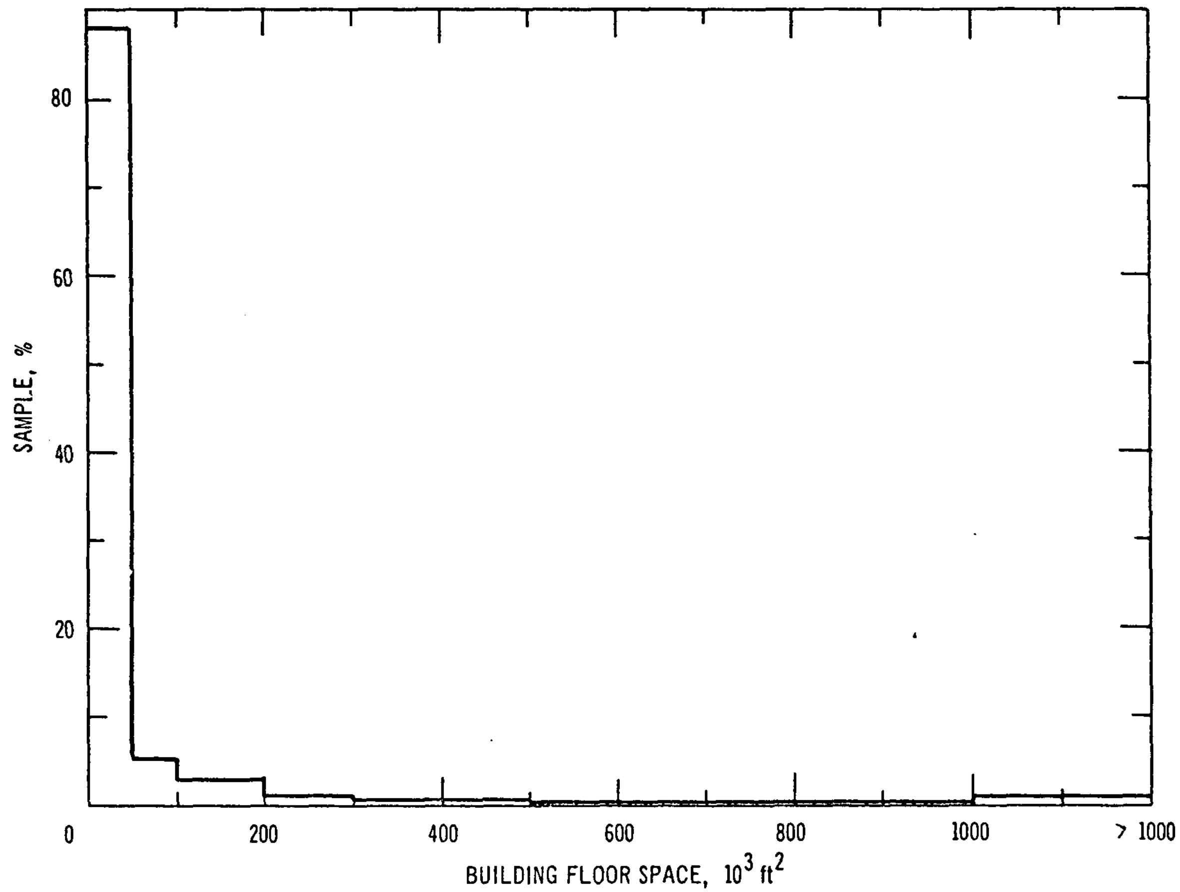


Figure 3.5. Commercial/institutional building size distribution in Chicago.

Table 3.3 SAMPLE DATA FOR HEAVY RESIDENTIAL ENERGY USE

(Single Source Data ≥ 20 DU/Building)

	20 - 100 DU's			100 - 200 DU's			400 DU's		
	Btu x 10^6/ Day	DU	Btu x 10^6/ Day/DU	Btu x 10^6/ Day	DU	Btu x 10^6/ Day/DU	Btu x 10^6/ Day	DU	Btu x 10^6/ Day/DU
1.	8	21	.38	53	148	.36	471	1256	.38
2.	13	27	.48	30	144	121	370	628	.59
3.	18	48	.38	58	187	.31	247	550	.45
4.	18	40	.45	21	114	.15	226	640	.35
5.	47	91	.52	27	103	.26	130	585	.22
6.	19	71	.27	53	190	.28	89	413	.21
		Mean	.41		Mean	.26		Mean	.37
	200 - 300 DU's			300 - 400 DU's			Grand Mean		.37
1.	106	232	.46	162	338	.48	DFB		4
2.	181	203	.89	94	364	.26	BSS		.11
3.	50	250	.20	170	320	.53	DFW		25
4.	61	250	.24	50	312	.16	WSS		1.08
5.	72	223	.32	158	324	.49	F		.64 - (NS)
6.	86	273	.33	170	300	.57			
		Mean	.41		Mean	.37			

the mean dwelling unit energy consumption of the building size classes of HR. The results are displayed in Table 3.3 and indicate that means of dwelling unit energy consumption are not materially different at the .05 significance level. Therefore, for this sample, we can conclude that energy estimation can be done on a dwelling unit density basis using .37 x 10^6 Btu/day/DU as an estimator. A similar result is obtained for heavy commercial classes (HC) using 10^3 ft^2, as shown in Table 3.4 indicating a mean of .29 MBtu/day/10^3 ft^2 for all buildings greater than 20,000 ft^2.

The difference of means between heavy (HR) and light (LR) residential for the small sample was tested using analyses of variance. The results are as follows:

LR Mean No. Sample Pts.	.53 MBtu/day/10^3 ft^2 25.
HR Mean No. Sample Pts	.37 BMtu/day/10^3 ft^2 30.
DFB	1
BSS	.35
DFW	53
WSS	1.44
F	12.96(s)

This result indicates that, for this sample, the hypothesis that the same mean estimator can be used for both light and heavy residential must be rejected. Therefore, we would use .53 x 10^6 Btu/day/DU as an estimator of light residential buildings and conclude that large residential buildings utilize less heat per dwelling unit than small residential buildings. This could be partially explained if small residential buildings generally were higher in square footage of floor space per DU than large residential buildings, but these data were not available to test this hypothesis.

Table 3.4 SAMPLE DATA FOR HEAVY COMMERCIAL ENERGY USE
(Single Source Data 20 x 10^3 Sq. Ft./Building)

	20-100 x 10^3 sq ft			100-200 x 10^3 sq ft			200-300 x 10^3 sq ft		
	Btu x 10^6/ Day	10^3 Sq.Ft.	Btu x 10^6/Day/ 10^3Sq.Ft.	Btu x 10/^{6} Day	10^3 Sq.Ft.	Btu x 10/^{6}/Day/ 10^3Sq.Ft.	Btu x 10^6/ Day	10^3 Sq.Ft.	Btu x 10^6/Day/ 10^3Sq.Ft.
1.	32	87	.37	46	150	.31	51	296	.17
2.	30	81	.37	16	110	.14	120	275	.44
3.	14	75	.19	36	120	.30	32	200	.16
4.	24	54	.44	21	112	.19	101	240	.42
5.	11	45	.24	17	130	.13	60	238	.25
6.	17	37	.46	30	150	.20	77	230	.33
	M e a n		.35	Mean		.21	Mean		.30

	300-400 x 10^3 sq ft			>400 x 10^3 sq ft			Grand Mean	.29
1.	51	350	.15	130	420	.31	DFB	4
2.	92	380	.24	261	768	.34	BSS	105
3.	84	351	.24	136	631	.22	DFW	25
4.	117	312	.38	115	637	.18	WSS	.42
5.	165	329	.50	340	510	.67	F	.74 - (NS)
6.	61	350	.17	90	504	.18		
	M e a n		.28	Mean		.31		

A similar result is obtained for commercial buildings, as shown in the following table:

LC Mean No. Sample Pts.	.60 MBtu/day/10^3 ft^2 25.
HC Mean No. Sample Pts.	.29 MBtu/day/10^3 ft^2 30.
DFB	1.
BSS	1.33
DFW	53.
WSS	1.02
F	66.5

For planning purposes, it is desirable to have energy use a linear function of dwelling units and independent of building size. If this assumption is approximately true, then dwelling unit density or floor area ratio (FAR) can be used. The previous section shows that an average estimator of energy use per unit is sufficient for the large heavy residential and commercial building classes.

Another way to view this result is that energy for HR use is linear with dwelling units per building. Figure 3.6 shows the fit of a simple regression model to the sample data. The result indicates that the regression line

$$Y = .40X - 6.7 ,$$

where

Y is Btu x 10^6/day

and X is Dwelling Units

is a good estimator of energy use for the small example of heavy residential buildings defined in the previous section.

A simple regression for the entire sample of heavy residential buildings for the City of Chicago that included 1103 sample points is also shown in Figure 3.6. The regression line is given by

$$Y = .59 x - 11.7 ,$$

where the units are the same as above. The regression slope for the large sample has shifted upward significantly, indicating a bias in the small sample toward low Btu x 10^6/day/DU readings.

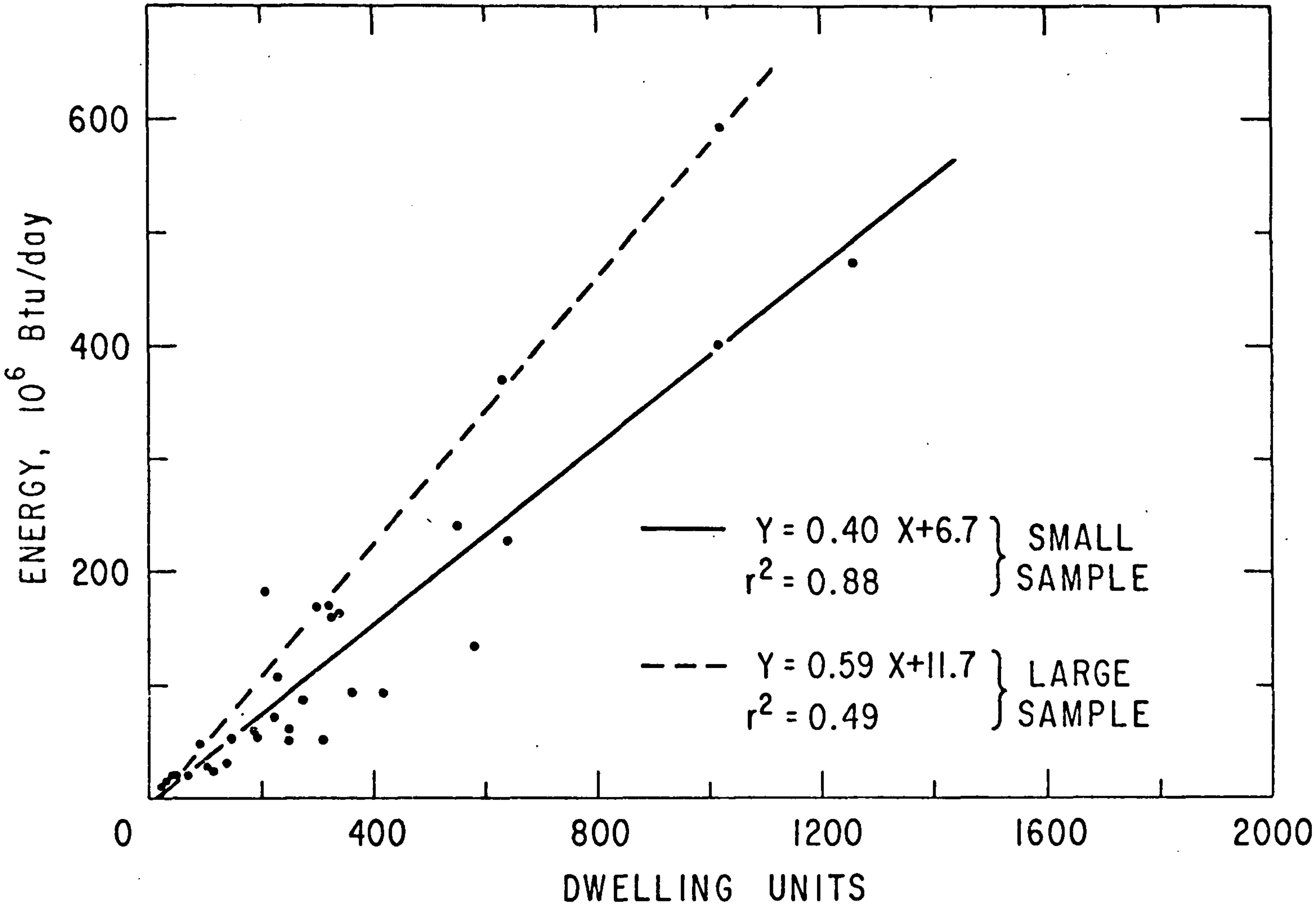


Figure 3.6. Large residential energy use.

The simple regression results for heavy commercial buildings are shown in Fig. 3.7. If building size is known, the simple regression model

$$Y = .30X - 4.2 \quad ,$$

where

$$Y \text{ is } 10^6 \text{ Btu/day}$$

and X is 10^3 sq ft ,

can be used as an estimator. The linear fit is displayed in Fig. 3.6.

A sample regression for the entire sample of heavy commercial buildings for the City of Chicago that included 1373 sample points is also shown in Fig. 3.7. The regression line is given by

$$Y = .19\,x + 24.5$$

when the units are the same as above.

The regression slope for the large sample has shifted downward somewhat , indicating a possible bias in the small sample toward high 10^6 Btu/day/10^3 sq ft readings.

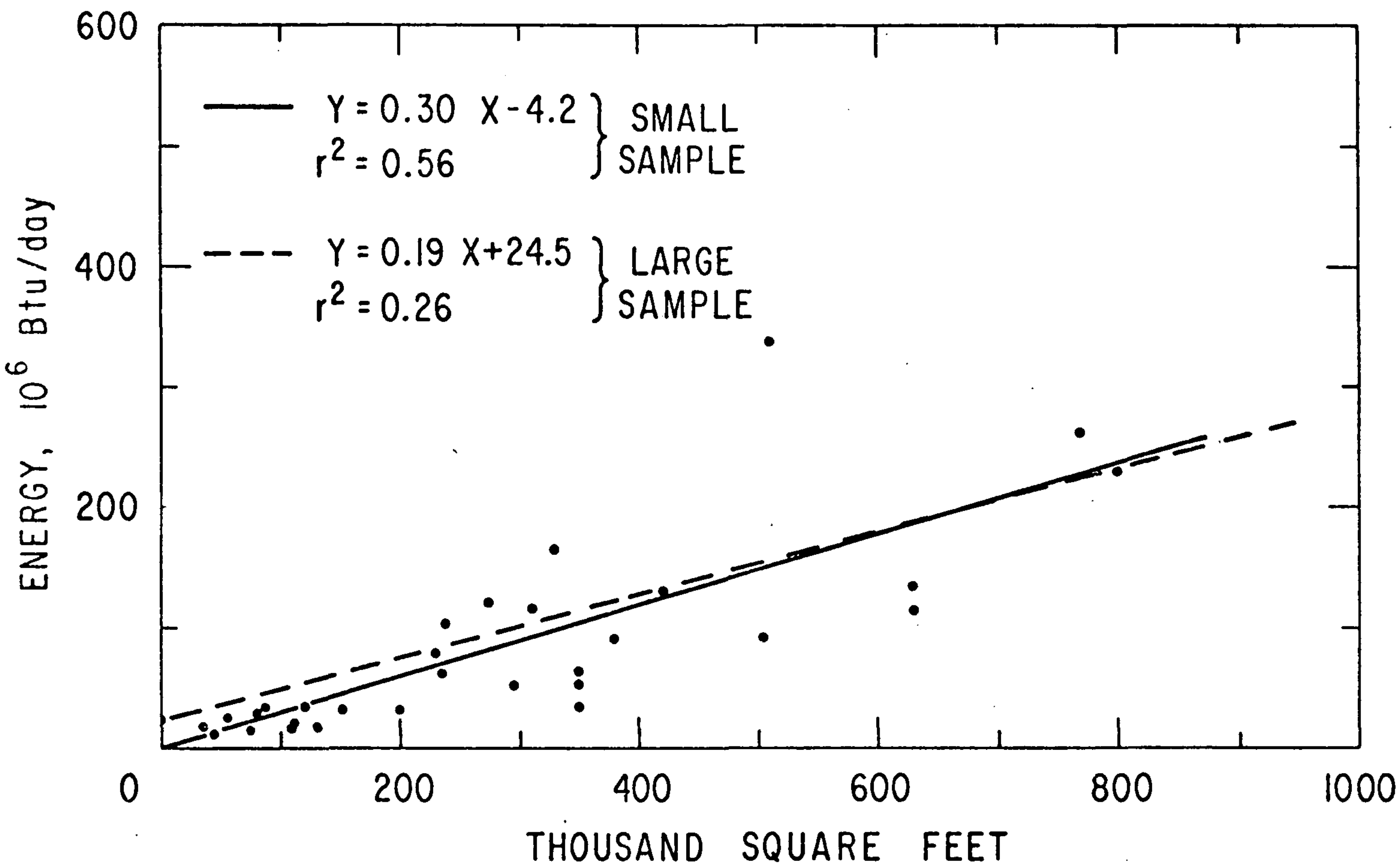


Figure 3.7. Large commercial energy use.

4.0 SUMMARY AND CONCLUSIONS

Comprehensive planning as a control mechanism to maintain regional air quality depends on: (1) the applicability of the plan over time; (2) the ability of public administrators to implement the plan; and (3) the ability of planners to forecast the air quality effects of land use decisions and policies and to rank land use or effects-assessment plans. The latter element has been addressed in this study.

The basic criterion for evaluating the land-use-based emission estimation methods was the ability of the estimates to reproduce regional air quality as represented by the AQDM dispersion model, using the best available point-source inventory information. When data deficiencies prohibited the application of this criterion, standard statistical measures were applied. Statistical techniques used were analysis of variance, multiple regression, and product-moment correlation analysis. Emission inventory and land use data were drawn from the Chicago metropolitan study area as described in Appendix A.

The following conclusions are drawn from this study:

(1) The major problem with the air quality prediction on the basis of manufacturing land use data is in the wide variance and skewness in emission density distributions; severe distortions in air quality representations occur when mean and median estimates based on land use are employed in the AQDM model.

(2) The use of mean and median estimates in representing air quality through dispersion modeling showed that results are highly sensitive to these estimates, particularly in the critical "hot spot" areas. A derivation of best-fit (minimum variance in relative error) emission density estimates by light and heavy industrial land use classes showed that the least standard deviation in relative error was 20%, with most of the contribution to the error occurring in hot spot regions. From this result, it was concluded that uniform emission density estimates by zoned land use class were insufficient by themselves to adequately represent air quality degradation due to manufacturing emission; measures of use intensity are also required.

(3) Further attempts to account for the variance in manufacturing emission patterns were made by disaggregating manufacturing land into major industrial sectors by 2-digit SIC categories. Since land use or spatially distributed employment data on this level were not available, the air quality representation of resulting estimates could not be computed. Rather, statistical measures were used to judge the utility of various parameters in estimating emissions. The results showed that land use and employment were sporadically successful in explaining emissions, process weight flow, and energy consumption. However, although process weight frequently explained controlled emissions by 2-digit SIC class (logically, since the Illinois process control regulation is of the Bay Area Curve Class), land use and

employment were poor predictors of process weight. Therefore, it can be concluded that other parameters for estimating process weight flow need to be incorporated into the analyses, perhaps measures of capital intensity; such measures were not available in the data inventory used for this study.

(4) Studies of residential and commercial energy use by building size class in the Chicago area indicated that dwelling unit density and floor area ratio are potentially useful parameters in estimating unit energy consumption. It was noted that a significant difference in unit energy consumption exists between large (high rise) buildings of greater than 20 DUs or 200,000 sq ft and small (low rise) buildings of less than that amount, the former being more efficient. No significant difference in unit energy consumption was observed between size classes of high rise buildings.

APPENDIX A

DESCRIPTION OF THE STUDY AREA

APPENDIX A

DESCRIPTION OF THE STUDY AREA

The purpose of this appendix material is to characterize the Chicago study area in terms of parameters that influence the air quality of the region, both present and future. This description provides a rationale for testing the utility of these parameters in estimating air pollutant emissions from land use, since they are commonly used for forecasting growth and development in the region. The first section characterizes current manufacturing land use in the region, and the second estimates development potential in the next decade. Finally, the data base used in the study is briefly described.

A.1 CURRENT MANUFACTURING ACTIVITY IN THE CHICAGO REGION

Chicago has traditionally been a large diverse and basically stable major industrial center as reflected by gross manufactures sales shown in Table A.1. In 1970, Chicago's share of the Gross National Product amounted to 5.28% or $51.4 billion. Current employment patterns in the major industrial sectors of the region and in the study subregion are shown in Table A.2. The study subregion comprises approximately 90% of the manufacturing employment of the region and 64% of the manufacturing employment of the State of Illinois. The Chicago area is one of the largest electrical equipment manufacturing areas in the nation and the largest manufacturer of household electrical equipment and appliances. This industry is the largest employer in the area with 145,000, but third in total sales volume behind the Primary Metals and Food and Kindred Industries.

TABLE A.1—MANUFACTURING OUTPUT - 1970 & 1971 - METROPOLITAN CHICAGO
(In Millions)

	Gross Manufacturers Sales		Value Added by Manufacture	
	1971	1970	1971	1970
TOTAL	$37,989	$37,299	$18,308	$18,024
Primary Metal Industries	6,514	6,539	2,585	2,595
Food & Kindred Products	5,378	5,159	2,162	2,074
Electrical Equipment & Supplies	4,174	4,194	2,075	2,086
Fabricated Metal Products	3,835	3,844	2,014	2,019
Machinery, Except Electrical	3,641	3,724	1,999	2,045
Chemicals & Allied Products	3,042	2,884	1,651	1,565
Printing and Publishing	2,428	2,448	1,572	1,585
Petroleum and Coal Products	1,598	1,478	420	388
Transportation Equipment	1,383	1,303	639	602
Paper and Allied Products	1,148	1,110	553	535
Instruments & Related Products	891	894	543	556
Rubber & Plastic Products	871	799	494	453
Stone, Clay & Glass Products	805	723	422	379
Apparel & Related Products	532	518	249	246
Furniture & Fixtures	521	521	275	275
Lumber & Wood Products	193	165	95	81
Leather & Leather Products	145	145	84	84
Textile Mill Products	103	101	42	42
Miscellaneous	787	750	434	414

Source: Chicago Association of Commerce and Industry (CACI), The Year-end Statistical Roundup for 1971.

Table A.2. SUMMARY OF MANUFACTURING PLANTS AND EMPLOYMENT BY MAJOR INDUSTRIAL SECTOR - 1970

2-Digit SIC	STATE		REGION		SUB-REGION					
					Cook County		DuPage County		Will County	
	Emp.	Units	Emp.	Units	Emp.	Units	Emp.	Units	Emp.	Units
19	12561	16	(D)	10	1034	9	-	-	(D)	1
20	118787	1441	80352	829	71344	734	2218	19	893	19
21	(D)*	3	(D)	3	(D)	3	-	-	-	-
22	4937	80	3493	67	3270	57	-	-	-	-
23	34813	670	22266	538	20367	499	-	-	453	6
24	12000	517	7614	277	6527	222	179	14	126	7
25	23281	490	(D)	395	13315	346	716	13	136	6
26	42305	484	33746	398	28117	336	1276	13	1319	13
27	110083	2623	91013	1947	83210	1711	2411	89	1141	26
28	57775	830	44043	660	32663	567	614	23	1654	17
29	10135	99	4996	71	2594	58	-	-	2027	7
30	38427	533	(D)	451	20715	347	2293	43	(D)	4
31	12387	132	5690	98	5431	94	-	-	-	-
32	36143	761	19311	383	13315	270	414	21	1165	20
33	108487	606	67063	425	58289	349	1276	20	2163	9
34	142188	2289	105926	1874	93960	1603	2998	102	1831	22
35	214792	2985	(D)	2239	91956	1816	3014	156	(D)	47
36	190831	927	144991	786	123635	644	5592	52	757	7
37	46476	256	30323	177	26247	140	218	8	221	8
38	41556	358	(D)	303	29421	271	1170	12	-	-
39	35332	756	29580	614	26936	549	259	23	(D)	6
Adm.	83857	690	72157	550	65311	483	2757	24	365	7
Total Mfg	1377471	17548	96730	13097	817985	11110	27570	645	28934	233
%/State	100	100	70.4	74.9	59.4	63.4	2.0	4.2	2.1	1.3
%/Region	-	-	100	100	84.3	84.7	2.8	4.9	3.0	1.8

*D - Denotes figures withheld to avoid disclosure of operations of individual reporting units.
Source: County Business Patterns, Illinois, 1970.

Current manufacturing land use for the study area is shown in Figure A.1. The subregion contains a total of 100 square miles of manufacturing land or approximately 5% of the 2130 square miles of surface area. Approximately 41 square miles is devoted to heavy industrial use, while the remainder is devoted to light and general manufacturing uses.

A.2. MANUFACTURING GROWTH POTENTIAL IN THE CHICAGO STUDY REGION

Total manufacturing activity in the Chicago region is expected to increase at a stable rate over the 10-year period from 1970 to 1980. The Department of Health, Education and Welfare sponsored research on economic projections for air quality control regions throughout the country. This research was conducted by the U.S. Department of Commerce, Office of Business Economics, Regional Economics Division, and resulted in the publication, "Economic Projections for Air Quality Control Regions." Table A.3 shows the resulting productive growth factors for the Chicago region through 1980. A base year of 1967 is used with projections made for 1970, 1975, and 1980. "Growth factors" for each economic activity are given. For example, the growth factor in Chicago for Food and Kindred Products in 1975 is 114.8 which means that 1975 production will be 1.148 as great as the 1967 production levels in the region.

The Chicago region will continue to dominate manufacturing employment in the State, increasing approximately 11% and accounting for 80% of the statewide increase in manufacturing employment according to the state Office of Planning and Analysis projections.[5] Figure A.2 shows recent manufacturing employment changes in the Chicago region and forecasted employment for 1985 by the Northeastern Illinois Planning Commission.[6]

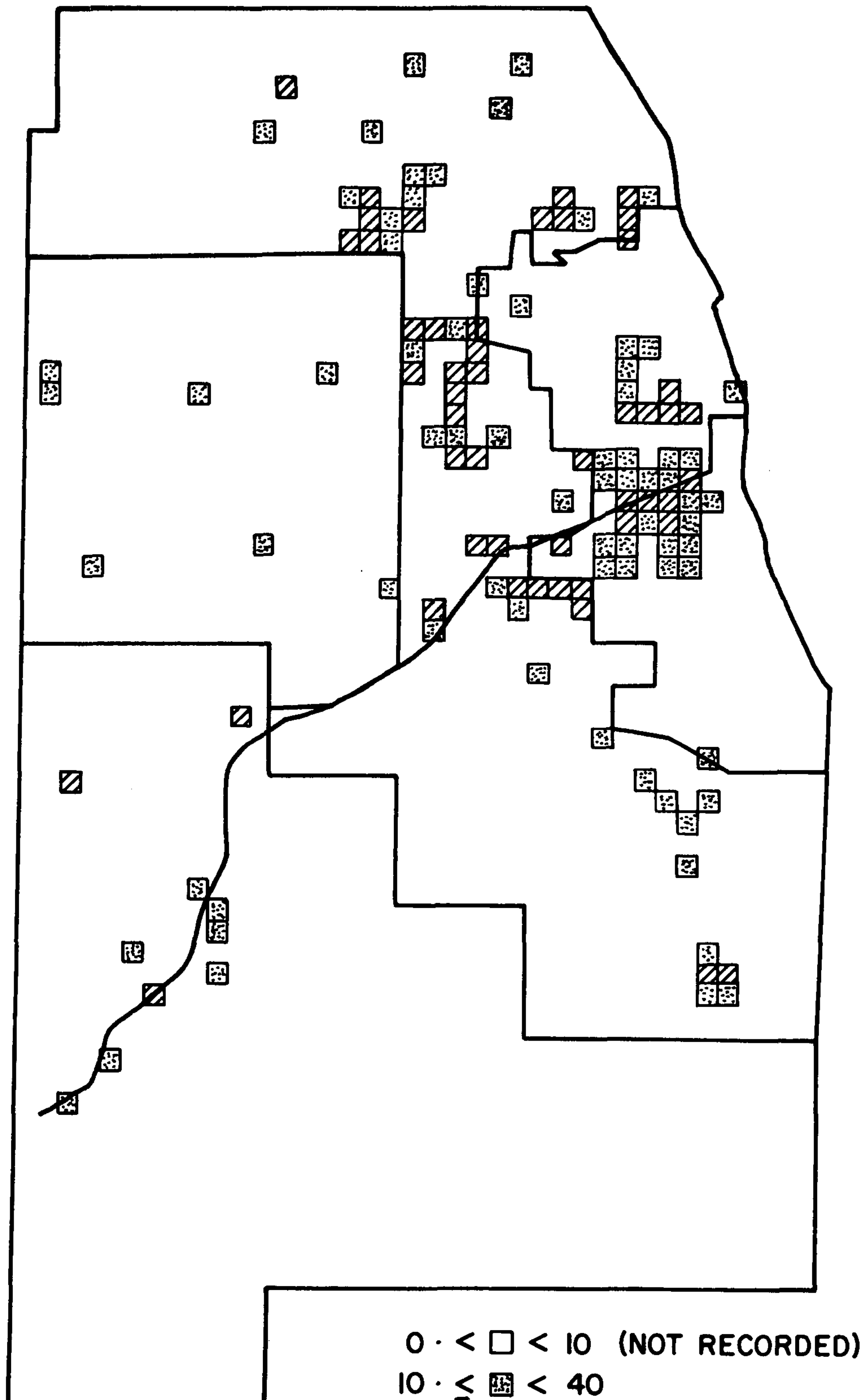


Figure A.1. Total industrial land use in Chicago study region.

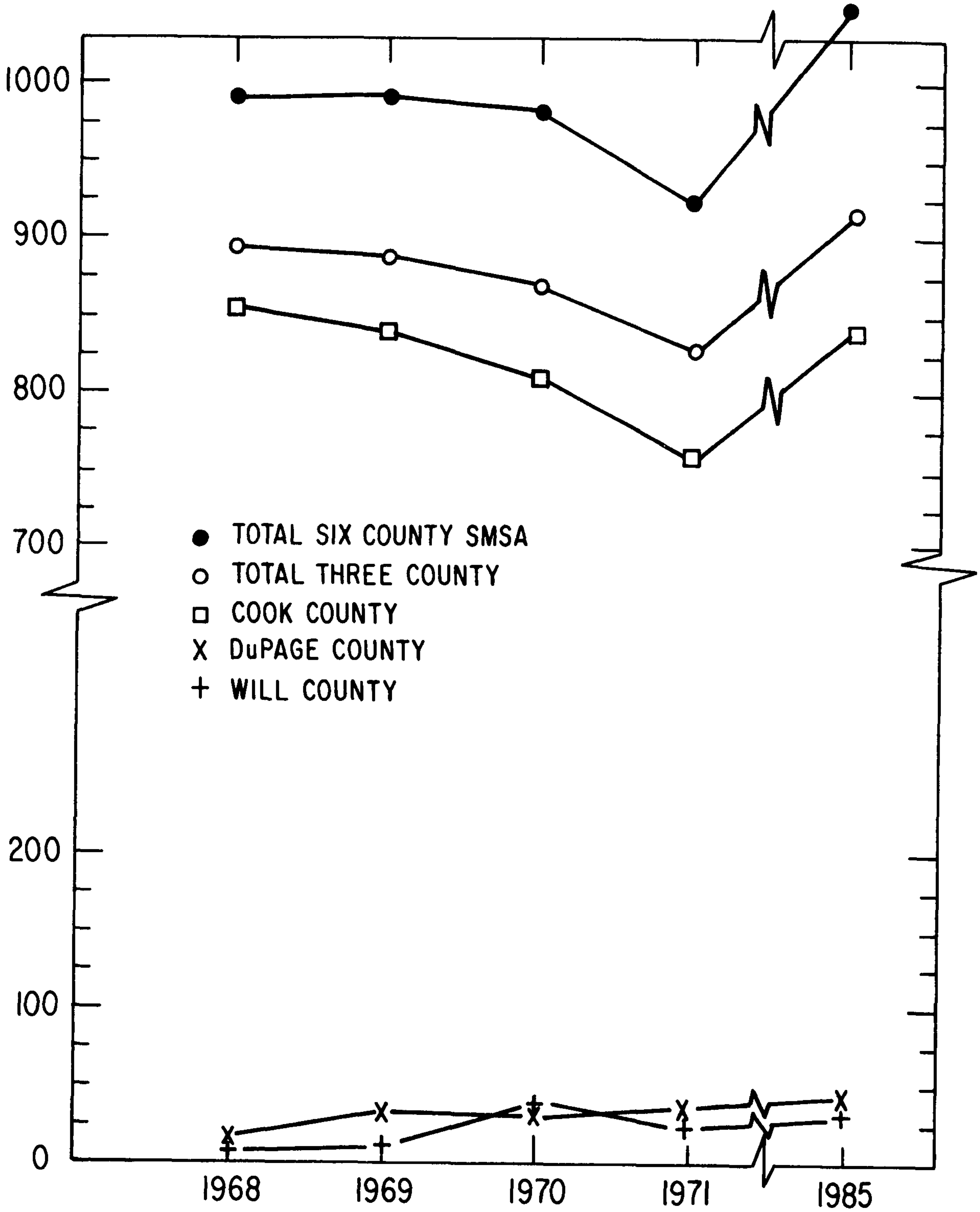
Table A.3

Growth Factors - Chicago Air Quality Control Region*

(1967 = 100.0)

Item	1970	1975	1980
Manufacturing	108.5	128.5	152.4
Food + Kindred Products	102.5	114.8	128.6
Textile Mill Products	104.1	115.1	127.2
Apparel + Other Textiles	104.2	116.7	130.6
Printing + Publishing	105.2	122.8	143.4
Chemicals + Allied Products	114.7	140.5	172.1
Lumber + Furniture	115.2	134.0	155.8
Machinery, All	108.0	131.1	159.3
Machinery, Excl. Electrical	106.0	123.4	143.6
Electrical Equipment + Supplies	109.8	138.3	174.1
Transportation Equipment	122.4	145.8	173.9
Motor Vehicles + Equipment	147.4	180.2	220.2
Transportation Equipment, Excl.	107.3	125.3	146.2
Other Manufacturing	108.7	128.1	151.2
Paper + Allied Products	109.5	135.2	166.9
Petroleum Refining	131.2	145.6	161.7
Primary Metals	108.9	123.6	140.2
Fabricated Metals + Ordinance	102.0	121.3	144.6
Miscellaneous Manufacturing	112.3	137.2	167.6
Stone, Clay and Glass	108.5	125.7	145.7
Other Misc. Manufacturing	113.3	140.0	173.0

*Source: Economic Projections for Air Quality Control Regions. A report to the National Air Pollution Control Administration, HEW, prepared by the U.S. Dept. of Commerce, Office of Business Economics, June 1970.



Sources: County Business Patterns. U.S. Bureau of Census: 1968-1971. Northeastern Illinois Planning Commission Planning Paper No. 10. Revised, 1972.

Figure A.2. Manufacturing employment trends Chicago SMSA.

Although it is difficult to project the fraction of growth that will result in new development or precisely where this new development will locate, some indications can be derived from land availability in the region. Presumably, this reflects regional planning for public and private transportation facilities, wastewater treatment systems, utilities, etc., as well as other locational advantages for manufacturers inclined to locate in the Chicago region.

Land zoned for manufacturing use in the study region totals approximately 267 square miles. In a ring surrounding the current high peaks of air pollution in the area, 19 square miles of land are currently used for manufacturing, while 84 square miles are zoned for manufacturing use (Figure A.3), a potential increase of 342%.

While the area of land zoned reflects potential manufacturing development as currently planned, no indication is given of the rate at which development is actually taking place. The Chicago Association of Commerce and Industry conducts an annual survey of industrial parks and districts in the metropolitan Chicago area. The summary table of this survey for 1971-72 is shown in Table A.4. This table indicates Will County as the most rapidly developing county in the study region having developed approximately 1 square mile of industrial land in the year under consideration and opening up approximately 1-1/2 square miles in new industrial districts. Suburban Cook County leads in total acreage of industrial development, but a significant withdrawal of lands from industrial use has occurred principally in the southern portion of the County. DuPage County leads in lands available to manufacturing, but is not realizing the rapid industrial growth that is occurring in Will County.

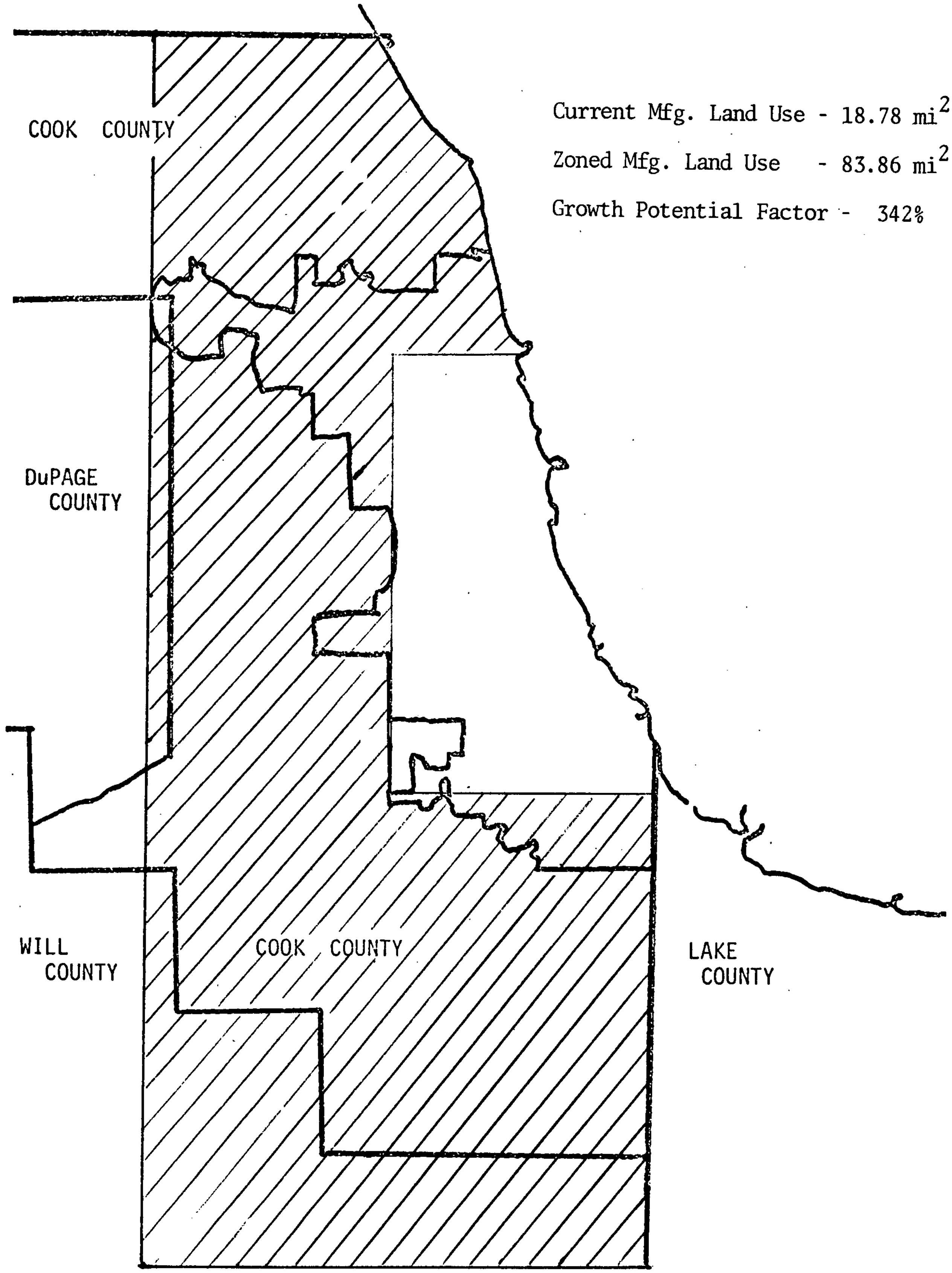


Figure A.3. Potential for Manufacturing Land development in area surrounding region at critical concern.

TABLE A.4. INDUSTRIAL PARKS SURVEY • 1971-1972*

	Number of industrial parks		Total no. of acres of land in parks		No. of acres sold and leased through		Number of acres available for industry	
	1972	1971	1972	1971	1972	1971	1972	1971
City of Chicago	37	36	2,826	3,064	2,416	2,355	410	709
Suburban Cook Co., Ill.	149	156	14,732	17,190	8,295	8,302	6,437	8,888
North Cook	79	83	8,640	8,720	5,274	4,891	3,366	3,829
West Cook	31	29	1,735	1,654	1,483	1,402	252	252
South Cook	39	41	4,377	6,416	1,542	2,009	2,835	4,407
DuPage Co., Ill.	48	49	10,325	10,560	2,983	3,035	7,342	7,525
Kane Co., Ill.	26	27	4,123	3,955	948	1,041	3,175	2,914
Lake Co., Ill.	19	21	2,642	2,846	414	701	2,228	2,145
McHenry Co., Ill.	1	1	250	260	0	0	250	260
Will Co., Ill.	23	18	7,502	6,766	1,687	1,088	5,815	5,678
Lake Co., Ind.	13	12	1,111	1,092	225	257	886	835
Porter Co., Ind.	2	2	770	770	144	144	626	626
Chicago metropolitan area	318	319	44,301	46,103	17,116	16,923	27,185	29,183

*June to June

Source: Chicago Association of Commerce and Industry

A.3 DATA BASE FOR THE STUDY REGION

The data base for this study consists of source inventories, land use information by square mile and a permitted-use zoning policy. The data is used for testing the estimation procedures as described in the body of this report. A description and summaries of the data are included here to further characterize the source patterns of the study region.

The regional source inventory file consists of source identification, fuel combustion, process emission, and stack data. A description of the data as recorded in the inventory can be seen in Table A.5. The data were collected as part of the Illinois State Implementation Planning Program during the summer of 1971 by a team of students, who, under the supervision of the Argonne Center for Environmental Studies, surveyed the entire state for manufacturing source information. The Census Bureau publications, "County Business Patterns in Illinois" and the "Directory of Manufacturers," were used to guide the information collection operations. The Illinois State emission inventory contains planning parameters such as land use, employment, energy consumption by type of fuel, and process output data, in addition to emission information.

Emission factor information was used to derive total emissions from data surveyed. No direct emission testing was performed in collecting these data. Information was obtained by secondary source review, telephone contact, or site visit. It should be noted that the City of Chicago supplied combustion information to the State directly, in their own format. Therefore, fuel combustion from manufacturing sources within the City proper was not collected in the survey. The emission factors utilized in the conversion equations were obtained from a report by the U.S. Environmental Protection Agency.[4]

TABLE A.5. STATE OF ILLINOIS EMISSION INVENTORY FILE PARAMETERS

Source Identification	Fuel Combustion	Process Emission Source	Stack Data
Source identification number	Boiler capacity (10^6 BTU/hr)	Emission factor table code	Height (ft)
Source name	Coal (tons/year)		Inside diameter (ft)
		Process quantity	
Source street address	Oil (10^3 gal/year)		Temperature (°F)
		Process weight rate (lb/hr)	
City	Oil grade		Velocity (ft/sec)
Zip code	Gas (10^6 ft^3/year)	Process name	Gas volume (acf/sec)
Geocode	Heat content:	Emission factor	Number of units
X-Coordinate (Km)	Coal (10^3 BTU/lb) Oil (10^3 BTU/gal)	Emissions (lb/hr)	
Y-Coordinate (Km)	Gas (BTU/ft^3)		
Standard land use classification number	Percent ash coal		
	Particulate emission factor		
Lot size (acres)			
Employees	Emissions (lb/hr)		
Zoning			

Tables A.6 and A.7 summarize the source file data by 2-digit SIC code for those classifications for which data existed in the source file. The SIC classes were ranked according to their percentage contribution to total emissions as shown in Table A.8. The top 12 ranking classes were then selected for analysis, accounting for 99% of emissions and 90% of the sources in the file.

In addition to point-source information, the estimation methodology requires land use information by zoning classification. For purposes of this study, manufacturing land use was divided into two categories—heavy industrial (HI) and light industrial (LI). Current land use information for the Chicago region was obtained from the regional planning body, the Northeastern Illinois Planning Commission (NIPC). The land use inventory was collected on a square-mile basis for the Chicago region and computerized as fractions of land area for each land use class.

Finally, the methodology requires that a permitted-use zoning policy be established. This was accomplished by a survey of county zoning administrators. The results indicate that heavy and light industrial activities are most commonly defined as shown in Table A.9.

TABLE A.6. MANUFACTURING DATA SUMMARIES

by 2-digit SIC code

SIC Code	Land (acres)	Employ-ment	Process Weight (t/hr)	Energy (MBtu/hr)	Coal (MBtu/hr)	Oil (MBtu/hr)	Gas (MBtu/hr)	UC Emissions (lb/hr)	CT Emissions (lb/hr)	% UC PR	% UC FC	% CT PR	% CT FC	# Sources
20.0	785.50	9576.00	523.88	1945.2	1084.41	66.26	775.72	840.61	314.94	29	70	53	46	21
22.0	17.00	415.00	2.41	14.0	0.00	0.00	14.02	76.83	4.21	100	0	94	6	4
23.0	42.00	483.00	0.00	4.4	0.00	4.47	0.00	0.68	0.45	0	100	0	100	1
24.0	323.20	2407.00	138.26	24.4	0.00	14.11	10.16	287.09	17.03	99	1	88	11	16
25.0	172.00	4156.00	0.50	65.8	0.01	7.08	59.76	217.40	5.31	99	1	67	33	16
26.0	593.30	6431.00	561.50	385.2	150.68	53.84	180.08	1293.88	127.02	49	50	80	19	25
27.0	32.70	6204.00	2.77	53.31	0.00	0.00	53.31	1981.72	9.84	100	0	90	10	12
28.0	12029.79	20370.00	3563.23	1908.1	757.84	145.88	992.77	5201.27	701.56	59	40	82	17	79
29.0	[illegible]	5283.00	4754.66	6035.8	0.00	884.14	5114.66	5110.02	767.37	94	5	69	30	40
30.0	652.46	4253.00	134.74	255.3	0.00	24.62	233.58	485.36	59.27	98	1	89	10	15
31.0	32.00	[illegible]	0.00	39.5	0.00	11.86	27.28	2.32	2.32	0	100	0	100	1
32.0	4725.80	6998.00	17337.85	920.0	36.86	46.14	833.65	88563.56	1330.62	98	2	87	3	50
33.0	1621.44	2450[illegible].00	1[illegible]39.74	2574.5	0.00	197.60	2365.65	9006.73	732.86	98	1	90	9	83
34.0	1373.92	1[illegible]65[illegible].00	68.04	1328.7	4.53	107.83	1211.33	2938.79	140.40	98	2	63	36	56
35.0	1749.37	34042.00	121.70	776.30	227.38	151.64	320.31	1798.53	160.68	54	45	65	35	56
36.0	663.40	53774.00	14.63	232.0	5.27	40.47	184.80	424.71	41.37	93	6	71	28	31
37.0	[illegible]	6976.00	20.51	222.6	124.60	9.75	87.90	699.77	50.42	36	64	70	30	12
38.0	180.00	327[illegible].00	4.10	56.5	0.00	44.62	11.82	28.21	5.43	72	27	12	88	6
39.0	105.47	5203.00	53.84	34.7	5.02	4.48	25.17	312.26	49.72	98	2	96	3	20
TOTALS	31348.82	194307.00	23284.42	16807.0	2396.61	1814.79	12497.94	119269.50	4520.80	94	5	82	17	544

TABLE A.7. MANUFACTURING DATA PERCENTAGES

by 2-digit SIC code

SIC Code	Land	Employ-ment	Process Weight	Energy	Coal	Oil	Gas	UC Emissions	CT Emissions	# Sources
20	2.25	4.93	1.85	11.57	45.25	3.65	6.21	0.70	6.97	4
22	0.05	0.21	0.01	0.08	0.00	0.00	0.11	0.06	0.09	1
23	0.13	0.25	0.00	0.03	0.00	0.25	0.00	0.00	0.01	0
24	1.22	1.24	0.49	0.15	0.00	0.78	0.08	0.24	0.38	3
25	0.55	2.14	0.00	0.39	0.00	0.39	0.47	0.18	0.12	3
26	1.89	3.31	1.99	2.29	6.29	2.97	1.44	1.08	2.81	5
27	0.10	3.19	0.01	0.32	0.00	0.00	0.43	1.66	0.22	2
28	41.13	10.48	12.62	11.35	31.62	8.04	7.94	4.36	15.52	15
29	12.43	2.72	16.81	35.91	0.00	48.72	40.92	4.28	16.97	7
30	2.11	2.19	0.37	1.52	0.00	1.36	1.84	0.41	1.31	3
31	0.10	0.15	0.00	0.24	0.00	0.65	0.22	0.00	0.05	0
32	15.06	3.60	61.30	5.47	1.54	2.54	6.67	74.25	29.43	9
33	5.17	12.61	3.57	15.32	0.00	10.89	18.93	7.55	16.21	15
34	6.29	10.12	0.24	7.91	0.19	5.94	9.69	2.46	3.11	10
35	5.64	17.52	0.43	4.20	9.49	8.36	2.56	1.51	3.55	10
36	2.11	12.24	0.05	1.38	0.22	2.23	1.48	0.36	0.92	6
37	2.87	8.74	0.07	1.32	5.20	0.54	0.70	0.59	1.12	2
38	0.57	1.69	0.00	0.34	0.00	2.46	0.09	0.02	0.12	1
39	0.34	2.68	0.19	0.21	0.21	0.25	0.20	0.26	1.10	4

Table A.8. SIC CLASSES BY PERCENTAGE CONTRIBUTIONS TO TOTAL EMISSIONS

No.	2-Digit SIC Code	% of Controlled SP* Emis.	Cumulative % of Cont. SP Emis.	No. of Sources	% of Sources	Cumulative % of Sources
1	32	29.4	29.4	50	9	9
2	29	17.0	46.4	40	7	16
3	33	16.2	62.6	83	15	31
4	28	15.5	78.1	79	14	45
5	20	7.0	85.1	21	4	49
6	35	3.6	88.7	56	10	59
7	34	3.1	91.8	56	10	69
8	26	2.8	94.6	25	5	74
9	30	1.3	95.9	15	3	77
10	37	[illegible]	97.0	12	2	79
11	39	1.[illegible]	98.1	20	4	83
12	36	.9	99.0	31	6	89
13	24	.4	99.4	16	3	92
14	27	.2	99.6	12	2	94
15	25	.1	99.7	16	3	97
16	38	.1	99.8	6	1	98
17	22	.1	99.9	4	1	99
18	31	.05	99.95	1	0	99
19	23	.01	99.96	1	0	99
Other	-	.04	100.00	-	0	99

Table A.9. ACTIVITIES BY ZONING CLASS

Heavy Industry		Light Industry	
SIC	Description	SIC	Description
26	Paper and Allied Products	20	Food and Kindred Products
27	Printing, Publishing, and Allied Industries	21	Tobacco Manufactures
28	Chemicals and Allied Products	22	Textile Mill Products
29	Petroleum Refining and Related Industries	23	Apparel & Other Finished Products Made from Fabrics & Similar Materials
30	Rubber and Miscellaneous Plastic Products	24	Lumber & Wood Products, Except Furniture
31	Leather and Leather Products	25	Furniture and Fixtures
32	Stone, Clay & Glass Products	34	Fabricated Metal Products, Except Ordnance, Machinery, & Transportation Equipment
33	Primary Metal Industries	35	Machinery, Except Electrical
		36	Electrical Machinery, Equipment, and Supplies
		37	Transportation Equipment
		38	Professional, Scientific, and Controlling Instruments; Photographic and Optical Goods; Watches and Clocks
		39	Miscellaneous Manufacturing Industries

APPENDIX B

SUMMARY OF STATE OF ILLINOIS

PARTICULATE EMISSION CONTROL REGULATIONS

APPENDIX B

SUMMARY OF STATE OF ILLINOIS PARTICULATE EMISSION CONTROL REGULATIONS

In implementing the federal guidelines for the State of Illinois, the Illinois Pollution Control Board adopted a set of comprehensive air pollution control regulations designed to limit emissions of sulfur dioxide, particulate matter, nitrogen oxides, carbon monoxide, and hydrocarbons from stationary sources throughout Illinois.

An additional provision that would have effectively banned coal for residential or commercial use in the Chicago area by mid-1975 was not included in the package due to a temporary restraining order. This order was entered against the Board by a Cook County circuit court judge, who termed the ban unconstitutional as presently structured.

The new regulations represent a major effort by the state to control the air contaminants, and to form the heart of the Illinois program for meeting federal standards and combatting air pollution. Except for controls on particulate matter, the state previously did not have emission limits on these air pollutants.

Specifically, in regard to particulate air contaminants, the program:

1) Significantly tightens limits on the emission of particulate matter from such operations as steel mills, oil refineries,

electric power plants, cement plants, and corn wet-milling facilities.

2) For the first time, requires sophisticated new equipment to control emissions from coke ovens.

3) Greatly strengthens existing standards for emissions from incinerators.

4) Adopts a statewide nondegradation standard to prevent the unnecessary deterioration of air that is now clean, and to prevent new sources of pollution from being located in inappropriate places.

5) Institutes a statewide requirement of operating permits for all pollution sources as an aid to enforcement.

6) Requires sources to monitor their emissions, to keep detailed records, to adequately maintain their equipment, and to make regular reports to the state.

7) Specified particulate emission standards and limitations for new and existing emission sources, for incinerators, and for fuel combustion emission sources.

The air pollution regulations are designed to enable the state to meet the national ambient air quality standard by 1975.

In the case of Illinois manufacturing sources, emission standards are divided into fuel combustion and process regulations. Fuel emission regulations in the Chicago major metropolitan area require that no person shall cause or allow the emission of particulate matter into the atmosphere from any existing fuel combustion source to exceed 0.1 pound of particulate matter per million Btu of actual heat input in any one-hour period.

For process emission sources, no person shall cause or allow the emission of particulate matter into the atmosphere in any one-hour period from any existing process emission source in excess of the allowable emission rates specified in Table B.1, either alone or in combination with the emission of particulate matter from all other similar new or existing process emission sources at a plant or premises. Interpolated and extrapolated values of the numbers in Table B.1 for process weight rates up to 30 tons per hour shall be determined by using the equation:

$$E = 4.10 \ (P)^{0.67} \tag{B.1}$$

and interpolated and extrapolated values of the data for process weight rates in excess of 30 tons per hour shall be determined by using the equation:

$$E = [55.0 \ (P)^{0.11}] - 40.0 \quad , \tag{B.2}$$

where E = allowable emission rate in pounds per hour

and P = process weight rate in tons per hour.

The process weight regulation in the Illinois Implementation Plan was modeled after the Bar Area Curve developed by the Bay Area Pollution Control District in San Francisco. This process weight regulation was based on well-controlled process industries found there. The Bay Area Curve rises to an allowable emission of 40 pounds per hour with increasing size of operation, and then allowable emissions increase at a reduced rate above 40 pounds per hour with increasing size of operation. The Bay Area Curve, as applied to the State of Illinois regulation, can be seen in Figure B.1. The Bay Area regulation is quite stringent for sources with a combination of large process weight rate and large emission factors,

TABLE B.1

Illinois Standards for Existing Process Emission Sources

Process Weight Rate Pounds Per Hour	Process Weight Rate Tons Per Hour	Allowable Emission Rate Pounds Per Hour
100	0.05	0.55
200	0.10	0.87
400	0.20	1.40
600	0.30	1.83
800	0.40	2.22
1,000	0.50	2.58
1,500	0.75	3.38
2,000	1.00	4.10
4,000	2.00	6.52
6,000	3.00	8.56
8,000	4.00	10.40
10,000	5.00	12.00
20,000	10.00	19.20
30,000	15.00	25.20
40,000	20.00	30.50
50,000	25.00	35.40
60,000	30.00	40.00
70,000	35.00	41.30
80,000	40.00	42.50
90,000	45.00	43.60
100,000	50.00	44.60
200,000	100.00	51.20
300,000	150.00	55.40
400,000	200.00	58.60
500,000	250.00	61.00
600,000	300.00	63.10
700,000	350.00	64.90
800,000	400.00	66.20
900,000	450.00	67.70
1,000,000	500.00	69.00

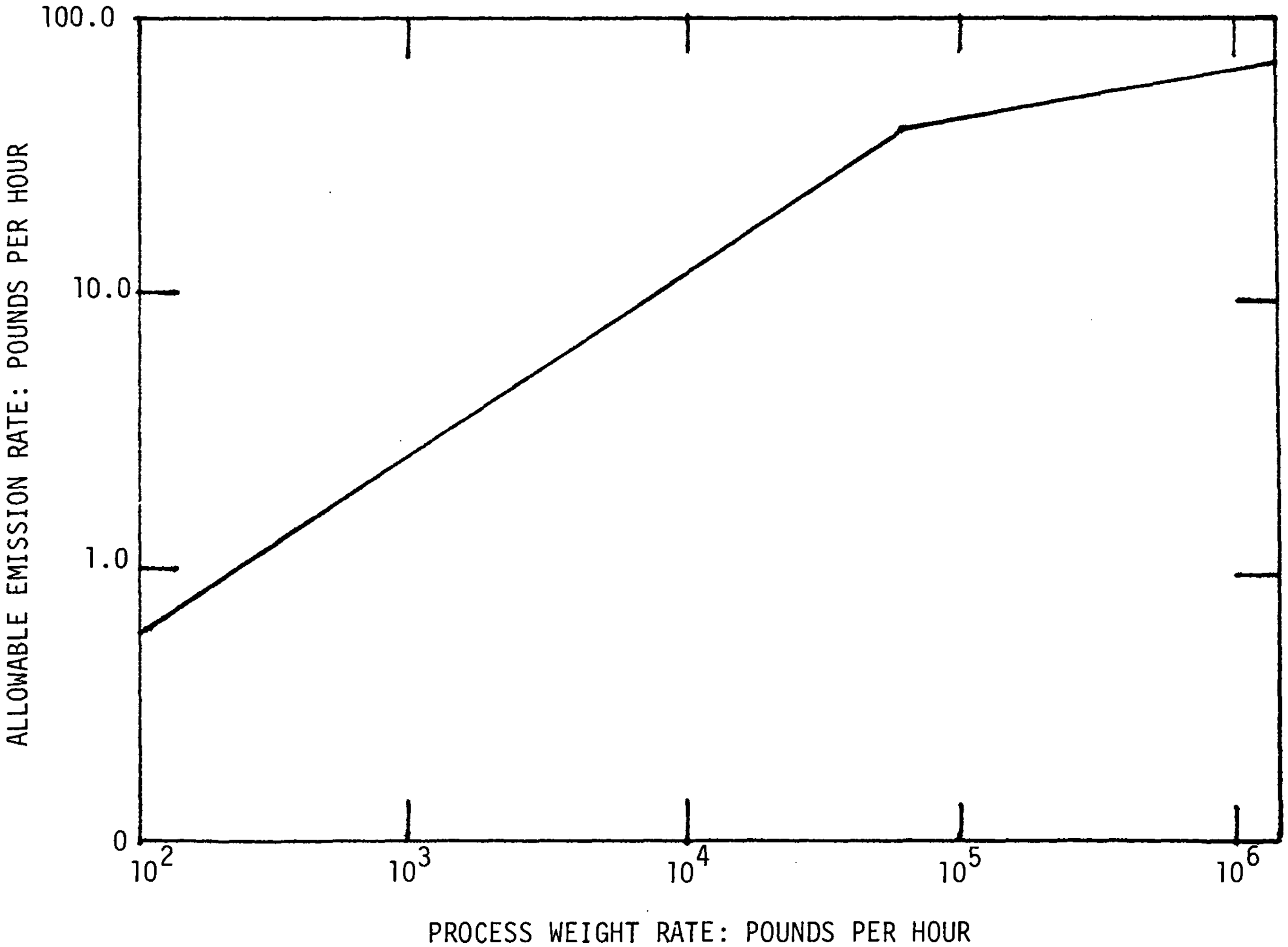


Figure B.1. State of Illinois allowable emission rate for point-source control such as the SIC class 32 (stone, clay, and glass industries). It is noticeably lenient for sources with small emission factors and large process weight, such as SIC 28 (chemicals and allied) and SIC 29 (petroleum).

APPENDIX C

DERIVATION OF BEST-FIT EMISSION-DENSITY ESTIMATORS BY MANUFACTURING ZONING CLASS

APPENDIX C

DERIVATION OF BEST-FIT EMISSION-DENSITY ESTIMATORS BY MANUFACTURING ZONING CLASS

This appendix provides the derivation of the equations for determining those emission-density estimates by manufacturing zoning class that best represents air quality as calculated by the Air Quality Display Model (AQDM) dispersion model, using best available point-source emission inventory information in the Chicago region. For purposes of calculation with AQDM, the air quality is determined at 237 receptor locations in the region, yielding 237 points at which to compare the representation achieved by using detailed point-source information with that achieved using an emission-density representation by land use class.

For purposes of this study, two manufacturing classes are considered, heavy industry (HI) and light industry (LI). Two estimates of emission density are sought, ED^{HI} and ED^{LI}, that best represent air quality in the sense of minimizing the standard deviation in the relative error in calculated air quality between the point-source (PS) representation and the emission-density (ED) representation, and simultaneously achieve a zero mean relative error (unbiased). In this appendix, the emission-density formulation of the AQDM dispersion model is derived, after which the best-fit equations are displayed.

If it is assumed that the region is divided into geographic grid squares indexed by ℓ, that k is an index of receptor points, and that m is an index of land use or zoning class, then the pollutant concentration X_k at receptor point k, is given by:

$$X_k = \sum_m \sum_\ell \alpha^m_{\ell k} \, ED^m_\ell \, A^m_\ell \quad , \tag{C.1}$$

where X_k is the pollutant concentration at receptor point k,

$\alpha^m_{\ell k}$ is the dispersion model transfer coefficient describing the contribution of a unit emission from land use class m in grid square ℓ to the concentration at location k (assumed independent of emissions),

ED^m_ℓ represents the expected emission density in tons/day/acre for land use class m in grid square ℓ,

A^m_ℓ is the specified percentage of land designated for land use class m in grid square ℓ,

If it is further assumed that the emission density, ED^m_ℓ, is a variable to be estimated uniformly over the entire region by land use class m, then the following emission-density formulation of the dispersion equation results:

or $$X_k = \sum_m \sum_\ell \alpha^m_{\ell k} \, A^m_\ell \, ED^m \tag{C.2}$$

or $$X_k = \sum_m ED^m \sum_\ell \alpha^m_{\ell k} \, A^m_\ell \tag{C.3}$$

where $$X_k = \sum_m P^m_k \, ED^m$$

$$P^m_k = \sum_\ell \alpha^m_{\ell k} \, A^m_\ell \tag{C.4}$$

For the case where m = HI, LI, we have:

$$\chi_k = P_k^{HI} \cdot ED^{HI} + P_k^{LI} \cdot ED^{LI} \quad . \tag{C.5}$$

Let χ_k^{PS} be the calculated concentration at reception point k using the point-source formulation

and χ_k^{ED} be the calculated concentration at reception point k using the emission-density formulation (eq. B.5).

Then the relative error is given by

$$\varepsilon_k = \frac{\chi_k^{PS} - \chi_k^{ED}}{\chi_k^{PS}}$$

$$= \frac{\chi_k^{PS} - \left(P_k^{HI} \cdot ED^{HI} + P_k^{LI} \cdot ED^{LI}\right)}{\chi_k^{PS}}$$

$$= 1 - \left(\frac{P_k^{HI}}{\chi_k^{PS}}\right) ED^{HI} - \left(\frac{P_k^{LI}}{\chi_k^{PS}}\right) ED^{LI}$$

$$= 1 - \hat{P}_k^{HI} \cdot ED^{HI} - \hat{P}_k^{LI} \cdot ED^{LI} \quad , \tag{C.6}$$

where
$$\hat{P}_k^{HI} = \frac{P_k^{HI}}{\chi_k^{PS}}$$

and
$$\hat{P}_k^{LI} = \frac{P_k^{LI}}{\chi_k^{PS}} \quad ,$$

and the mean relative error is:

$$\mu_R = 1 - \frac{ED^{HI}}{N} \sum_R \hat{P}_k^{HI} - \frac{ED^{LI}}{N} \sum_R \hat{P}_k^{LI} \tag{C.7}$$

and the standard deviation of the relative error is:

$$\sigma_R = \left[\frac{\sum_k \varepsilon_k^2}{N} - \mu_R^2 \right]^{1/2} \tag{C.8}$$

To select the best-fit unbiased emission-density estimators, $\overset{**}{ED}{}^{HI}$ and $\overset{**}{ED}{}^{LI}$, the following minimization problem must be solved:

$$\min \quad \sigma_R \tag{C.9}$$

$$\text{s.t.} \quad \mu_R = 0 \; .$$

This can be solved explicitly using the Lagrange multiplier technique to give the following result:

$$\overset{**}{ED}{}^{HI} = -N \left[\frac{\sum_k \hat{P}_k^{LI} \sum_k \hat{P}_k^{HI} \cdot \hat{P}_k^{LI} - \sum_k \hat{P}_k^{HI} \left(\sum_k \hat{P}_k^{LI} \right)^2}{D} \right] \tag{C.10}$$

$$\overset{**}{ED}{}^{LI} = N \; \frac{\sum_k \hat{P}_k^{LI} \left(\sum_k \hat{P}_k^{HI} \right)^2 - \sum_k \hat{P}_k^{HI} \sum_k \hat{P}_k^{HI} \cdot \hat{P}_k^{LI}}{D} \tag{C.11}$$

where

$$\begin{aligned} D \quad = \quad & \sum_k \hat{P}_k^{LI} \quad \sum_k \hat{P}_k^{LI} \quad \sum_k \hat{P}_k^{HI} \quad {}^2 \\ & - \sum_k \hat{P}_k^{HI} \quad \sum_k \hat{P}_k^{HI} \cdot \hat{P}_k^{LI} \\ & - \sum_k \hat{P}_k^{HI} \quad \sum_k \hat{P}_k^{LI} \quad \sum_k \hat{P}_k^{HI} \cdot \hat{P}_k^{LI} \\ & - \sum_k \hat{P}_k^{HI} \quad \sum_k \hat{P}_k^{HI} \quad {}^2 \end{aligned} \tag{C.12}$$

APPENDIX D

CORRELATION AND MULTIPLE LINEAR REGRESSION RESULTS

Table D.1. CORRELATION TABLE - SIC 32 Stone, Clay & Glass Products

	Space	Employment	Process Weight	Energy	Coal	Controlled Emissions
Space	-	.13	.66	.04	.15	.58
Employment		-	-.10	.90	.82	-.004
Process Weight			-	-.14	-.06	.74
Energy				-	.62	-.05
Coal					-	-.01
Controlled Emissions						-

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FILE CORRES (CREATION DATE = 05/03/73)

SIC 32 Stone, Clay & Glass Products

VARIABLE	CASES	MEAN	STD DEV	
VAR002	50	94.5159	242.9510	Space (acres)
VAR003	50	139.9500	275.8376	Employment
VAR004	50	346.7568	869.3699	Process Weight (t/hr)
VAR005	50	18.4403	40.5452	Energy (MBtu/hr)
VAR006	50	0.7372	5.1955	Coal (MBtu/hr)
VAR007	50	1771.2712	4905.0156	Uncontrolled Emissions (lbs/hr)
VAR008	50	26.6123	29.8296	Controlled Emissions (lbs/hr)

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR004	0.74242	0.55119	0.55119	0.74242	0.02235	0.44253
VAR002	0.75319	0.56729	0.01610	0.58377	0.01914	0.15587
VAR003	0.75404	0.56858	0.00129	-0.00427	0.02030	0.18774
VAR006	0.75562	0.57096	0.00238	-0.01025	-0.61915	-0.12784
VAR005	0.75605	0.57162	0.00066	-0.04769	-0.05294	-0.26910
(CONSTANT)					15.70910	

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.58377	0.34078	0.34078	0.58377	0.07297	0.59432
VAR003	0.58932	0.34729	0.00651	-0.00427	-0.00880	-0.08137
(CONSTANT)					20.94699	

DEPENDENT VARIABLE.. VAR004

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.65752	0.43234	0.43234	0.65752	2.43851	0.68146
VAR003	0.68250	0.46581	0.03347	-0.09611	-0.58151	-0.18450
(CONSTANT)					197.56742	

DEPENDENT VARIABLE.. VAR005

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.90432	0.81779	0.81779	0.90432	0.13440	0.91435
VAR002	0.90756	0.82367	0.00589	0.04122	-0.01291	-0.07739
(CONSTANT)					0.81032	

Table D.2. CORRELATION TABLE - SIC 29 Petroleum Refining and Related Industries

	Space	Employment	Process Weight	Energy	Coal	Controlled Emissions
Space	-	.76	.01	.80	-	.52
Employment		-	.02	.74	-	.49
Process Weight			-	.24	-	.44
Energy				-	-	.73
Coal					-	-
Controlled Emissions						-

FILE CORREG (CREATION DATE = 05/03/73)

SIC 29 Petroleum Refining and Related Industries

VARIABLE	CASES	MEAN	STD DEV	
VAR002	40	97.5750	237.4664	Space (acres)
VAR003	40	132.0750	193.6956	Employment
VAR004	40	118.8666	185.2731	Process Weight (t/hr)
VAR005	40	150.8974	455.3191	Energy (MBtu/hr)
VAR006	40	0.0	0.0	Coal (MBtu/hr)
VAR007	40	127.7504	375.8899	Uncontrolled Emissions (lbs/hr)
VAR008	40	19.1841	31.9510	Controlled Emissions (lbs/hr)

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR005	0.73045	0.53355	0.53355	0.73045	0.04667	0.66504
VAR004	0.78164	0.61096	0.07741	0.44468	0.04944	0.28670
VAR003	0.78175	0.61113	0.00017	0.48836	0.00489	0.02964
VAR002	0.78192	0.61140	0.00027	0.52646	-0.00418	-0.03106
(CONSTANT)					6.02699	

DEPENDENT VARIABLE.. VAR003

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.52646	0.27716	0.27716	0.52646	0.04944	0.36742
VAR003	0.54389	0.29582	0.01867	0.48836	0.03458	0.20966
(CONSTANT)					9.79277	

DEPENDENT VARIABLE.. VAR004

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.02242	0.00050	0.00050	-0.02242	-0.06383	-0.06674
VAR002	0.04418	0.00195	0.00145	0.00780	0.04558	0.05842
(CONSTANT)					122.85007	

DEPENDENT VARIABLE.. VAR005

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.80114	0.64182	0.64182	0.80114	1.10056	0.57399
VAR003	0.82456	0.67990	0.03808	0.73485	0.70393	0.29946
(CONSTANT)					-49.46099	

Table D.3. CORRELATION TABLE - SIC 33 Primary Metal Industries

	Space	Employment	Process Weight	Energy	Coal	Controlled Emissions
Space	-	.28	.05	.10	-	.14
Employment		-	.17	.16	-	.35
Process Weight			-	.07	-	.72
Energy				-	-	.27
Coal					-	-
Controlled Emissions						-

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FILE CORREG (CREATION DATE = 05/03/73)

SIC 33 Primary Metal Industries

VARIABLE	CASES	MEAN	STD DEV	
VAR002	83	19.5154	51.6155	Space (acres)
VAR003	83	295.1107	688.4092	Employment
VAR004	83	12.1155	45.8586	Process Weight (t/hr)
VAR005	83	31.0092	130.1583	Energy (MBtu/hr)
VAR006	83	0.0	0.0	Coal (MBtu/hr)
VAR007	83	108.5148	529.7297	Uncontrolled Emissions (lbs/hr)
VAR008	83	8.8197	14.8433	Controlled Emissions (lbs/hr)

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR004	0.72278	0.52241	0.52241	0.72278	0.21824	0.67426
VAR003	0.76043	0.57825	0.05584	0.35494	0.00434	0.20122
VAR005	0.78293	0.61297	0.03472	0.26951	0.02135	0.18719
VAR002	0.78359	0.61401	0.00103	0.14314	0.02965	0.03356
(CONSTANT)					4.04349	

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.35494	0.12598	0.12598	0.35494	0.00737	0.34165
VAR002	0.35786	0.12806	0.00208	0.14314	0.01366	0.04749
(CONSTANT)					6.38850	

DEPENDENT VARIABLE.. VAR004

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.16884	0.02851	0.02851	0.16884	0.01125	0.16884
(CONSTANT)					8.84553	

DEPENDENT VARIABLE.. VAR005

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.16295	0.02655	0.02655	0.16295	0.02772	0.14659
VAR002	0.17234	0.02970	0.00315	0.09949	0.14739	0.05845
(CONSTANT)					19.95876	

Table D.4. CORRELATION TABLE - SIC 28 Chemicals and Allied Products

	Space	Employment	Process Weight	Energy	Coal	Controlled Emissions
Space	-	.72	-0	.52	.61	.35
Employment		-	.01	.63	.77	.33
Process Weight			-	.34	.40	.78
Energy				-	.83	.54
Coal					-	.61
Controlled Emissions						-

FILE CORRES (CREATION DATE = 05/03/73)

SIC 28 Chemicals and Allied Products

VARIABLE	CASES	MEAN	STD DEV	
VAR002	79	163.4150	1127.7778	Space (acres)
VAR003	79	257.8479	763.4949	Employment
VAR004	79	45.1801	223.5915	Process Weight (t/hr)
VAR005	79	24.1541	55.8047	Energy (MBtu/hr)
VAR006	79	9.5930	41.9244	Coal (MBtu/hr)
VAR007	79	65.8388	267.4426	Uncontrolled Emissions (lbs/hr)
VAR008	79	8.8806	19.6010	Controlled Emissions (lbs/hr)

• MULTIPLE REGRESSION •

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR004	0.76765	0.58929	0.58929	0.76765	0.06072	0.69262
VAR002	0.84213	0.70918	0.11989	0.34615	0.00362	0.20827
VAR006	0.85410	0.72948	0.02031	0.61289	0.05526	0.11828
VAR005	0.85525	0.73145	0.00197	0.54476	0.02865	0.08157
VAR003	0.85542	0.73174	0.00028	0.33326	0.00086	0.03348
(CONSTANT)					4.10266	

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.34615	0.11982	0.11982	0.34615	0.00383	0.22055
VAR003	0.36690	0.13454	0.01472	0.33326	0.00448	0.17463
(CONSTANT)					7.09823	

DEPENDENT VARIABLE.. VAR004

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.01151	0.00013	0.00013	0.01151	0.00704	0.02405
VAR002	0.01671	0.00028	0.00015	-0.00013	-0.00345	-0.01743
(CONSTANT)					43.92893	

DEPENDENT VARIABLE.. VAR005

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.62588	0.39172	0.39172	0.62588	0.03822	0.52296
VAR002	0.63372	0.40161	0.00988	0.51922	0.00708	0.14310
(CONSTANT)					13.14117	

Table D.5. CORRELATION TABLE - SIC 20 Food and Kindred Products

	Space	Employment	Process Weight	Energy	Coal	Controlled Emissions
Space	-	.85	.38	.88	.90	.88
Employment		-	.44	.84	.83	.83
Process Weight			-	.23	.23	.43
Energy				-	.96	.92
Coal					-	.95
Controlled Emissions						-

FILE COPPEG (CREATION DATE = 05/03/73)

SIC 20 Food and Kindred Products

VARIABLE	CASES	MEAN	STD DEV	
VAR002	21	33.59[illegible]2	68.2297	Space
VAR003	21	456.00[illegible]0	758.7634	Employment
VAR004	21	24.94[illegible]7	74.9341	Process Weight (t/hr)
VAR005	21	92.63[illegible]4	262.3921	Energy (MBtu/hr)
VAR006	21	51.63[illegible]5	232.2444	Coal
VAR007	21	40.02[illegible]0	144.0615	Uncontrolled Emissions (lbs/hr)
VAR008	21	14.99[illegible]1	37.7325	Controlled Emissions (lbs/hr)

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR006	0.94801	0.89873	0.89873	0.94801	0.14460	0.89338
VAR004	0.97242	0.94560	0.04687	0.43300	0.12270	0.24367
VAR003	0.97277	0.94628	0.00068	0.83140	-0.00276	-0.05553
VAR005	0.97299	0.94670	0.00042	0.91830	0.01222	0.08498
VAR002	0.97310	0.94693	0.00023	0.88056	-0.02149	-0.23885
(CONSTANT)					5.31777	

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.88056	0.77538	0.77538	0.88056	0.34488	0.62363
VAR003	0.89527	0.80151	0.02613	0.83140	0.01509	0.30354
(CONSTANT)					-3.47244	

DEPENDENT VARIABLE.. VAR004

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.43921	0.19291	0.19291	0.43921	0.04338	0.43921
(CONSTANT)					5.16717	

DEPENDENT VARIABLE.. VAR005

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.88272	0.77920	0.77920	0.88272	2.36663	0.61539
VAR003	0.89860	0.80749	0.02828	0.83672	0.10922	0.31583
(CONSTANT)					-36.68071	

Table D.6. CORRELATION TABLE - SIC 35 Machinery, Except Electrical

	Space	Employment	Process Weight	Energy	Coal	Controlled Emissions
Space	-	.81	-.07	.89	.85	.36
Employment		-	-.07	.90	.83	.41
Process Weight			-	-.05	-.04	.83
Energy				-	.95	.44
Coal					-	.42
Controlled Emissions						-

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FILE CORREG (CREATION DATE = 05/03/73)

SIC 35 Machinery, Except Electrical

VARIABLE	CASES	MEAN	STD DEV	
VAR002	56	31.5959	66.6823	Space (acres)
VAR003	56	607.8928	1091.9629	Employment
VAR004	56	2.1732	12.0812	Process Weight (t/hr)
VAR005	56	12.6124	38.9831	Energy (MBtu/hr)
VAR006	56	4.0604	20.6633	Coal (MBtu/hr)
VAR007	56	32.1167	96.2852	Uncontrolled Emissions (lbs/hr)
VAR008	56	2.8693	7.9479	Controlled Emissions (lbs/hr)

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR004	0.83193	0.69211	0.69211	0.83193	0.56625	0.96042
VAR005	0.96066	0.92287	0.23076	0.44187	0.04605	0.22587
VAR003	0.96544	0.93207	0.00920	0.41023	0.00169	0.23272
VAR006	0.96567	0.93251	0.00045	0.42875	0.02772	0.07207
VAR002	0.96574	0.93265	0.00014	0.36038	-0.00309	-0.02591
(CONSTANT)					0.01368	

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.41023	0.16829	0.16829	0.41023	0.00252	0.34594
VAR002	0.41280	0.17041	0.00212	0.36038	0.00942	0.07906
(CONSTANT)					1.04093	

DEPENDENT VARIABLE.. VAR004

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.07567	0.00573	0.00573	-0.07567	-0.00768	-0.04238
VAR003	0.07933	0.00629	0.00057	-0.07540	-0.00045	-0.04093
(CONSTANT)					2.69111	

DEPENDENT VARIABLE.. VAR005

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.90052	0.81094	0.81094	0.90052	0.01861	0.52128
VAR002	0.94053	0.88460	0.07366	0.89026	0.27264	0.46635
(CONSTANT)					-7.31434	

Table D.7. CORRELATION TABLE - SIC 34 Fabricated Metal Products, Except Ordnance, Machinery, and Transportation Equipment

	Space	Employment	Process Weight	Energy	Coal	Controlled Emissions
Space	-	.01	.84	.23	.98	.68
Employment		-	-.02	.05	-.03	.04
Process Weight			-	.19	.86	.86
Energy				-	.20	.48
Coal					-	.67
Controlled Emissions						-

SIC 34 Fabricated Metal Products, Except Ordnance, Machinery & Transportation Equipment

FILE CORREG (CREATION DATE = 05/03/73)

VARIABLE	CASES	MEAN	STD DEV	
VAR002	56	35.2486	162.0347	Space (acres)
VAR003	56	351.0356	972.5554	Employment
VAR004	56	1.2150	3.7497	Process Weight (t/hr)
VAR005	56	23.7278	87.6151	Energy (MBtu/hr)
VAR006	56	0.0829	0.6053	Coal (MBtu/hr)
VAR007	56	52.4783	252.7663	Uncontrolled Emissions (lbs/hr)
VAR008	56	2.5071	5.1106	Controlled Emissions (lbs/hr)

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR004	0.86218	0.74335	0.74335	0.86218	1.50905	1.10721
VAR005	0.92040	0.84714	0.10379	0.47983	0.01883	0.32287
VAR006	0.93748	0.87887	0.03174	0.66539	-6.46685	-0.76599
VAR002	0.94187	0.88713	0.00825	0.67944	0.01331	0.42225
VAR003	0.94216	0.88767	0.00054	0.04447	0.00012	0.02377
(CONSTANT)					0.23685	

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.67944	0.46163	0.46163	0.67944	0.02142	0.67905
VAR003	0.68047	0.46305	0.00141	0.04447	0.00020	0.03757
(CONSTANT)					1.68291	

DEPENDENT VARIABLE.. VAR004

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.84179	0.70861	0.70861	0.84179	0.01949	0.84207
VAR003	0.84225	0.70939	0.00078	-0.01939	-0.00011	-0.02796
(CONSTANT)					0.56596	

DEPENDENT VARIABLE.. VAR005

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.23005	0.05292	0.05292	0.23005	0.12415	0.22961
VAR003	0.23415	0.05483	0.00190	0.04596	0.00393	0.04363
(CONSTANT)					17.97187	

Table D.8. CORRELATION TABLE - SIC 26 Paper and Allied Products

	Space	Employment	Process Weight	Energy	Coal	Controlled Emissions
Space	-	.14	.11	-.02	-.02	.03
Employment		-	.72	.40	.30	.74
Process Weight			-	.16	-.05	.90
Energy				-	.88	.35
Coal					-	.19
Controlled Emissions						-

FILE CORREG (CREATION DATE = 05/03/73)

SIC 26 Paper and Allied Products

VARIABLE	CASES	MEAN	STD DEV	
VAR002	25	23.7320	48.9834	Space (acres)
VAR003	25	257.2400	244.3931	Employment
VAR004	25	22.4631	101.5388	Process Weight (t/hr)
VAR005	25	15.4079	31.9324	Energy (MBtu/hr)
VAR006	25	6.0272	30.1360	Coal (MBtu/hr)
VAR007	25	51.7551	142.9213	Uncontrolled Emissions (lbs/hr)
VAR008	25	5.0808	11.2124	Controlled Emissions (lbs/hr)

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR004	0.90038	0.81068	0.81068	0.90038	0.09833	0.89249
VAR006	0.93057	0.86595	0.05527	0.19341	0.09428	0.25343
VAR002	0.93262	0.86979	0.00383	0.03127	-0.01522	-0.06649
VAR003	0.93312	0.87072	0.00093	0.73719	0.00256	0.24888
VAR005	0.93327	0.87100	0.00028	0.34927	-0.01381	-0.03934
(CONSTANT)					2.22023	

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.73719	0.54344	0.54344	0.73719	0.03905	0.74668
VAR002	0.74044	0.54825	0.00481	0.03127	-0.01602	-0.07000
(CONSTANT)					-4.58419	

DEPENDENT VARIABLE.. VAR004

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.71538	0.51178	0.51178	0.71538	0.33881	0.71538
(CONSTANT)					-64.69324	

DEPENDENT VARIABLE.. VAR005

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.40012	0.16009	0.16009	0.40012	0.06112	0.41035
VAR002	0.40704	0.16568	0.00559	-0.01979	-0.04919	-0.07545
(CONSTANT)					0.85312	

Table D.9. CORRELATION TABLE - SIC 30 Rubber & Miscellaneous Plastic Products

	Space	Employment	Process Weight	Energy	Coal	Controlled Emissions
Space	-	.71	.17	.63	-	-.09
Employment		-	.28	.31	-	-.16
Process Weight			-	.35	-	.30
Energy				-	-	.67
Coal					-	-
Controlled Emissions						-

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FILE COPREG (CREATION DATE = 05/03/73)

SIC 30 Rubber & Misc. Plastic Products

VARIABLE	CASES	MEAN	STD DEV	
VAR002	15	44.1640	74.6698	Space (acres)
VAR003	15	283.5332	405.7395	Employment
VAR004	15	6.9827	16.2064	Process Weight (t/hr)
VAR005	15	17.0220	31.5517	Energy (MBtu/hr)
VAR006	15	0.0	0.0	Coal (MBtu/hr)
VAR007	15	32.3573	92.2821	Uncontrolled Emissions (lbs/hr)
VAR008	15	3.9513	9.6017	Controlled Emissions (lbs/hr)

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR005	0.66565	0.44309	0.44309	0.66565	0.36972	1.21485
VAR002	0.92747	0.86020	0.41712	-0.08526	-0.12091	-0.94032
VAR003	0.93188	0.86840	0.00819	-0.15536	0.00311	0.13153
(CONSTANT)					2.11550	

DEPENDENT VARIABLE.. VAR009

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.15536	0.02414	0.02414	-0.15536	-0.00449	-0.18955
VAR002	0.15911	0.02532	0.00118	-0.08526	0.03623	0.04846
(CONSTANT)					4.94754	

DEPENDENT VARIABLE.. VAR004

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.28063	0.07875	0.07875	0.28063	0.01267	0.31720
VAR002	0.28302	0.08010	0.00135	0.17194	-0.01125	-0.05184
(CONSTANT)					3.89726	

DEPENDENT VARIABLE.. VAR005

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.62742	0.39366	0.39366	0.62742	0.34392	0.81391
VAR003	0.65479	0.42876	0.03510	0.30987	-0.02056	-0.26433
(CONSTANT)					7.66147	

Table D.10. CORRELATION TABLE - SIC 37 Transportation Equipment

	Space	Employment	Process Weight	Energy	Coal	Controlled Emissions
Space	-	.45	-.22	.19	.28	-.13
Employment		-	-.25	.51	.60	-.03
Process Weight			-	-.16	-.12	.94
Energy				-	.93	.19
Coal					-	.23
Controlled Emissions						-

FILE CORREG (CREATION DATE = 05/03/73)

SIC 37 Transportation Equipment

VARIABLE	CASES	MEAN	STD DEV	
VAR002	12	75.0417	112.2263	Space (acres)
VAR003	12	1414.6665	1552.3701	Employment
VAR004	12	1.7092	5.4622	Process Weight (t/hr)
VAR005	12	18.5525	30.3073	Energy (MBtu/hr)
VAR006	12	10.3833	30.8047	Coal (MBtu/hr)
VAR007	12	58.3141	77.9441	Uncontrolled Emissions (lbs/hr)
VAR008	12	4.2017	8.6579	Controlled Emissions (lbs/hr)

* M U L T I P L E   R E G R E S S I O N *

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR004	0.93645	0.87694	0.87694	0.93645	1.57085	0.99104
VAR005	0.99586	0.99173	0.11480	0.18794	0.05792	0.20275
VAR006	0.99754	0.99509	0.00335	0.22704	0.03759	0.13371
VAR003	0.99781	0.99563	0.00054	-0.02956	0.00017	0.03027
(CONSTANT)					-0.18679	

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.13124	0.01722	0.01722	-0.13124	-0.01144	-0.14835
VAR003	0.13548	0.01835	0.00113	-0.02956	0.00021	0.03773
(CONSTANT)					4.76285	

DEPENDENT VARIABLE.. VAR004

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.24593	0.06048	0.06048	-0.24593	-0.00064	-0.18328
VAR002	0.27502	0.07564	0.01515	-0.22126	-0.00672	-0.13813
(CONSTANT)					3.12599	

DEPENDENT VARIABLE.. VAR005

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.51427	0.26447	0.26447	0.51427	0.01051	0.53851
VAR002	0.51647	0.26674	0.00227	0.19079	-0.01444	-0.05346
(CONSTANT)					4.76272	

Table D.11. CORRELATION TABLE - SIC 39 Miscellaneous Manufacturing Industries

	Space	Employment	Process Weight	Energy	Coal	Controlled Emissions
Space	-	.28	-.24	.55	.57	-.22
Employment		-	-.07	.10	-.0	-.07
Process Weight			-	-.10	-.05	.99
Energy				-	.28	-.09
Coal					-	-.03
Controlled Emissions						-

FILE CORREG (CREATION DATE = 05/03/73)

SIC 39 Misc. Manufacturing Industries

VARIABLE	CASES	MEAN	STD DEV	
VAR002	20	5.2735	5.2509	Space
VAR003	20	260.1499	203.8884	Employment
VAR004	20	2.6920	11.9097	Process Weight (t/hr)
VAR005	20	1.7380	2.7630	Energy (MBtu/hr)
VAR006	20	0.2510	1.1225	Coal (MBtu/hr)
VAR007	20	15.6130	29.5590	Uncontrolled Emissions (lbs/hr)
VAR008	20	2.4860	10.0567	Controlled Emissions (lbs/hr)

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR004	0.99949	0.99897	0.99897	0.99949	0.84573	1.00157
VAR006	0.99967	0.99934	0.00037	-0.03291	0.14948	0.01668
VAR005	0.99969	0.99938	0.00004	-0.09413	0.01905	0.00523
VAR003	0.99969	0.99939	0.00001	-0.06667	0.00010	0.00234
VAR002	0.99969	0.99939	0.00000	-0.22242	0.00417	0.00218
(CONSTANT)					0.09052	

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.22242	0.04947	0.04947	-0.22242	-0.42598	-0.22242
(CONSTANT)					4.73243	

DEPENDENT VARIABLE.. VAR004

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.23719	0.05626	0.05626	-0.23719	-0.53797	-0.23719
(CONSTANT)					5.52897	

DEPENDENT VARIABLE.. VAR005

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR002	0.54902	0.30142	0.30142	0.54902	0.29739	0.56518
VAR003	0.55181	0.30450	0.00307	0.10038	-0.00078	-0.05774
(CONSTANT)					0.37328	

Table D.12. CORRELATION TABLE - SIC 36 Electrical Machinery, Equipment and Supplies

	Space	Employment	Process Weight	Energy	Coal	Controlled Emissions
Space	-	.15	-.11	.08	.11	.01
Employment		-	.14	.68	.13	.24
Process Weight			-	.21	-.07	.81
Energy				-	.47	.27
Coal					-	.20
Controlled Emissions						-

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FILE CORRES (CREATION DATE = 05/03/73)

SIC 36 Electrical Machinery, Equipment, and Supplies

VARIABLE	CASES	MEAN	STD DEV	
VAR002	31	21.4000	22.4546	Space
VAR003	31	766.9675	766.8181	Employment
VAR004	31	0.4719	1.2750	Process Weight (t/hr)
VAR005	31	7.4864	13.1412	Energy (MBtu/hr)
VAR006	31	0.1700	0.9465	Coal (MBtu/hr)
VAR007	31	13.7002	21.6211	Uncontrolled Emissions (lbs/hr)
VAR008	31	1.3345	2.5488	Controlled Emissions (lbs/hr)

* M U L T I P L E R E G R E S S I O N *

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR004	0.81061	0.65708	0.65708	0.81061	1.71054	0.85566
VAR006	0.84947	0.72161	0.06453	0.19773	0.87124	0.32355
VAR003	0.85483	0.73074	0.00913	0.23904	0.00073	0.22099
VAR005	0.86544	0.74898	0.01824	0.27151	-0.04220	-0.21764
VAR002	0.86703	0.75174	0.00276	0.00777	0.00612	0.05395
(CONSTANT)					0.00068	

DEPENDENT VARIABLE.. VAR008

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.23904	0.05714	0.05714	0.23904	0.00081	0.24328
VAR002	0.24069	0.05793	0.00079	0.00777	-0.00323	-0.02846
(CONSTANT)					0.78347	

DEPENDENT VARIABLE.. VAR004

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.13580	0.01844	0.01844	0.13580	0.00026	0.15633
VAR002	0.19239	0.03701	0.01857	-0.11453	-0.00782	-0.13791
(CONSTANT)					0.44004	

DEPENDENT VARIABLE.. VAR005

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
VAR003	0.67982	0.46215	0.46215	0.67982	0.01171	0.68301
VAR002	0.68015	0.46260	0.00045	0.08029	-0.01255	-0.02145
(CONSTANT)					-1.22231	

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6. County Business Patterns. U.S. Bureau of Census: 1968-1971. Northeastern Illinois Planning Commission Planning Paper No. 10. Revised, 1972.

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1. REPORT NO. EPA-450/3-74-028-b	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Air Pollution/Land Use Planning Project Volume II. Methods for Predicting Air Pollution Concentrations from Land Use		5. REPORT DATE May 1973 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) A.S. Kennedy, T.E. Baldwin, K.G. Croke, J.W. Gudenas		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Argonne National Laboratory Energy and Environmental Studies Division 9700 South Cass Avenue Argonne, Illinois 60439		10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. EPA-IAG-0159(D)
12. SPONSORING AGENCY NAME AND ADDRESS Transportation and Land Use Planning Branch Office of Air Quality Planning and Standards Environmental Protection Agency Research Triangle Park, North Carolina 27711		13. TYPE OF REPORT AND PERIOD COVERED Final 14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

In order to evaluate or rank land use plans in terms of air quality, it is necessary for planners to be able to project emission density (mass of pollutant per unit of land for any specified time period) using only planning variables, because detailed source characteristics are not available at the time alternative plans are being developed and evaluated. The objective of this study is to analyze the u·ility of various land use paramters in describing the air quality impacts of land use plans.

Parameters that are tested include land use by zoning class and 2-digit SIC code, employment dwelling units, and square footage of floor space. Variables that are to be explained by these parameters include air quality as represented by the Air Quality Display Model (AQDM), emissions and emission densities, process weight for industrial sources, and energy consumption.

17. KEY WORDS AND DOCUMENT ANALYSIS

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Land Use Planning and Zoning Local Government Air Pollution Control Agencies Area Emission Allocations		

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