MASTER

ARGONNE NATIONAL LABORATORY

CENTER FOR ENVIRONMENTAL STUDIES

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

NOTICE
This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Evaluation of Emission Control Strategies for
Sulfur Dioxide and Particulates in the
Chicago Metropolitan Air Quality Control Region*

IIPP-2

NOTICE

PORTIONS OF THIS REPORT ARE ILLEGIBLE. It
has been reproduced from the best available
copy to permit the broadest possible avail-
ability.

J. E. Norco
M. A. Snider
J. J. Roberts
K. G. Croke
A. S. Cohen
A. S. Kennedy
O. Skala

December 1970

Center for Environmental Studies

* Study performed under contract #31-109-38-2464 with
the Illinois Institute for Environmental Quality.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

ACKNOWLEDGEMENTS

The success of this study depended upon the acquisition of a detailed emission inventory and extensive observations of air quality. Information in these two categories was provided by the Illinois Environmental Protection Agency, the Chicago Department of Environmental Control, and the National Air Pollution Control Administration.

NOTE

This report is, in essence, an informal communication between Argonne National Laboratory and the Illinois Institute for Environmental Quality regarding the evaluation of control regulations for emissions of SO₂ and particulates in the Chicago Metropolitan Air Quality Control Region. As such, it should be reviewed not only in terms of its conclusions but also in terms of the accuracy of input data, the suitability of methodology, and the desirability of follow-on studies. The wide distribution accorded this document is therefore to invite public participation in forthcoming hearings before the Illinois Pollution Control Board.

1.0 Introduction

Argonne National Laboratory, under contract to the Illinois Institute for Environmental Quality, is engaged in a program to assist the State of Illinois in the implementation of an air pollution control program for the Illinois portion of the Chicago Metropolitan Air Quality Control Region (CMAQCR). The purpose of the air pollution control system and the overriding consideration in all stages of its design is the serious need to minimize pollutant concentration in accordance with the NAPCA Criteria Documents and the air quality standards of the State of Illinois.

The system is a union of many elements - including a framework of enabling legislation and regulations, operational features such as source and air quality surveillance subsystems, and a capability for data storage display and analysis using statistical techniques and atmospheric dispersion models. The system functions on two time scales:

- (1) A long-term response whereby routine emissions are reduced and adequate documentation and surveillance are maintained, and
- (2) A short-term episodal response whereby an episode control task force is convened and special, real-time surveillance and source-control measures are initiated as indicated by rapid and progressive deterioration of regional air quality.

A major task area in the Argonne study is the evaluation of long-term emission control standards in terms of the air quality standards of the State of Illinois. These long-range regulations are to be supplemented by episode control plans. The distinction in time scales and control philosophy between

TABLE OF CONTENTS

	<u>Page</u>
1.0 Introduction	1
2.0 The Diffusion Model	4
2.1 Introduction	4
2.2 Model Calibration	9
2.3 Emission Inventory	16
2.4 Climatology	45
2.5 Air Quality	53
3.0 The Strategy Model	63
3.1 Control Philosophy	63
3.2 Strategy Model Operation	77
3.3 Area Source Calculations	79
4.0 Emission Control Standards	82
4.1 Introduction	82
4.2 Fossil Fuel Availability	85
4.3 Particulate Emission Standards	96
4.4 Sulfur Dioxide Emission Standards	102
4.5 A Control Strategy for the Short Term (1 Hr/Day) Sulfur Dioxide Air Quality Standard	106
5.0 Results and Analysis	111
5.1 Introduction	111
5.2 The Effect of Indiana Sources	118
5.3 Selection of a Single Index for the Comparison of Alternate Control Strategies - The Annual Geometric Mean of 24-Hr Averages	124
5.4 Control Strategies Yielding Acceptable Air Quality.	128
APPENDIX A Description of Dispersion and Statistical Models .	A-1
APPENDIX B Sample Output from the Computer Code for Evaluating Strategies	B-1
APPENDIX C Isopleth Maps Showing Annual Geometric Means ($\mu\text{g}/\text{m}^3$) for the Particulate Control Strategies Listed in Table 5.1 - Illinois Standard - 75	C-1
APPENDIX D Isopleth Maps Showing Annual Geometric Means ($\mu\text{g}/\text{m}^3$) for the Sulfur Dioxide Control Strategies Listed in Table 5.2 - Illinois Standard - 40	D-1

REFERENCES

FIGURES AND TABLES

long-range and episode plans is important. Long-range planning implies routine source controls which, as they are tightened according to approved schedules, gradually reduce ambient pollutant levels so that, by some target date, regional air quality standards are met most of the time. Episode alert plans anticipate unacceptably high, short-term (4 hour to 4 day) air pollution levels, usually caused by poor atmospheric ventilation. A peak shaving approach is thus employed, in which, as long-range regulations become effective in reducing ambient pollution levels, the thresholds for alert actions are gradually reduced so that, ideally, the air quality standards are eventually met throughout the region at all times.

For each of these control modes, there are two types of regulations being considered: "per source" and "per unit area." Regulations governing sulfur content of fuels or pounds of permissible particulate emission per pound of process material are examples of "per source" regulations since they prescribe maximum emissions from each individual plant but do not limit the number or size of plants in the region. Regulations of this sort are most effective in governing very short-term (1 sec- 1 hr) peaks. Long-term levels, as well as certain episode situations, can best be governed by limiting the density of emissions (pounds of pollutant per hour per acre). These "per unit area" regulations, in combination with the more typical "per source" versions will form the basis of the control program to be designed for the State. The "per unit area" regulations will be designed to anticipate regional growth by incorporating a regional zoning inventory in the dispersion model calculations.

This report documents the results of extensive computer analyses testing per source regulations for long-term control of emissions of sulfur

dioxide and particulates in the Chicago Metropolitan Air Quality Control Region. The basic input to the analyses is an inventory of sulfur dioxide and particulate emissions acquired by the Environmental Protection Agency with assistance from NAPCA, the Chicago DEC, and Argonne. The inventory reflects emissions from residential, commercial, and industrial sources as of 1968, with some updating of major point sources. This inventory serves as the input to a computerized model of atmospheric dispersion of pollutants in the Chicago region. The calculations then yield profiles of existing air pollution levels.

Per source emission standards for SO_2 and particulates have been formulated in many ways. For example, there are several standard tables of particulate emission limits as functions of existing plant process weight rates. Controls for sulfur dioxide can be specified as maximum percentages of sulfur in coal and oil, or a maximum emission in pounds of sulfur dioxide per million Btu of fuel combustion, or combinations of these. Furthermore, control regulations can be applied uniformly to all sources or selectively according to classifications of sources such as residential, commercial, and industrial. Each combination of emission control standards will be considered as a control strategy for that pollutant. The dispersion model has been augmented by a strategy model in order to provide the user with the ability to easily test a wide range of strategies for control of SO_2 and particulates. The results are displayed in two ways: region-wide profiles of annual geometric means and statistical distributions of pollutant levels for various sampling periods.

This report documents all aspects of the analyses of long-range regulations for control of SO_2 and particulates in the Chicago Metropolitan Air Quality Control Region: dispersion model, strategy model, emission inventory, present regional air quality, a compendium of possible control regulations for SO_2 and particulates, and extensive calculational results.

2.0 The Diffusion Model

2.1 Introduction

This section describes the application of the Air Quality Display Model (AQDM),* a computer program designed to estimate the spacial distribution of sulfur dioxide and particulate concentrations.

The AQDM, which is derived from the Martin-Tikvart [1968] diffusion model, is based on the Gaussian-diffusion equation which describes the spreading, or diffusing, of a plume as it is transported downwind from an elevated, continuously emitting point source. The model is utilized here to compute annual, arithmetic-, and geometric-mean ^{ground-level} pollutant concentrations resulting from specified point and area sources. The model calculates the effects of each source on each receptor for the observed combinations of wind direction, wind speed, and stability class. The relative frequency of occurrence for each combination is then included as a factor, and the resulting data are summed for each receptor over all combinations and all sources. The plume is assumed to be normally distributed about its center line (i.e., a Gaussian distribution) in the vertical direction and distributed as a linear function of crosswind distance in the crosswind direction. The pollutant distribution in the vertical direction is controlled by the magnitude of the vertical standard deviation of pollutant concentration. The program uses the vertical standard deviation values given by Pasquill [1961] and Gifford [1961]. These values are functions of the source-receptor downwind distance and atmospheric stability category. The stability categories (1 through 5, in order of increasing stability) are defined on the basis of the objective criteria specified by Turner [1964]. These categories are used

* A detailed description of the structure of the diffusion and statistical models is given in Appendix A.

to define both the standard deviation of the plume concentration distribution and the mixing depth of the atmosphere.

Input data to the diffusion model consists of receptor data, emission data, and meteorological data. These data will be discussed in detail in later sections.

It is important to note that the diffusion model described above should be applied in the light of certain limitations which include:

- (a) The basis of the model calculations, the point source diffusion formulate, was developed to represent the behavior of plumes from actual point sources. The field data available for confirmation of the plume behavior were obtained from open, flat terrain and for travel distances of no more than a few kilometers in most cases. Thus, the use of the point-source model for urban scale projections has three specific weaknesses: (1) area sources are only imperfectly modeled by "effective point sources;" (2) plume behavior during horizontal transport of more than a few miles is not well known; and (3) plume behavior in regions of varying thermal and surface-roughness characteristics has not been systematically observed.
- (b) The climatological data used in the model calculations is obtained from airport weather observing stations in nearly all cases. Frequently, the character of the lower atmosphere varies significantly between an out-of-town observing site and the urban central region.

- (c) The use of surface meteorological data only in the estimation of mixing-layer depths has not been very successful. Better modeling should result when climatological data based upon vertical wind and temperature soundings is used.
- (d) The emission inventories presently available for use in the model calculations are subject to error, and they cannot fully describe the variability within the urban region.
- (e) The present model uses annual average emission inventory data. However, significant diurnal and seasonal variabilities in emission rates normally occur. Such variabilities are often (partially) correlated with the stability wind rose data. A future version of the model should include co-variable meteorological and emissions data in the development of annual average concentration estimates.

A statistical model [Larsen, 1969] is used to define the distribution of pollutant concentrations at each selected receptor as a function of averaging time, arithmetic average concentration, and standard geometric deviation at the given receptor. This statistical output includes such concentration distribution characteristics as the geometric mean concentration, expected maximum concentration, and standard geometric deviation (all of which are output for each of the specified averaging times).

The Larsen model is constructed on the basis of the following empirical characteristics of pollutant concentration distributions:

- (a) Concentrations are lognormally distributed for all pollutants in all cities for all averaging times.

- (b) The median (geometric mean) concentration is proportional to averaging time raised to an exponent.

From these characteristics, relationships between the arithmetic-mean, geometric-mean, and expected maximum concentrations are obtained. These relationships are illustrated in Figure 2.1. The arithmetic mean is not a function of averaging time, and thus the arithmetic mean line in the figure is horizontal.

The standard geometric deviation, which describes the slope of the concentration-vs-frequency line for a fixed averaging time, does not appear here but is required in order to relate the arithmetic mean to the geometric mean and expected maximum concentration.

Figure 2.1

2.2 Model Calibration

The calibration procedure (repeated for each pollutant) begins with the use of the diffusion model to calculate concentration values at each of the measuring sites (see Tables 2.8 and 2.9). The calculated values at these points will include any input background values. A least-square regression line of observed (i.e., measured) concentration values versus the calculated values is then obtained. This procedure is used to determine the straight line which best fits the plot of calculated vs. observed concentrations. The scatter diagram (Fig 2.2) illustrates the procedure. Each point plotted represents both the calculated and observed concentration values at a given receptor. For each pollutant, then, there is a regression line:

$$\hat{x}_p = A_p + B_p x_p$$

where

$\hat{x}_p$ = observed concentration of pollutant p,

x_p = calculated concentration of pollutant p,

A_p = y-axis (observed concentration) intercept of best-fit line,

B_p = slope of best-fit line.

The observed concentration values include the background concentration. The line of best fit will have the same slope, B_p , whether or not background values are input. Inclusion of background values (which are added to the calculated values) simply shifts the line of best fit to the right. Thus the y-axis intercept, A_p , will automatically account for missing input background concentration values.

Figure 2.2 Calibration of the Dispersion Model

If the regression line adequately describes the relationship between the observed and calculated concentration values, it may then be applied to the region in general (within the range of calculated values used to determine the regression line). The model output would thus be adjusted at each receptor point according to the regression line equation.

To determine if the regression lines are adequate, the coefficient of correlation, a measure of data-scatter about the regression line, is calculated and compared with the maximum theoretical value that could arise due to chance.* The maximum theoretical value is determined for a 5% confidence level (that is, there are fewer than 5 chances in 100 that a coefficient of correlation as high as this value would arise due to random sampling variation). If the coefficient of correlation is greater than the theoretical value, the regression line is used to adjust the calculated values. If, on the other hand, the coefficient of correlation is less than the theoretical value, the regression line will not be used. A poor correlation warns the user that the input data (e.g., emission inventory, meteorological data, and observed concentration data) should be revised and, if an improved correlation does not result, the model assumptions should be reviewed by a meteorologist familiar with such modeling techniques.

The regression lines produced using the 1968 CMAQCR data with a zero input background for both pollutants are as follows:

		<u>R</u>	<u>5%</u>
Particulates	$y = 85.1 + .2145X$	.582	.219
SO ₂	$y = 33.1 + .2355X$	.490	.321

* For a general discussion of these concepts, see Fisher [1954].

These results agree with a calibration run made by NAPCA - using their in-house version of the IPP (Implementation Planning Program).

The regression equations, of the form $x_{\text{observed}} = mx_{\text{calculated}} + B$, represent the best linear fit of the set of pairs $\{x_{\text{observed}}, x_{\text{calculated}}\}$. The observed concentrations can be considered as the superposition of two components: pollutant levels due to (proportional to) emissions in the region and a background (usually assumed steady) due to natural causes such as wind-blown soil and to sources beyond the region. For the CMAQCR, the latter category is probably insignificant. The generally accepted background levels for particulates and SO_2 are 40 and 0 $\mu\text{g}/\text{m}^3$, respectively.

The concentrations $x_{\text{calculated}}$ are those due solely to emissions in the region. If a strategy were to require all sources to cease operations, the regression equation would still yield a value for the expected pollutant levels, namely, the backgrounds (intercepts) 85.1 $\mu\text{g}/\text{m}^3$ for particulates and 33.1 $\mu\text{g}/\text{m}^3$ for SO_2 . Since the Illinois air quality standard for the annual geometric mean of 24-hour averages of particulates is 75 $\mu\text{g}/\text{m}^3$, the arbitrary application of the simple, linear regression equation ensures that regardless of the amount of control, the standard will never be met. This problem - a statistical one - is probably due to the lack of "clean" monitoring stations and thus a lack of sensitivity in the low end of the scale (several of the lowest stations in Illinois are Crystal Lake, 43.6 $\mu\text{g}/\text{m}^3$, Lake Bluff, 59 $\mu\text{g}/\text{m}^3$, and Godfrey, 59 $\mu\text{g}/\text{m}^3$).

The alternative employed to circumvent this problem was to "fit" a line segment through the accepted background values in the lower end and use the original regression line for higher values. The two equations for each

pollutant were then used to adjust the model predictions. The modified calibrations are shown in Figs 2.3 and 2.4. The equations for the new line segments are:

Particulates	$y = 40 + .9231X$	for all $x \leq 65 \mu\text{g}/\text{m}^3$
SO ₂	$y = .4667X$	for all $x \leq 150 \mu\text{g}/\text{m}^3$

Figure 2.3 Modified Particulate Calibration
Based on 1968 Air Quality Data

Figure 2.4 Modified Sulfur Dioxide
Calibration Based on
1968 Air Quality Data

2.3 Emission Inventory

The major portion of the emission inventory for the CMAQCR was collected in 1968 by the State of Illinois, City of Chicago, NAPCA, Argonne and other local agencies. The Implementation Planning Program (IPP) input data format was used (see Fig 2.5 and 2.6) for both point and area sources. Area sources are defined as the aggregation of all sources too small and too numerous to be considered individually. They range in size from 1 square mile in the high, source density areas to 100 square miles in the rural areas. Point sources are those with greater than 50 tons of emissions per year of either SO₂ or particulates. Point source data was collected by personal interview or mailout questionnaires while area source emission figures were estimated based on fuel-use records, population densities, and a residential survey.

The basic IPP inventory received by Argonne has been modified to reflect necessary changes and additions as follows:

1. Since IPP input data format is not compatible with the AQDM code, computer routines were developed to extract and manipulate the required parameters for efficient use with AQDM. Table 2.1 lists the input parameters used with AQDM.
2. Area source emissions were broken down into two categories, industrial and residential/commercial. This apportionment is required to facilitate the simulation of regulation types that are selective to these particular source classes. For example, if a "London Law" (selective control on space heating) were desired, then only the residential/commercial contribution

Figure 2.5 IPP Input Data Form - Point Source

REGION		SOURCE FILE		(point)		RETPUNCHED BY		VERIFIED BY	
NO. OF CARDS									
1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100
101	102	103	104	105	106	107	108	109	110
111	112	113	114	115	116	117	118	119	120
121	122	123	124	125	126	127	128	129	130
131	132	133	134	135	136	137	138	139	140
141	142	143	144	145	146	147	148	149	150
151	152	153	154	155	156	157	158	159	160
161	162	163	164	165	166	167	168	169	170
171	172	173	174	175	176	177	178	179	180
181	182	183	184	185	186	187	188	189	190
191	192	193	194	195	196	197	198	199	200
201	202	203	204	205	206	207	208	209	210
211	212	213	214	215	216	217	218	219	220
221	222	223	224	225	226	227	228	229	230
231	232	233	234	235	236	237	238	239	240
241	242	243	244	245	246	247	248	249	250
251	252	253	254	255	256	257	258	259	260
261	262	263	264	265	266	267	268	269	270
271	272	273	274	275	276	277	278	279	280
281	282	283	284	285	286	287	288	289	290
291	292	293	294	295	296	297	298	299	300
301	302	303	304	305	306	307	308	309	310
311	312	313	314	315	316	317	318	319	320
321	322	323	324	325	326	327	328	329	330
331	332	333	334	335	336	337	338	339	340
341	342	343	344	345	346	347	348	349	350
351	352	353	354	355	356	357	358	359	360
361	362	363	364	365	366	367	368	369	370
371	372	373	374	375	376	377	378	379	380
381	382	383	384	385	386	387	388	389	390
391	392	393	394	395	396	397	398	399	400
401	402	403	404	405	406	407	408	409	410
411	412	413	414	415	416	417	418	419	420
421	422	423	424	425	426	427	428	429	430
431	432	433	434	435	436	437	438	439	440
441	442	443	444	445	446	447	448	449	450
451	452	453	454	455	456	457	458	459	460
461	462	463	464	465	466	467	468	469	470
471	472	473	474	475	476	477	478	479	480
481	482	483	484	485	486	487	488	489	490
491	492	493	494	495	496	497	498	499	500
501	502	503	504	505	506	507	508	509	510
511	512	513	514	515	516	517	518	519	520
521	522	523	524	525	526	527	528	529	530
531	532	533	534	535	536	537	538	539	540
541	542	543	544	545	546	547	548	549	550
551	552	553	554	555	556	557	558	559	560
561	562	563	564	565	566	567	568	569	570
571	572	573	574	575	576	577	578	579	580
581	582	583	584	585	586	587	588	589	590
591	592	593	594	595	596	597	598	599	600
601	602	603	604	605	606	607	608	609	610
611	612	613	614	615	616	617	618	619	620
621	622	623	624	625	626	627	628	629	630
631	632	633	634	635	636	637	638	639	640
641	642	643	644	645	646	647	648	649	650
651	652	653	654	655	656	657	658	659	660
661	662	663	664	665	666	667	668	669	670
671	672	673	674	675	676	677	678	679	680
681	682	683	684	685	686	687	688	689	690
691	692	693	694	695	696	697	698	699	700
701	702	703	704	705	706	707	708	709	710
711	712	713	714	715	716	717	718	719	720
721	722	723	724	725	726	727	728	729	730
731	732	733	734	735	736	737	738	739	740
741	742	743	744	745	746	747	748	749	750
751	752	753	754	755	756	757	758	759	760
761	762	763	764	765	766	767	768	769	770
771	772	773	774	775	776	777	778	779	780
781	782	783	784	785	786	787	788	789	790
791	792	793	794	795	796	797	798	799	800
801	802	803	804	805	806	807	808	809	810
811	812	813	814	815	816	817	818	819	820
821	822	823	824	825	826	827	828	829	830
831	832	833	834	835	836	837	838	839	840
841	842	843	844	845	846	847	848	849	850
851	852	853	854	855	856	857	858	859	860
861	862	863	864	865	866	867	868	869	870
871	872	873	874	875	876	877	878	879	880
881	882	883	884	885	886	887	888	889	890
891	892	893	894	895	896	897	898	899	900
901	902	903	904	905	906	907	908	909	910
911	912	913	914	915	916	917	918	919	920
921	922	923	924	925	926	927	928	929	930
931	932	933	934	935	936	937	938	939	940
941	942	943	944	945	946	947	948	949	950
951	952	953	954	955	956	957	958	959	960
961	962	963	964	965	966	967	968	969	970
971	972	973	974	975	976	977	978	979	980
981	982	983	984	985	986	987	988	989	990
991	992	993	994	995	996	997	998	999	1000

DATE _____
NAME _____
REGION _____
NO OF CARDS _____

IMPLEMENTATION PLANNING PROGRAM
SOURCE FILE (area)

PAGE ____ OF ____
KEYPUNCHED BY _____
VERIFIED BY _____

REGION	SOURCE ID	SOURCE DESCRIPTIVE NAME	LOCATION X (KM)	LOCATION Y (KM)	
		0,0,1	0,0,2	0,0,3	
		0,0,4			
REGION	SOURCE ID	AREA (KM ²)	EMISSION RATE SO2 SUMMER (T/DAY)	EMISSION RATE SO2 WINTER (T/DAY)	EMISSION RATE SO2 ANNUAL (T/DAY)
		0,0,5	0,5,6	0,5,7	0,5,8
REGION	SOURCE ID	EMISSION RATE CO SUMMER (T/DAY)	EMISSION RATE CO WINTER (T/DAY)	EMISSION RATE CO ANNUAL (T/DAY)	EMISSION RATE PART, SUMMER (T/DAY)
		0,5,9	0,6,0	0,6,1	0,6,2
REGION	SOURCE ID	EMISSION RATE PART, WINTER (T/DAY)	EMISSION RATE PART, ANNUAL (T/DAY)	POLITICAL JURISDICTION	STACK HEIGHT (M)
		0,6,3	0,6,4	0,0,8	0,1,2
REGION	SOURCE ID	SOURCE DESCRIPTIVE NAME	LOCATION X (KM)	LOCATION Y (KM)	
		0,0,1	0,0,2	0,0,3	
		0,0,4			
REGION	SOURCE ID	AREA (KM ²)	EMISSION RATE SO2 SUMMER (T/DAY)	EMISSION RATE SO2 WINTER (T/DAY)	EMISSION RATE SO2 ANNUAL (T/DAY)
		0,0,5	0,5,6	0,5,7	0,5,8
REGION	SOURCE ID	EMISSION RATE CO SUMMER (T/DAY)	EMISSION RATE CO WINTER (T/DAY)	EMISSION RATE CO ANNUAL (T/DAY)	EMISSION RATE PART, SUMMER (T/DAY)
		0,5,9	0,6,0	0,6,1	0,6,2
REGION	SOURCE ID	EMISSION RATE PART, WINTER (T/DAY)	EMISSION RATE PART, ANNUAL (T/DAY)	POLITICAL JURISDICTION	STACK HEIGHT (M)
		0,6,3	0,6,4	0,0,8	0,1,2
REGION	SOURCE ID	SOURCE DESCRIPTIVE NAME	LOCATION X (KM)	LOCATION Y (KM)	
		0,0,1	0,0,2	0,0,3	
		0,0,4			
REGION	SOURCE ID	AREA (KM ²)	EMISSION RATE SO2 SUMMER (T/DAY)	EMISSION RATE SO2 WINTER (T/DAY)	EMISSION RATE SO2 ANNUAL (T/DAY)
		0,0,5	0,5,6	0,5,7	0,5,8
REGION	SOURCE ID	EMISSION RATE CO SUMMER (T/DAY)	EMISSION RATE CO WINTER (T/DAY)	EMISSION RATE CO ANNUAL (T/DAY)	EMISSION RATE PART, SUMMER (T/DAY)
		0,5,9	0,6,0	0,6,1	0,6,2
REGION	SOURCE ID	EMISSION RATE PART, WINTER (T/DAY)	EMISSION RATE PART, ANNUAL (T/DAY)	POLITICAL JURISDICTION	STACK HEIGHT (M)
		0,6,3	0,6,4	0,0,8	0,1,2

Figure 2.6 IPP Input Data Form - Area Source

TABLE 2.1

AQDM Input Parameters

1. X-km)
) Coordinate values defining source location
2. Y-km)
3. Size of area source km²
4. Particulate emission rate (annual average given as Tons/day)
5. SO₂ emission rate " " " " "
6. Source type (1 = combustion, 2 = process, 3 = incineration)
7. Standard industrial classification (SIC)
8. Height - m)
9. Exit velocity - M/sec)
10. Exit temperature - °K)
11. Diameter - m)
12. Coal heat content Btu/ton
13. Oil heat content Btu/ton
14. Annual coal rate Tons/day
15. Annual oil rate Tons/day
16. Annual gas rate ft³/day
17. Process weight rate lb/hr
18. Percent sulfur coal - %
19. Percent sulfur oil - %
20. Exhaust gas volume - ACFM
21. Political jurisdiction

01 Illinois outside of	06 Indiana outside of
02 Chicago	07 Lake County
03 Bedford Park	08 Gary
04 Morton Grove	09 E. Chicago
05 McCook	10 Hammond
22. Combustion equipment rated capacity Btu/hr

of each area source would be controlled. Fortunately, the Peoples Gas Light and Coke Company was able to supply detailed figures on fuel use for the different source classes for the City of Chicago on a square mile basis. For area sources in the remainder of the regions, estimates were based on county-wide fuel-use records.

3. During the period from 1963 to present, many source-changes have occurred for various reasons: primarily, conversion to cleaner fuels and installation of control devices. Emission estimates for such major point sources (about 15) were updated.
4. A set of retrieve, sort and analysis computer programs has been developed to analyze the source file in various ways. These routines can generate listings ordered by any of the AQDM input parameters, calculate regionwide totals and percentages of emissions by source classes, fuel use, by type (such as coal, oil, etc.) and plot cumulative frequency distributions of the sources (ordered by emission rates) vs. percent of total region emissions (see Figs 2.7-2.12).

A set of revised distributions can also be generated for each control strategy.

The updated emission inventory or source file, as it is called, contains a total of 459 point sources and 169 area sources. A listing of all sources is given in Table 2.2. The file contains all sources in both the Illinois and Indiana portions of the region.

Figure 2.7 Illinois Process Data for Particulates

Figure 2.8 Illinois Combustion Data for Particulates

Figure 2.9 Illinois Combustion Data for SO₂

Figure 2.10 Chicago Process Data for Particulates

Figure 2.11 Chicago Combustion Data for Particulates

Figure 2.12 Chicago Combustion Data for SO₂

TABLE 2.2

GENERAL SOURCE FILE
CHICAGO METRO AIR QUALITY REGION

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POL IT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
1	009340 CORN PRODUCTS	3	57.2	68.9	0.0	0.0	4.8	33.6
2	014070 48-INSULATIONS	1	15.8	74.2	0.0	0.0	0.2	18.3
3	255070 UNIROYAL JOLIET	1	27.4	27.4	0.0	0.0	9.7	18.3
4	255070 UNIROYAL	1	27.4	27.4	0.0	23.3	0.0	22.9
5	354880 ABBOTT LABS N CGO	1	59.2	131.5	0.0	0.0	0.3	4.6
6	208420 STAUFFER CHEMICAL	1	73.9	39.6	0.0	0.0	1.4	17.0
7	295420 AMER CYANAMID	1	35.2	39.1	0.0	4.2	0.0	33.5
8	035130 CHGO CU & CHEM	1	70.1	56.4	0.0	8.7	0.5	7.3
9	503340 AMOCO CHEMICAL	1	27.2	32.7	0.0	0.0	1.8	23.2
10	312370 PURE OIL CO	1	38.2	56.3	0.0	0.0	0.9	55.5
11	317050 TEXACO REFINERY	1	38.1	50.4	0.0	0.0	2.5	59.5
12	442620 GALLAGHER ASPHALT	1	74.5	45.7	0.0	0.0	0.2	11.6
13	502040 CROWN TRYGG JOLET	1	28.7	39.2	0.0	0.0	0.1	19.2
14	312160 CROWN-TRYGG CORP	1	42.4	59.5	0.0	0.0	0.8	13.4
15	501480 GEO H HARTONG INC	5	54.6	69.6	0.0	0.0	0.0	12.2
16	281800 LIBERTY ASPHALT	1	40.4	131.2	0.0	0.0	0.1	9.1
17	453390 SKOKIE VAL ASPHAL	1	52.8	133.6	0.0	0.0	0.1	6.1
18	501960 STEFFAN BROS INC	1	19.7	107.6	0.0	0.0	0.0	9.1
19	427840 MAYER ASPHALT CO	1	66.9	95.6	0.0	0.0	0.0	10.7
20	501760 MONARCH ASPHALT	1	67.6	96.8	0.0	0.0	0.0	12.8
21	296230 CROWN TRYGG TROY	1	30.0	37.8	0.0	0.0	0.2	16.8
22	302710 GAF CORP 5	1	35.9	45.2	0.0	0.0	0.7	19.5
23	302710 GAF CORP 3	1	35.9	45.2	0.0	0.0	0.5	21.4
24	247120 GIERTZ-MELAHN CO	1	18.8	94.9	0.0	0.0	0.0	9.8
25	208960 WESTRNMETAL ABRSV	1	72.7	37.8	0.0	0.0	2.2	19.8
26	291760 VULCANMTRLS HODK	1	55.3	68.8	0.0	0.0	0.1	22.9
27	452460 JOHNS-MANVILLE WK	1	59.9	136.9	0.0	0.0	0.5	15.3
28	442710 MARBLEHEAD LIME	1	74.6	45.6	0.0	0.0	4.8	22.9
29	MCCOOK STANDARD LINE	5	55.3	71.0	0.0	0.0	25.5	16.3
30	297310 JOHNS MANVILLE J	1	29.4	38.0	0.0	0.0	0.1	12.0
31	302710 GAF CORP 4	1	35.9	45.2	0.0	0.0	0.6	18.0
32	206230 CALUMET STEEL	1	73.9	40.4	0.0	0.0	1.6	30.0
33	206620 COLUMBIA TOOL STL	1	74.0	38.8	0.0	0.0	0.1	15.3
34	452220 GM CRP-CHEVROLET	1	60.2	134.5	0.0	3.0	0.3	76.3
35	206440 CHGO HTS GRY FE F	1	73.5	39.5	0.0	0.0	0.1	18.3
36	502700 GREENLEE FOUNDRY	1	64.7	78.4	0.0	0.0	0.1	18.3
37	431080 WELLS MANUFACTURN	1	61.7	96.5	0.0	0.0	0.0	12.2

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POLIT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
38	028770 CLOW & SONS INC	1	50.1	89.0	0.0	0.0	0.9	24.4
39	249040 WOODRUFF-EDWARDS	10	19.7	99.1	0.0	0.0	0.6	19.8
40	453060 NORTH SHORE FNDY	1	57.6	131.7	0.0	0.0	0.0	12.2
41	322000 MARENGO FOUNDRY	1	0.0	123.0	0.0	0.0	0.1	9.1
42	386410 RYCHMOND FOUNDRY	1	18.7	148.0	0.0	0.0	0.0	12.2
43	416170 MOLINE-MALLEABLE	1	15.7	85.9	0.0	0.0	0.5	21.4
44	205870 ABEX CORP	1	73.9	38.9	0.0	0.0	1.7	10.2
45	30265 HOWARD FDY	2	64.6	82.2	0.0	0.0	0.4	15.0
46	MCCOOK PILET BROS	5	55.4	70.5	0.0	0.0	0.7	12.5
47	207130 HALL ALUMINUM	1	74.2	38.2	0.0	0.0	0.1	9.1
48	014880 W F JOBBINS CO	1	16.7	70.6	0.0	0.0	0.6	13.7
49	MCCOOK REYNOLDS METALS	5	56.2	71.8	0.0	0.0	12.1	19.8
50	207220 BENJ HARRIS CO	1	74.0	39.6	0.0	0.1	1.4	19.3
51	312250 LEMONT MFG CORP	1	40.1	57.1	0.0	0.0	0.1	20.0
52	336370 HARPER CO	4	61.3	97.0	0.0	0.0	0.0	12.3
53	502900 WESTRN ELECTRIC	1	64.5	77.0	0.0	0.0	0.1	20.4
54	452490 JOHNSON MOTORS	1	59.8	134.8	0.0	0.0	0.7	13.7
55	MCCOOK MCCOOK DRUM & BBL	5	55.2	69.0	0.0	0.0	0.2	10.0
56	310720 VULCANMOLD & IRON	1	80.1	49.1	0.0	0.0	0.1	21.3
57	500100 METRO SANI DIST	1	62.0	73.2	0.0	0.0	6.4	49.7
58	JOLIET ARMY AMMO PLANT	1	27.4	27.4	0.0	27.4	38.4	5.0
59	20050 DIXIEMILLS	2	71.3	81.5	0.0	0.0	0.6	50.0
60	16116 CONT ELEV A	2	80.8	62.8	0.0	0.0	0.3	53.4
61	16125 CONT ELEV B	2	79.2	58.4	0.0	0.0	2.1	53.4
62	24895 GARVEYGRAIN	2	80.3	62.1	0.0	0.0	0.6	62.5
63	31015 INDIANAGRAI	2	76.9	56.5	0.0	0.0	1.0	50.0
64	52706 RIALTO ELEV	2	80.1	61.0	0.0	0.0	0.6	62.5
65	55015 SANTEFEELEV	2	70.3	76.3	0.0	0.0	0.2	62.5
66	52722 CONT ELEV C	2	77.2	56.5	0.0	0.0	1.6	75.8
67	42802 NEWCENTURY	2	72.9	74.0	0.0	0.0	0.1	32.5
68	22466 FALSTAFF	2	82.2	61.2	0.0	0.0	0.4	30.0
69	10666 CARGILL	2	79.2	57.4	0.0	0.0	4.3	21.4
70	10725 CENTRALSOYA	2	63.2	84.5	0.0	0.0	0.7	43.2
71	10625 CAMPBELLS	2	68.7	75.0	0.0	0.0	2.3	64.7
72	22890 UNCARBIDE	2	67.4	75.2	0.0	0.0	0.6	22.5
73	26530 GRANDWOODWK	2	69.5	81.2	0.0	0.0	0.5	7.0
74	66415 ZANGERLIE	2	70.4	85.6	0.0	0.0	0.3	15.0
75	63260 TURNER MFG	2	65.5	77.0	0.0	0.0	0.2	15.0

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POLIT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
76	26140	GLOBECABINE	2	71.6	81.4	0.0	0.0	20.0
77	45700	BONNETT	2	69.7	80.0	0.0	0.0	7.0
78	22950	FIELDENTERP	2	74.3	81.6	0.0	0.0	20.0
79	65190	WFHALLPRNT6	2	64.7	86.4	0.0	0.0	11.3
80	06230	ARRCO CARD	2	71.6	80.0	0.0	0.0	14.6
81	28390	HANDSCHYCHE	2	69.5	85.8	0.0	0.0	20.0
82	09120	BLACK PROD	2	74.7	55.0	0.0	0.0	5.0
83	44170	MORTON SALT	2	71.6	83.4	0.0	0.0	15.0
84	58100	STDPASTE&GL	2	67.0	74.4	0.0	0.0	13.4
85	58165	MILLSSTAUFFERCHE	2	75.3	54.4	0.0	0.0	42.0
86	58165	MIXSTAUFFERCHE	2	75.3	54.4	0.0	0.0	50.0
87	58400	STEREOTYPE	2	71.0	84.6	0.0	0.0	5.2
88	58665	STUART OIL	2	67.8	76.1	0.0	0.0	22.9
89	61295	FUMESSHERWIN-WMS	2	75.2	58.7	0.0	0.0	15.0
90	32935	JM CORBETT	2	70.3	76.6	0.0	0.0	15.0
91	49370	POZZOLANPRO	2	66.8	92.7	0.0	0.0	15.0
92	028980	DU-KANE ASPHALT C	1	48.3	91.4	0.0	0.0	18.3
93	09025	BIRD & SON	2	80.1	56.6	0.0	0.0	30.5
94	208000	OWENS ILLINOIS	1	73.8	39.4	0.0	0.0	22.5
95	41140	MARBLEHEAD	2	80.7	61.3	0.0	0.0	22.9
96	68558	MISS. LIME	2	76.0	57.4	0.0	0.0	5.0
97	MCCOOK	MATERIAL SERVICE	5	55.4	72.1	0.0	0.0	14.8
98	31735	INTERLAKE	2	80.0	60.0	0.0	0.0	4.3
99	31735	INTERLAKE	2	80.0	60.0	0.0	0.0	2.5
100	31735	INTERLAKE	2	80.0	60.0	0.0	0.0	14.6
101	31735	INTERLAKE	2	80.0	60.0	0.0	0.0	1.5
102	52455	REPUBLIC ST	2	80.0	58.4	0.0	0.0	4.7
103	52455	REPUBLIC ST	2	80.0	58.4	0.0	0.0	12.6
104	52455	REPUBLIC ST	2	80.0	58.4	0.0	0.0	8.9
105	52455	REPUBLIC ST	2	80.0	58.4	0.0	0.0	11.6
106	63857	USSTEEL	2	81.3	64.2	0.0	0.0	32.9
107	63857	USSTEEL	2	81.3	64.2	0.0	0.0	30.1
108	63857	USSTEEL	2	81.3	64.2	0.0	0.0	2.2
109	63857	USSTEEL	2	81.3	64.2	0.0	0.0	59.3
110	31975	WISCONSINST	2	79.5	60.3	0.0	0.0	5.9
111	31975	WISCONSINST	2	79.5	60.3	0.0	0.0	6.6
112	31975	WISCONSINST	2	79.5	60.3	0.0	0.0	0.8
113	31	WISCONSINST	2	79.5	60.3	0.0	0.0	20.5

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SOURCE	SOURCE NAME	POLIT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
114	22800	FERGUSONFDY	2	71.8	84.2	0.0	0.4	18.3
115	43440	MILLES EQPT	2	69.4	74.8	0.0	0.1	12.2
116	16640	CLARK EQPT	2	71.7	57.9	0.0	0.2	18.3
117	49250	PORTEC	2	75.0	58.9	0.0	0.3	10.0
118	8711	BERKSON&SON	2	72.7	77.1	0.0	0.2	20.0
119	28750	HARCO ALUM	2	64.8	83.0	0.0	0.2	18.0
120	05650	APEX SMELT	2	69.0	79.2	0.0	0.2	18.0
121	44978	NATL LEAD	2	72.2	77.6	0.0	1.7	13.7
122	45300	NATL CAN	2	67.4	72.2	0.0	0.3	20.0
123	52705	RHEEM MFG	2	67.4	66.4	0.0	0.5	11.0
124		MEDILLM. INC	2	70.6	85.0	0.0	2.5	82.0
125		SW MUN. INC.	2	71.3	74.2	0.0	3.7	82.0
126		CALUMETM INC	2	76.9	61.4	0.0	2.8	82.0
127	026940	STANDARD SCREW CO	1	57.3	80.8	0.0	0.0	15.8
128	452280	GRISS-PFLEGER TAN	1	59.7	135.9	0.0	0.3	55.5
129	245710	CHICAGO RAWHIDE	1	19.1	104.1	0.0	0.0	45.8
130	355240	FANSTEEL MTL CORP	1	58.5	130.9	0.0	0.3	30.5
131	303220	US STEEL	1	36.2	43.6	0.0	0.0	38.1
132	453570	U.S. STEEL CORP	1	58.4	132.0	0.0	1.2	56.3
133	452490	JOHNSON MOTORS	1	59.8	134.8	0.0	0.0	11.3
134	505420	O M C BOATS	1	54.1	133.4	0.0	0.0	15.3
135	331600	INTRN HARVESTER	1	52.9	84.1	0.0	0.0	30.5
136	295900	CATERPILLAR	1	31.3	38.0	0.0	0.4	23.8
137	012870	BARBER-GREENE CO	1	17.7	68.5	0.0	0.0	25.3
138	012780	AUSTIN-WESTERN CO	1	18.7	69.0	0.0	0.0	30.5
139	313300	HOUGH DIV INT HAR	1	48.5	125.1	0.0	0.0	13.7
140	461970	WOODSTOCK DIECAST	1	6.7	130.4	0.0	1.0	62.3
141	502900	WESTRN ELECTRIC	1	64.5	77.0	0.0	3.0	76.3
142	458850	GM FISHER BODY	1	52.6	67.4	0.0	0.1	28.1
143	206950	FORD MOTOR CO	1	75.3	38.6	0.0	0.0	24.4
144	255940	AMER PHOTO COPY	1	68.0	98.3	0.0	0.0	9.1
145	298090	LENNONWALL PAPER	1	35.9	41.0	0.0	0.3	18.3
146	310720	VULCANMOLD & IRON	1	80.0	49.1	0.0	0.3	10.1
147	506160	C B Q RAILROAD	1	19.7	69.2	0.0	0.0	45.6
148	307690	GM CORP LAGRANGE	5	55.2	71.1	0.0	0.7	29.3
149	285790	SINCLAIR RESEARCH	1	72.9	51.6	0.0	0.0	21.0
150	312170	ARGONNE NATL LABS	1	43.6	62.2	0.0	0.3	46.4
151	013590	DAVIS-AURORA CO	1	15.6	68.9	0.0	0.1	38.1

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POLIT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
152	BFD PK MILES LABS	3	59.7	68.4	0.0	0.3	0.0	9.1
153	BFD PK BORG & BECK DIV	3	62.2	68.5	0.0	0.3	0.0	63.3
154	BFD PK JOHNSON & JOHNSON	3	64.0	68.5	0.0	0.9	0.0	48.0
155	500260 COM EDOLD JOLIET1	1	32.8	38.5	0.0	171.5	1.3	137.3
156	500260 COM EDOLD JOLIET2	1	32.9	38.4	0.0	89.5	39.0	75.6
157	500270 COM EDNEW JOLIET	1	32.1	38.5	0.0	570.0	18.5	168.0
158	507900 WINNETKA MUN ELEC	1	65.8	106.5	0.0	1.4	0.5	75.3
159	500200 COM ED RIDGELAND	1	60.9	72.5	0.0	84.0	1.9	65.0
160	500380 COM ED WAUKEGAN	1	60.5	136.3	0.0	258.0	16.9	125.0
161	502300 COM EDWILL CO 1	1	37.5	53.8	0.0	150.0	6.4	106.5
162	502300 COM EDWILL CO 2	1	37.5	53.9	0.0	316.5	12.3	145.6
163	502320 COM ED N DIV HQ	1	61.5	108.5	0.0	0.0	0.1	22.9
164	GREAT LAKES TRAIN,CTR.	1	56.8	128.1	0.0	18.0	12.6	55.0
165	FT. SHERIDAN	1	58.9	118.0	0.0	2.5	0.3	55.0
166	FEDERAL BLDG	2	73.9	80.3	0.0	0.4	0.6	100.0
167	OHARE AIRPORT	2	52.6	93.2	0.0	1.3	1.9	23.0
168	037710 ROSSI & SONS	1	24.6	13.4	0.0	0.5	0.4	15.2
169	503940 ELGIN STATE HOSP	1	19.7	96.8	0.0	4.6	1.6	68.7
170	507980 STATE-VILLE PEN.	1	34.6	27.6	0.0	2.9	0.9	67.0
171	508000 JOLIETSTATE PEN.	1	36.4	44.3	0.0	0.1	0.7	38.1
172	247630 KERBER PACKING CO	1	20.2	97.0	0.0	1.7	1.0	38.1
173	448530 OVALTINE FOOD PRO	1	45.4	81.5	0.0	1.4	0.0	48.8
174	454680 GENERAL MILLS INC	1	25.4	81.8	0.0	0.2	0.0	21.3
175	009340 CORN PRODUCTS	3	57.1	69.0	0.0	35.5	3.0	81.5
176	285340 HARRIS HUB CO	1	72.2	51.1	0.0	0.2	0.0	33.5
177	012420 AURORA PAPERBOARD	1	18.7	69.4	0.0	0.8	0.1	30.5
178	415960 HAWLEY PRODUCTS	1	16.7	85.7	0.0	0.0	0.0	45.8
179	BFD PK M M M CO	3	59.1	68.5	0.0	0.3	0.0	12.8
180	BFD PK H P SMITH PAPER	3	63.8	68.3	0.0	0.2	0.0	21.4
181	321700 SMITH CHEMICAL WK	1	0.0	85.6	0.0	0.3	0.0	19.8
182	208420 STAUFFER CHEMICAL	1	73.8	39.6	0.0	1.8	0.3	67.0
183	454380 AMER POTASH CORP	1	25.9	81.5	0.0	0.3	0.2	36.6
184	354880 ABBOTT LABS N CGO	1	59.2	130.5	0.0	6.9	0.8	34.1
185	429940 SEARLE & CO	1	63.9	95.5	0.0	0.4	0.0	15.6
186	500920 ABBOTT PARK	1	52.0	127.9	0.0	0.2	0.0	24.4
187	035130 CHGO CU & CHEM	1	70.1	56.4	0.0	0.1	0.2	27.5
188	042690 COSDEM OIL CO	1	78.4	53.4	0.0	0.0	0.0	38.1
189	BFD PK NALCO CHEMICAL CO	3	61.4	68.5	0.0	0.8	0.0	18.9

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POLIT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
190	255070 UNIROYAL	1	27.4	27.4	0.0	21.2	35.5	38.2
191	BFD PK UNION CARBIDE	3	60.3	68.6	0.0	0.4	0.1	45.0
192	355330 GOODYEAR RUBBER	1	54.2	125.8	0.0	0.2	0.0	16.5
193	345820 ARMOUR-DIAL CO	1	12.4	65.6	0.0	0.0	0.0	18.9
194	535220 CLARK REFINERY	1	67.1	55.7	0.0	21.4	0.3	33.6
195	365170 UNION OIL PALATIN	1	40.6	98.7	0.0	0.1	0.0	9.1
196	312370 PURE OIL CO	1	38.2	56.3	0.0	9.7	0.5	30.5
197	317050 TEXACO REFINERY	1	38.1	50.4	0.0	17.9	0.5	30.5
198	505160 TRUMBUL ASPHALT	1	57.8	69.7	0.0	0.3	0.0	18.3
199	206350 CERTAIN-TEED	1	74.2	39.8	0.0	0.4	0.0	15.3
200	452460 JOHNS-MANVILLE WK	1	59.9	136.9	0.0	1.9	2.1	61.5
201	MCCOOK STANDARD LIME	5	55.3	71.0	0.0	3.8	0.8	18.3
202	302710 GAF CORP 1 COAL	1	35.8	45.2	0.0	5.3	3.2	32.3
203	302710 GAF CORP 2 OIL	1	35.8	45.2	0.0	0.1	0.0	53.3
204	416170 MOLINE-MALLEABLE	1	15.7	86.0	0.0	1.0	0.3	30.5
205	206620 COLUMBIA TOOL STL	1	74.0	38.8	0.0	0.3	0.0	47.0
206	452220 GM CRP-CHEVROLET	1	60.1	134.5	0.0	0.3	0.3	68.7
207	430600 TELE TYPE CORP	1	63.0	94.6	0.0	0.6	0.0	19.8
208	286030 KYMAN-GORDON CO	1	70.6	52.6	0.0	5.8	0.9	47.6
209	BFD PK COMRL STAMPING	3	62.4	68.5	0.0	0.2	0.0	15.2
210	506700 TAYLORFORGE	1	64.4	78.2	0.0	0.0	0.1	53.4
211	357910 BLISS-LAUGHLIN IN	1	72.7	46.9	0.0	0.2	0.0	12.3
212	BFD PK CONTNL CAN CO	3	63.1	68.5	0.0	0.4	0.4	45.8
213	53440 STEWARTWARN	2	70.3	86.2	0.0	0.3	0.0	40.0
214	02750 BELDEN MFG	2	64.8	79.8	0.0	0.3	0.0	40.0
215	10550 CORN PRODUC	2	73.2	80.8	0.0	0.3	0.0	40.0
216	34545 BELL FIBRE	2	76.4	65.0	0.0	0.3	0.0	40.0
217	50350 PURE ASPHAL	2	67.3	75.6	0.0	0.3	0.0	40.0
218	08455 BELL FIBRE	2	76.3	65.0	0.0	0.3	0.1	40.0
219	66036 WARD BAKING	2	73.9	70.4	0.0	0.3	0.0	40.0
220	09431 BORG-WARNER	2	71.8	57.8	0.0	0.3	0.0	40.0
221	06091 ARMSTRONG P	2	65.0	78.6	0.0	0.2	0.0	40.0
222	31715 INTER CHEM	2	71.4	84.3	0.0	0.2	0.0	40.0
223	04320 AM LICORICE	2	65.6	85.3	0.0	0.2	0.1	40.0
224	29374 HEWITT-ROBI	2	69.2	72.7	0.0	0.2	0.1	40.0
225	52560 REVERE COPR	2	60.7	85.0	0.0	0.2	0.0	40.0
226	03901 ALLIED CHEM	2	79.8	57.3	0.0	0.2	0.0	40.0
227	26300 GOLDBLATT	2	74.2	79.8	0.0	0.2	0.0	40.0

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POLIT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
228	16030	CHICAGO CAR	2	65.6	73.4	0.0	0.2	40.0
229	43300	MIEHLE-GOSS	2	71.4	78.6	0.0	0.2	40.0
230	38471	LIBBY,MCN,L	2	71.1	58.1	0.0	0.2	10.0
231	37520	LANZIT BOX	2	68.9	76.4	0.0	0.2	40.0
232	58495	STONE CONTA	2	65.3	73.4	0.0	0.2	40.0
233	11965	CONT.CAN	2	71.1	74.5	0.0	0.2	40.0
234	18451	RR DONNELLY	2	75.2	77.2	0.0	0.2	40.0
235	30820	ILL.PACKING	2	72.1	74.5	0.0	0.2	40.0
236	36355	KRAFT FOODS	2	74.8	81.4	0.0	0.2	40.0
237	59840	TEE-PAK	2	71.6	74.8	0.0	0.2	40.0
238	09490	BOWEYS	2	73.2	73.9	0.0	0.2	40.0
239	20710	LRCO PROD.	2	64.5	84.5	0.0	0.2	40.0
240	11270	CHICURLEOHA	2	70.6	77.1	0.0	0.2	40.0
241	53540	ROSENSBAKER	2	67.9	80.0	0.0	0.2	40.0
242	60070	GRIFFITH LP	2	71.3	74.5	0.0	0.2	40.0
243	46145	NOVO IND.	2	75.6	62.4	0.0	0.2	10.0
244	64740	VICTOR MFG.	2	62.4	79.0	0.0	0.2	10.0
245	44976	NATL LEAD	2	72.1	57.9	0.0	0.2	40.0
246	30860	ILLMOULDING	2	69.1	76.9	0.0	0.2	40.0
247	05770	APPLETON EL	2	70.5	86.5	0.0	0.2	40.0
248	44195	MOTOROLA	2	64.4	83.2	0.0	0.2	40.0
249	52110	RELIABLEPCK	2	71.3	72.9	0.0	0.2	40.0
250	61350	PYLENATIONA	2	64.5	83.2	0.0	0.2	40.0
251	78480	PETER HAND	2	72.1	83.6	0.0	0.2	40.0
252	50260	PULLMAN	2	74.3	80.1	0.0	0.2	40.0
253	60910	HUGH LEATHE	2	71.0	84.5	0.0	0.2	40.0
254	68140	ZENITHRADIO	2	61.8	84.3	0.0	0.2	40.0
255	23495	FORD MOTOR	2	78.9	56.3	0.0	0.1	40.0
256	28890	HAW-MELODY	2	65.5	82.0	0.0	0.1	40.0
257	14550	CHIMOLDEDPE	2	64.8	82.7	0.0	0.1	40.0
258	44978	NATL LEAD	2	72.1	77.6	0.0	0.1	40.0
259	60265	BORDEN	2	64.7	77.6	0.0	0.1	10.0
260	48650	PHOENIX CAP	2	69.0	78.0	0.0	0.1	10.0
261	61240	MARTINSENOD	2	71.6	76.8	0.0	0.1	40.0
262	63640	UNITED SCRE	2	68.9	77.8	0.0	0.1	40.0
263	66470	WENDNAGEL	2	72.8	77.3	0.0	0.1	40.0
264	07020	BARNESMETAL	2	64.8	78.1	0.0	0.1	40.0
265	663	WEIL&EISEND	2	70.5	85.0	0.0	0.1	40.0

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POLIT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
266	14700 CHI-ALLIS	2	72.2	83.2	0.0	0.1	0.1	40.0
267	SWIFT CO FUEL	10	87.2	48.4	0.0	0.1	0.0	25.0
268	UNION CARBIDE LINDE COMB	9	87.4	53.1	0.0	22.5	3.2	43.1
269	STAUFFER CHEMCO. FUEL	10	85.9	48.6	0.0	0.1	0.0	9.0
270	UNION CARBIDE POLYETHYLEN	9	87.4	53.3	0.0	15.4	6.2	45.0
271	UNION CARBIDE WHITING COM	7	86.7	57.1	0.0	19.0	6.2	30.0
272	LEVER BROTHERS	10	83.5	59.4	0.0	1.3	0.9	46.0
273	MOBIL OIL FLARE	9	86.1	54.2	0.0	0.4	0.0	60.0
274	ATLANTIC GAS DEA ABS	9	85.8	54.7	0.0	11.4	0.0	30.0
275	CIT SER SOUR STRIP	9	89.5	51.8	0.0	8.1	0.0	21.3
276	ANOCO WAT SOUR STRIP	9	86.4	56.6	0.0	6.8	0.0	40.0
277	MOBIL OIL REFBUILDERS	9	86.1	54.2	0.0	16.7	0.2	18.0
278	WITCO CHEMICAL FUEL	10	85.1	53.6	0.0	0.1	0.0	12.2
279	CITIES SERVICE 25 SCRUBBE	9	89.5	51.8	0.0	6.8	0.0	57.3
280	ATLANTIC BOILERS	9	85.8	54.7	0.0	68.0	1.5	50.0
281	ANOCO WHIT BOILERS	9	86.4	56.6	0.0	13.9	4.8	45.0
282	CIT SER BOILERS	9	89.5	51.8	0.0	20.0	0.2	45.7
283	INLAND STEEL BLK SMTH SHP	9	89.2	56.0	0.0	0.4	0.0	22.0
284	INLAND STEEL PWR GEN 211	9	89.6	56.2	0.0	0.5	0.1	44.0
285	INLAND STEEL PLATE MILL	9	89.2	55.8	0.0	1.7	0.1	46.0
286	INLAND STEEL 10 IN MILL	9	89.0	56.0	0.0	1.1	0.0	46.6
287	INLAND STEEL PWR GEN 301	9	88.0	55.2	0.0	4.9	0.1	68.7
288	INLAND STEEL PWR GEN 305	9	88.0	55.2	0.0	1.4	0.0	68.7
289	INLAND STEEL PWR GEN 401	9	87.7	55.0	0.0	51.7	10.4	44.0
290	INLAND STEEL COKE OVN 3	9	88.0	55.2	0.0	5.8	0.0	70.5
291	INLAND STEEL COKE OVN 2	9	89.6	56.2	0.0	13.6	0.0	76.5
292	INLAND STEEL OPH HRTH 3	9	88.0	55.2	0.0	2.1	0.0	45.8
293	INLAND STEEL OPN HRTH 2	9	89.6	56.2	0.0	11.7	0.0	47.3
294	INLAND STEEL MILLS 1	9	88.4	55.5	0.0	3.5	0.1	45.8
295	INLAND STEEL MILLS 2	9	89.6	56.2	0.0	10.3	0.3	45.8
296	INLAND STEEL BLM MILL 3	9	88.0	55.2	0.0	5.8	0.1	45.9
297	INLAND STEEL SLAB MILL 4	9	87.7	55.0	0.0	1.5	0.0	42.8
298	INLAND STEEL 44 STRIP ML	9	89.6	56.6	0.0	4.9	0.3	44.0
299	INLAND STEEL 76 STRIP ML	9	89.6	56.6	0.0	6.6	0.5	29.0
300	INLAND STEEL TIN MILL	9	89.2	56.0	0.0	0.7	0.0	20.0
301	INLAND STEEL COLD STRIP	9	89.2	56.0	0.0	2.0	0.0	20.0
302	INLAND STEEL SPIKE MILL	9	89.0	56.0	0.0	0.1	0.0	20.0
303	INLAND STEEL 14 IN MILL	9	89.0	56.0	0.0	2.5	0.1	47.3

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POLIT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
304	INLAND STEEL 80 STRIP ML	9	89.6	56.6	0.0	12.6	1.1	37.8
305	YNGSTWN S T 84 IN STRIP	9	89.0	57.3	0.0	0.5	0.1	75.0
306	YNGSTWN S T TIN MILL 1	9	87.5	55.7	0.0	0.0	0.0	20.0
307	YNGSTWN S T SHT MILL 2	9	87.2	55.5	0.0	0.6	0.0	40.0
308	YNGST STEEL POW ST PT	9	88.2	56.3	0.0	4.2	0.7	52.0
309	YNGSTWN S T UTIL BOIL 3	9	88.7	57.3	0.0	0.7	0.1	49.0
310	YNGSTWN S T SMLSS PIPE	9	88.2	56.6	0.0	0.4	0.0	47.0
311	YNGSTN S T MEP MILL	9	87.7	56.8	0.0	0.3	0.0	56.0
312	YNGSTWN S T BLDOM NO 1	9	88.0	56.5	0.0	0.5	0.1	54.0
313	YNGSTWN S T BLMG MILL 2	9	89.0	57.3	0.0	1.1	0.1	49.0
314	YNGSTWN S T OPEN HTH 2	9	87.5	57.1	0.0	0.8	0.0	82.0
315	YNGSTWN S T OPEN HERTH1	9	87.9	56.6	0.0	1.6	0.3	56.0
316	YNGSTWN S T COKE PLANT	9	87.9	56.0	0.0	5.2	0.2	38.6
317	YNGSTWN S T SHEET MILL2	9	87.2	55.5	0.0	0.3	0.1	52.0
318	YNGSTWN S T POWER PT	9	88.2	56.3	0.0	0.0	0.7	52.0
319	YNGSTWN S T STEEL PL	9	88.2	56.3	0.0	43.3	34.3	52.0
320	US STEEL OIL COMBUSTION	8	96.6	51.5	0.0	85.5	3.3	48.0
321	US STEEL COALFOR FUEL	8	96.6	51.5	0.0	118.0	39.9	48.0
322	BETHLEHEM ST EEL BOILERS	6	111.3	53.4	0.0	4.6	0.6	72.0
323	MIDWESTSTEEL	6	111.0	51.6	0.0	1.0	0.2	32.0
324	AMERICAN STEEL FOUNDRIES	10	82.2	52.0	0.0	1.5	0.4	18.0
325	US LEAD REFINERY INC	9	0.0	51.2	0.0	0.1	0.0	37.0
326	TAYLOR CHAIN	10	82.1	53.6	0.0	0.1	0.0	33.6
327	STAND FORGE BOILERS OIL	9	87.9	54.7	0.0	0.2	0.0	40.0
328	SCREW BOLT CORP OF AM	8	99.3	48.6	0.0	0.5	0.2	21.0
329	UN TANK CAR	10	84.6	55.7	0.0	0.4	0.0	27.3
330	COM EDISON STATE LINE	6	82.1	61.5	0.0	375.0	1.1	116.0
331	NIPSCO BURNSHARBOR	6	115.1	53.8	0.0	28.5	0.1	122.0
332	MITCHELL POWER PLANT	8	91.7	53.6	0.0	267.0	5.4	72.0
333	PORTER MEM HOSPITAL	6	121.2	34.4	0.0	1.0	0.0	23.4
334	28335 HAMMOND WHS	2	71.6	72.6	0.0	0.2	0.0	52.8
335	25140 GNL RENDERI	2	70.8	73.5	0.0	0.4	0.0	38.0
336	31071 ILLINIS OI	2	72.9	73.9	0.0	1.1	1.3	45.6
337	17322 DARLING & CO	2	71.3	72.6	0.0	3.4	3.5	47.0
338	17320 DARLING & CO	2	70.8	73.4	0.0	4.7	5.0	84.7
339	10725 CENTRALSOYA	2	63.2	84.5	0.0	10.0	10.5	45.6
340	SQUIR) DING	2	71.6	83.8	0.0	0.2	0.3	12.0
	JOANNA WICK	2	70.6	77.4	0.0	1.8	2.2	76.0

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POLIT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)	
342	53281	ROCK-OLA	2	67.6	82.1	0.0	0.5	0.3	55.0
343	79025	BIRD & SON	2	79.5	56.5	0.0	1.6	2.0	33.0
344	65190	WFHALLPRNTG	2	64.7	86.4	0.0	0.5	0.0	58.0
345	62260	CUNEO PRESS	2	72.7	77.1	0.0	0.5	0.0	42.5
346	26885	G.LAKYSCARE	2	79.8	58.9	0.0	0.8	0.1	33.0
347	49915	PROCTER&GAM	2	71.6	83.7	0.0	8.3	3.6	68.0
348	61295	SHERW2N-WMS	2	75.2	58.7	0.0	5.8	2.5	60.1
349	05040	AMERICAN OI	2	74.2	79.2	0.0	0.3	0.0	105.0
350	41140	MARBL)HEAD	2	80.7	61.3	0.0	5.9	6.9	33.0
351	31735	INTERLAKE	2	73.7	54.7	0.0	7.3	3.3	68.0
352	31735	INTERLAKFIB	2	80.0	60.0	0.0	3.7	1.3	18.0
353	62455	REPUBLIC ST	2	80.0	58.4	0.0	3.7	0.5	33.0
354	63857	USSTEEL	2	81.3	64.2	0.0	5.0	0.8	45.6
355	04095	AMERICAN CA	2	69.4	69.7	0.0	2.3	0.9	63.0
356	66650	WESTERN FEL	2	65.8	76.9	0.0	0.6	0.0	48.5
357	57715	STD. BRANDS	2	69.4	72.1	0.0	1.3	0.6	42.0
358	66515	WESSON OIL	2	65.0	75.5	0.0	0.2	0.0	45.6
359	44895	NAT BISCUIT	2	67.4	67.3	0.0	0.6	0.0	28.0
360	60313	GORDEN BAKI	2	73.9	71.1	0.0	0.3	0.0	45.6
361	06512	ARVEY CORP.	2	67.3	87.5	0.0	0.3	0.2	38.0
362	59100	SUPER.TANNI	2	71.6	82.9	0.0	0.3	0.6	33.0
363	30000	HORWEEN LTH	2	70.8	84.5	0.0	0.5	0.1	24.0
364	14650	CHI.RAWHIDE	2	73.2	83.0	0.0	0.3	0.4	41.0
365		INGERSOLL P	2	72.1	57.9	0.0	1.1	0.1	25.7
366	52705	RHEEM MFG	2	67.4	66.6	0.0	0.4	0.0	55.0
367	28460	HANDY BUTTO	2	68.9	76.9	0.0	0.3	0.4	55.0
368	48540	PETTIBONE-M	2	64.5	82.8	0.0	1.6	0.5	60.0
369		LINK BELT	2	73.4	74.0	0.0	0.2	0.1	47.0
370		WEST.ELECTR	2	64.8	77.2	0.0	0.0	0.0	76.0
371	10625	CAMPBELLS	2	68.7	75.0	0.0	11.3	12.4	67.0
372	60057	GLIDDEN CO	2	69.4	85.8	0.0	3.0	4.0	45.6
373	19500	EJBRACH&SON	2	64.7	81.3	0.0	1.6	0.7	55.0
374	67590	WMWRIGLEYCO	2	74.5	81.3	0.0	0.3	0.0	36.1
375	12195	CONTAINERCO	2	74.8	81.3	0.0	3.8	2.0	59.0
376	12185	CONTAINERCO	2	72.1	82.2	0.0	3.4	1.5	60.0
377	31974	INTERNATHAR	2	68.9	76.8	0.0	8.7	3.4	46.0
378	31975	INTERNATHAR	2	79.7	60.5	0.0	3.0	0.3	33.0
379	31976	INTERNATHAR	2	71.9	57.6	0.0	2.0	1.0	36.1

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POLIT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
380	NORTHWESTPP	2	68.4	87.2	0.0	0.0	0.0	100.0
381	FISK PP OLD	2	71.8	77.4	0.0	89.8	1.8	96.0
382	FISK PP NEW	2	71.8	77.4	0.0	116.7	3.9	147.5
383	CRAWFORD PP	2	66.1	74.8	0.0	303.3	11.2	124.7
384	CALUMET PP	2	80.5	61.8	0.0	22.2	2.0	100.0
385	CENT PARKPS	2	62.8	80.0	0.0	3.3	1.8	79.4
386	MAYFAIR PS	2	64.4	90.1	0.0	3.4	1.8	93.4
387	ROSELAND PS	2	73.2	61.2	0.0	3.0	1.6	72.7
388	SPRFIELD PS	2	66.3	78.8	0.0	2.9	1.5	78.7
389	WESTERN PS	2	69.2	72.2	0.0	2.7	1.4	71.0
390	METROSANTOI	2	62.1	74.0	0.0	47.0	29.0	52.8
391	TAYLORHOMES	2	73.9	72.2	0.0	1.8	0.1	36.7
392	ALBA APTS	2	71.4	79.3	0.0	1.9	0.1	61.0
393	CABRINIHOME	2	73.2	82.7	0.0	1.0	0.1	13.1
394	TRUMBULLAPT	2	79.0	60.5	0.0	1.9	0.1	52.5
395	STATEWAYAPT	2	74.0	74.5	0.0	0.7	0.0	50.5
396	ICKES HOMES	2	73.9	76.6	0.0	0.6	0.0	24.6
397	WENTWORTH A	2	73.9	75.4	0.0	0.5	0.2	36.0
398	LATHROPHOME	2	70.0	86.1	0.0	0.4	0.3	44.3
399	ROCKWELLAPT	2	69.0	79.7	0.0	0.3	0.0	46.2
400	MURRAYHOMES	2	76.1	55.0	0.0	0.2	0.1	23.0
401	HORNERHOMES	2	70.3	80.8	0.0	0.2	0.0	49.2
402	OLDTOWNAPTS	2	73.2	77.4	0.0	0.3	0.1	33.8
403	SANDBURGVIL	2	74.0	83.7	0.0	0.3	0.0	105.0
404	COOKCOHOSP	2	70.3	81.3	0.0	1.0	0.1	82.0
405	ILLINSTTECH	2	73.7	75.3	0.0	0.7	0.0	65.5
406	MERCH. MART	2	73.4	81.3	0.0	0.6	0.5	125.0
407	PRUDENTIAL	2	75.2	80.8	0.0	0.2	0.0	222.0
408	SEARSROEBUC	2	74.0	80.1	0.0	3.9	1.5	65.0
409	GOLDBLATTS	2	74.0	80.3	0.0	2.8	0.2	27.9
410	UNIVCHICAGO	2	76.4	70.2	0.0	5.4	2.5	52.5
411	UNIV.ILL.	2	72.4	80.0	0.0	5.0	1.8	55.0
412	NORTHWESTER	2	75.2	81.8	0.0	2.9	1.3	80.0
413	CHI.VOCATIO	2	78.2	64.5	0.0	0.7	0.2	65.0
414	OHARE AIRPORTJET PLANES	2	51.0	92.0	0.0	0.0	19.7	100.0
415	OHARE AIRPORTTURBOPROPS	2	51.0	92.0	0.0	0.0	0.4	100.0
416	OHARE AIRPORTPISTONS	2	51.0	92.0	0.0	0.0	0.4	100.0
417	MAYFAIRPORTJET PLANES	2	63.6	70.0	0.0	0.0	0.7	100.0

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POLY JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
418	MIDWAYAIRPORTPISTONS	2	63.6	70.0	0.0	0.0	1.1	100.0
419	STAUFFER CHEMICAL CO	10	85.9	48.6	0.0	23.7	0.0	90.0
420	UNION CARBIDE PROCESS	9	87.4	53.4	0.0	0.1	0.2	23.0
421	DUPONT SULF AC MFG	9	87.9	51.3	0.0	35.0	0.0	60.0
422	UNION CARBIDE WHITING	7	86.7	57.1	0.0	0.0	0.3	35.0
423	ATLANTIC FCC STRIP	9	85.8	54.7	0.0	12.5	0.0	40.0
424	AMOCO WHIT SULF REC	9	86.4	56.6	0.0	10.0	0.0	62.0
425	ATLANTIC FCC RESEN	9	85.8	54.7	0.0	5.9	3.3	41.0
426	CIT SER FCC REGEN	9	89.5	51.8	0.0	0.6	1.3	22.5
427	AMOCO WHIT FCC CAT REG	9	86.4	56.6	0.0	22.3	1.2	65.0
428	AMOCO WHIT ING	7	85.8	57.1	0.0	96.3	0.0	55.0
429	MORTIL OIL CAT REGEN	9	86.1	54.2	0.0	0.9	0.7	38.0
430	CIT SER GIBBOTOL	9	89.5	51.8	0.0	6.8	0.0	27.2
431	CIT SER CAUS REGEN	9	89.5	51.8	0.0	0.6	0.0	54.9
432	UNIV ATLAS CEMENT MILL 6	8	90.7	53.5	0.0	36.5	102.0	100.0
433	US STEEL ATLAS HARBOR	8	91.4	53.6	0.0	24.1	50.2	30.0
434	YNGSTWN ST SINTERING	9	88.2	56.6	0.0	0.0	1.2	39.0
435	US STEEL OPENHEARTHS	8	97.0	50.8	0.0	0.0	85.5	51.0
436	YNGSTN S T SCARFING 1	9	88.0	56.8	0.0	0.0	1.1	33.0
437	INLAND STEEL BLAST FURN	9	89.6	56.2	0.0	0.0	0.7	61.0
438	INLAND STEEL BOFS	9	87.7	55.0	0.0	0.0	1.1	36.6
439	INLAND STEEL SINTERING D	9	88.8	56.2	0.0	0.0	1.0	39.6
440	INLAND STEEL COKING PL	9	88.0	55.2	0.0	0.0	11.3	10.0
441	INLAND STEEL OP H PL 2	9	89.6	56.2	0.0	0.0	20.6	50.3
442	YNGST S T SCARFING 2	9	87.9	56.6	0.0	0.0	0.1	33.0
443	US STEEL BLAST FURNACE I	8	98.0	50.8	0.0	0.0	10.4	33.0
444	US STEEL BOF	8	97.7	51.0	0.0	0.0	1.2	45.3
445	INLAND STEEL SINTERING	9	88.8	56.2	0.0	0.0	0.8	39.6
446	US STEEL COKE PLANT	9	99.4	50.4	0.0	0.0	0.7	10.0
447	INLAND STEEL OP HE PL 3	9	88.0	55.2	0.0	0.0	0.4	42.8
448	INLAND STEEL SCARANG	9	89.6	56.2	0.0	0.0	1.5	32.0
449	US STEEL SINTERING PLANT	8	98.6	50.8	0.0	0.0	64.4	37.5
450	HARRISON WN KER REFRACT	10	87.7	50.5	0.0	0.0	0.8	11.3
451	KEEN FNDRY GRAY IRON	7	90.9	40.2	0.0	0.0	0.5	18.3
452	AMER STEEL FOUNDRIES IHW	9	87.4	54.4	0.0	0.0	0.2	14.0
453	AMER STEEL FOUNDRY IHW	9	87.4	54.4	0.0	0.0	0.1	15.0
454	US LEAD REFINERY	9	87.4	51.2	0.0	0.3	0.0	37.0
455	US RED CHLOR	9	87.2	52.5	0.0	0.0	0.9	15.3

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POL IT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
456	US RED SECON AL	9	87.2	52.5	0.0	0.0	0.1	15.3
457	AMER SMELTING AND REFIN	7	85.0	57.3	0.0	0.0	0.3	91.4
458	STAND FORGE PUSHER FCE	9	87.9	54.7	0.0	0.0	1.0	40.0
459	STAND FORGE ROTARY FCE	9	87.9	54.7	0.0	0.0	0.8	40.0
460	AREA SORCE	2	74.0	82.1	2.6	4.4	1.7	40.0
461	AREA SORCE	2	72.4	82.1	2.6	5.7	2.9	40.0
462	AREA SORCE	2	70.8	82.1	2.6	3.4	1.6	40.0
463	AREA SORCE	2	69.2	82.1	2.6	3.8	2.4	40.0
464	AREA SORCE	2	67.6	82.1	2.6	2.8	1.5	10.0
465	AREA SORCE	2	74.0	80.5	2.6	5.1	1.8	40.0
466	AREA SORCE	2	72.4	80.5	2.6	5.6	2.3	40.0
467	AREA SORCE	2	70.8	80.5	2.6	4.5	5.3	40.0
468	AREA SORCE	2	69.2	80.5	2.6	3.6	2.3	40.0
469	AREA SORCE	2	67.6	80.5	2.6	3.5	1.9	10.0
470	AREA SORCE	2	74.0	78.8	2.6	3.0	1.3	40.0
471	AREA SORCE	2	72.4	78.8	2.6	5.0	1.8	40.0
472	AREA SORCE	2	70.8	78.8	2.6	4.8	2.0	40.0
473	AREA SORCE	2	69.2	78.8	2.6	3.9	1.6	40.0
474	AREA SORCE	2	67.6	78.8	2.6	3.6	2.0	10.0
475	AREA SORCE	2	74.2	77.2	2.6	3.2	1.2	40.0
476	AREA SORCE	2	72.4	77.2	2.6	2.0	0.8	40.0
477	AREA SORCE	2	70.8	77.2	2.6	4.4	1.9	40.0
478	AREA SORCE	2	69.2	77.2	2.6	2.7	1.1	40.0
479	AREA SORCE	2	67.6	77.2	2.6	3.0	1.4	10.0
480	AREA SORCE	2	74.0	75.6	2.6	2.8	1.3	40.0
481	AREA SORCE	2	72.4	75.6	2.6	3.4	1.9	40.0
482	AREA SORCE	2	70.8	75.6	2.6	1.3	0.5	40.0
483	AREA SORCE	2	69.2	75.6	2.6	1.2	1.6	40.0
484	AREA SORCE	2	67.6	75.6	2.6	2.3	1.6	40.0
485	AREA SORCE	2	75.6	74.0	2.6	0.9	0.4	10.0
486	AREA SORCE	2	74.0	74.0	2.6	3.9	2.0	40.0
487	AREA SORCE	2	72.4	74.0	2.6	2.1	0.8	40.0
488	AREA SORCE	2	70.8	74.0	2.6	3.8	3.0	40.0
489	AREA SORCE	2	69.2	74.0	2.6	1.2	0.5	40.0
490	AREA SORCE	2	67.6	74.0	2.6	1.7	0.7	10.0
491	AREA SORCE	2	70.8	86.9	10.4	16.0	9.3	10.0
492	AREA SORCE	2	67.6	86.9	10.4	10.1	5.1	10.0
493	AREA SORCE	2	64.4	84.9	10.4	0	4.	0.

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POL IT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
494	AREA SORCE	2	70.8	83.7	10.4	17.3	12.8	40.0
495	AREA SORCE	2	67.6	83.7	10.4	11.1	6.3	10.0
496	AREA SORCE	2	64.4	83.7	10.4	10.6	5.7	10.0
497	AREA SORCE	2	64.4	80.5	10.4	8.2	5.6	10.0
498	AREA SORCE	2	64.4	77.2	10.4	14.6	12.6	10.0
499	AREA SORCE	2	64.4	74.0	10.4	4.4	2.2	40.0
500	AREA SORCE	2	74.0	70.8	10.4	18.5	10.8	10.0
501	AREA SORCE	2	70.8	70.8	10.4	6.7	3.5	10.0
502	AREA SORCE	2	67.6	70.8	10.4	7.7	3.0	10.0
503	AREA SORCE	2	64.4	70.8	10.4	4.8	2.1	10.0
504	AREA SORCE	2	77.2	67.6	10.4	7.2	2.0	10.0
505	AREA SORCE	2	74.0	67.6	10.4	15.4	9.0	10.0
506	AREA SORCE	2	70.8	67.6	10.4	9.2	4.5	10.0
507	AREA SORCE	2	67.6	67.6	10.4	4.6	2.4	10.0
508	AREA SORCE	2	64.4	67.6	10.4	2.3	0.9	10.0
509	AREA SORCE	2	80.5	62.8	10.4	0.6	2.6	40.0
510	AREA SORCE	2	80.5	59.5	10.4	1.2	0.6	40.0
511	AREA SORCE	1	48.3	140.0	259.0	1.0	1.0	10.0
512	AREA SORCE	1	32.2	140.0	259.0	1.0	1.0	10.0
513	AREA SORCE	1	16.1	140.0	259.0	0.3	0.3	10.0
514	AREA SORCE	1	0.0	140.0	259.0	0.3	0.3	10.0
515	AREA SORCE	1	48.3	123.9	259.0	1.3	1.2	10.0
516	AREA SORCE	1	32.2	123.9	259.0	1.0	1.0	10.0
517	AREA SORCE	1	16.1	123.9	259.0	0.3	0.3	10.0
518	AREA SORCE	1	0.0	123.9	259.0	0.3	0.4	10.0
519	AREA SORCE	1	48.3	107.8	259.0	1.0	1.0	10.0
520	AREA SORCE	1	32.2	107.8	259.0	1.0	1.0	10.0
521	AREA SORCE	1	16.1	107.8	259.0	0.3	0.3	10.0
522	AREA SORCE	1	0.0	107.8	259.0	0.3	0.3	10.0
523	AREA SORCE	1	64.4	98.2	64.8	7.5	2.4	10.0
524	AREA SORCE	1	56.3	99.8	64.8	5.6	1.8	10.0
525	AREA SORCE	1	48.3	99.8	64.8	5.6	1.8	10.0
526	AREA SORCE	1	32.2	91.7	259.0	1.9	0.6	10.0
527	AREA SORCE	1	16.1	91.7	259.0	1.9	0.6	10.0
528	AREA SORCE	1	0.0	91.7	259.0	1.1	2.0	10.0
529	AREA SORCE	1	64.4	90.1	64.8	27.4	18.6	10.0
530	AREA SORCE	4	56.3	91.7	64.8	10.9	3.8	10.0
531	AREA SORCE	1	48.3	91.7	64.8	18.8	6.0	10.0

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POL IT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
532	AREA SORCE	2	56.3	83.7	64.8	15.2	6.6	10.0
533	AREA SORCE	1	48.3	83.7	64.8	19.2	6.3	10.0
534	AREA SORCE	1	32.2	75.6	259.0	1.7	2.5	10.0
535	AREA SORCE	1	16.1	75.6	259.0	0.0	1.9	10.0
536	AREA SORCE	1	0.0	75.6	259.0	0.5	0.8	10.0
537	AREA SORCE	1	56.3	75.6	64.8	15.6	6.9	10.0
538	AREA SORCE	1	48.3	75.6	64.8	9.4	3.9	10.0
539	AREA SORCE	1	56.3	67.6	64.8	16.9	3.0	40.0
540	AREA SORCE	1	48.3	67.6	64.8	12.7	4.0	10.0
541	AREA SORCE	1	32.2	59.5	259.0	2.9	2.5	10.0
542	AREA SORCE	1	16.1	59.5	259.0	1.2	1.0	10.0
543	AREA SORCE	1	0.0	59.5	259.0	1.1	2.0	10.0
544	AREA SORCE	2	72.4	59.5	64.8	24.2	14.3	10.0
545	AREA SORCE	2	64.4	59.5	64.8	12.2	6.3	10.0
546	AREA SORCE	1	56.3	59.5	64.8	9.4	3.0	10.0
547	AREA SORCE	1	48.3	59.5	64.8	9.4	3.0	10.0
548	AREA SORCE	2	72.4	51.5	64.8	4.4	2.0	10.0
549	AREA SORCE	1	64.4	51.5	64.8	2.0	0.8	10.0
550	AREA SORCE	1	48.3	43.4	259.0	1.9	0.6	10.0
551	AREA SORCE	1	32.2	43.4	259.0	0.1	0.3	10.0
552	AREA SORCE	1	16.1	43.4	259.0	0.1	0.2	10.0
553	AREA SORCE	1	72.4	43.4	64.8	9.4	3.0	10.0
554	AREA SORCE	1	64.4	43.4	64.8	9.4	3.0	10.0
555	AREA SORCE	1	72.4	35.4	64.8	9.4	3.2	10.0
556	AREA SORCE	1	64.4	35.4	64.8	37.6	12.0	10.0
557	AREA SORCE	0	48.3	27.4	259.0	0.1	0.2	10.0
558	AREA SORCE	1	32.2	27.4	259.0	0.8	1.2	10.0
559	AREA SORCE	1	16.1	27.4	259.0	0.3	0.4	10.0
560	AREA SORCE	1	72.4	27.4	64.8	0.3	0.4	10.0
561	AREA SORCE	1	64.4	27.4	64.8	0.3	0.4	10.0
562	AREA SORCE	1	64.4	11.3	259.0	0.1	0.2	10.0
563	AREA SORCE	1	48.3	11.3	259.0	0.1	0.2	10.0
564	AREA SORCE	1	32.2	11.3	259.0	0.1	0.2	10.0
565	AREA SORCE	1	16.1	11.3	259.0	0.3	0.5	10.0
566	AREA SORCE	7	83.7	57.9	2.6	1.7	0.9	10.0
567	AREA SORCE	7	85.3	56.3	2.6	0.9	0.5	10.0
568	AREA SORCE	10	83.7	56.3	2.6	1.8	1.0	10.0
569	AREA SORCE	9	88.5	54.7	2.6	0.9	0.5	10.0

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POLIT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
570	AREA SORCE	9	86.9	54.7	2.6	0.7	0.4	10.0
571	AREA SORCE	9	85.3	54.7	2.6	0.6	0.3	10.0
572	AREA SORCE	10	83.7	54.7	2.6	0.5	0.3	10.0
573	AREA SORCE	9	88.5	53.1	2.6	1.9	1.0	10.0
574	AREA SORCE	9	86.9	53.1	2.6	2.1	1.2	10.0
575	AREA SORCE	9	85.3	53.1	2.6	0.8	0.4	10.0
576	AREA SORCE	10	83.7	53.1	2.6	0.5	0.3	10.0
577	AREA SORCE	8	94.9	51.5	2.6	0.5	0.3	10.0
578	AREA SORCE	8	93.3	51.5	2.6	0.5	0.3	10.0
579	AREA SORCE	8	91.7	51.5	2.6	0.1	0.0	10.0
580	AREA SORCE	8	90.1	51.5	2.6	0.5	0.3	10.0
581	AREA SORCE	9	88.5	51.5	2.6	1.0	0.5	10.0
582	AREA SORCE	9	86.9	51.5	2.6	1.4	0.8	10.0
583	AREA SORCE	9	85.3	51.5	2.6	2.4	1.3	10.0
584	AREA SORCE	10	83.7	51.5	2.6	1.8	1.0	10.0
585	AREA SORCE	8	98.2	49.9	2.6	0.5	0.3	10.0
586	AREA SORCE	8	96.6	49.9	2.6	0.5	0.3	10.0
587	AREA SORCE	8	94.9	49.9	2.6	0.6	0.4	10.0
588	AREA SORCE	8	93.3	49.9	2.6	0.6	0.4	10.0
589	AREA SORCE	8	91.7	49.9	2.6	0.5	0.3	10.0
590	AREA SORCE	8	90.1	49.9	2.6	1.0	0.5	10.0
591	AREA SORCE	9	88.5	49.9	2.6	4.5	2.6	10.0
592	AREA SORCE	9	86.9	49.9	2.6	1.0	0.6	10.0
593	AREA SORCE	9	85.3	49.9	2.6	0.9	0.5	10.0
594	AREA SORCE	10	83.7	49.9	2.6	1.5	0.8	10.0
595	AREA SORCE	10	80.5	59.5	10.4	0.3	0.2	10.0
596	AREA SORCE	10	80.5	53.1	10.4	1.0	0.6	10.0
597	AREA SORCE	10	80.5	51.5	10.4	1.4	0.8	10.0
598	AREA SORCE	10	80.5	46.7	10.4	1.9	1.0	10.0
599	AREA SORCE	10	83.7	46.7	10.4	4.8	2.7	10.0
600	AREA SORCE	10	86.9	46.7	10.4	4.2	2.3	10.0
601	AREA SORCE	8	90.1	46.7	10.4	3.1	1.7	10.0
602	AREA SORCE	8	93.3	46.7	10.4	8.1	4.4	10.0
603	AREA SORCE	8	96.6	46.7	10.4	7.6	4.1	10.0
604	AREA SORCE	8	99.8	46.7	10.4	1.2	0.7	10.0
605	AREA SORCE	7	80.5	43.4	10.4	0.7	0.4	10.0
606	AREA SORCE	10	83.7	43.4	10.4	2.3	1.3	10.0
607	AREA SORCE	7	86.9	43.4	10.4	3.4	1.8	10.0

GENERAL SOURCE FILE CHICAGO METRO AIR QUALITY REGION

SORCE	SOURCE NAME	POLIT JURIS	X KM	Y KM	AREA	SO2(TN/DA) EMISSIONS	PART(TN/DA) EMISSIONS	STACK HT(M)
608	AREA SORCE	7	90.1	43.4	10.4	0.7	0.4	10.0
609	AREA SORCE	7	93.3	43.4	10.4	1.4	0.8	10.0
610	AREA SORCE	8	96.6	43.4	10.4	2.0	1.1	10.0
611	AREA SORCE	7	99.8	43.4	10.4	1.2	0.7	10.0
612	AREA SORCE	6	103.0	43.4	93.2	4.7	2.7	10.0
613	AREA SORCE	6	112.6	35.4	259.0	3.6	1.8	10.0
614	AREA SORCE	7	80.5	35.4	64.8	3.3	1.9	10.0
615	AREA SORCE	7	88.5	35.4	64.8	4.7	2.6	10.0
616	AREA SORCE	7	96.6	35.4	64.8	7.8	4.2	10.0
617	AREA SORCE	6	104.6	35.4	64.8	1.5	0.8	10.0
618	AREA SORCE	7	80.5	19.3	259.0	4.6	2.6	10.0
619	AREA SORCE	7	96.6	19.3	259.0	1.2	0.7	10.0
620	AREA SORCE	6	112.6	19.3	259.0	3.6	1.9	10.0
621	AREA SORCE	7	80.5	3.2	259.0	1.2	0.7	10.0
622	AREA SORCE	7	96.6	3.2	259.0	0.4	0.2	10.0
623	AREA SORCE	6	112.6	3.2	259.0	0.8	0.4	10.0
624	AREA SORCE	6	112.6	51.5	64.8	0.3	0.1	10.0
625	AREA SORCE	6	120.7	51.5	64.8	0.5	0.3	10.0
626	AREA SORCE	8	99.8	49.9	10.4	0.4	0.3	10.0
627	AREA SORCE	9	86.9	56.3	2.6	0.4	0.3	10.0
628	AREA SORCE	8	90.1	53.1	2.6	0.9	0.5	10.0

2.4 Climatology

This section describes the important meteorological variables necessary to characterize the transport and dispersion of pollutants as computed by the AQDM code.

The CMAQCR has relatively level topography and experiences a high frequency of westerly and southwesterly winds as indicated by the monthly wind roses based on hourly observations at Argonne's meteorology station (Fig. 2.13). While Midway Airport is the official U. S. Weather Bureau reporting station, Argonne is also representative of the prevailing meteorology. Midway data was used in all computations described in this report.

The parameters considered in this computation of pollution concentration are as follows:

Wind Direction - The direction from which the wind is blowing usually measured in degrees with north equal to zero and progressing clockwise. The importance of wind direction is obvious since it determines which area of a region will be downwind of any given pollution source or source cluster.

Wind Speed - The rate at which the air is moving over the surface usually expressed in knots. The relation between wind speed and air pollution is relatively complicated. For example, with elevated sources, low wind speeds under stable conditions are associated with low concentrations at the ground because plumes rise appreciably. With low level sources, low wind speeds are associated with high concentrations since diffusion rates are low.

Figure 2.13 Wind Roses Based on All Hourly Observations.
January 1950-December 1964. 19-foot Level

Stability - Stability is a measure of turbulent mixing in the lower layers of the atmosphere and is a function of the wind speed, incoming solar radiation and surface roughness. It is generally expressed by a stability class number ranging from 1 to 6 where class 6 is the most stable. In Chicago, typical daytime conditions are neutral (4) and occasionally unstable (3). Night time conditions are usually neutral (4) or stable (5).

Mixing Depth - The mixing depth is defined as the height above the surface through which the pollutants are mixed. Since this depth varies greatly from season to season, day to day, and diurnally, it is practical to account for only major changes. The AQDM program used a single input value (the annual average mixing depth) and modifies it according to the stability class. The average value used is based on the balloon soundings taken at Midway.

The approach used in the AQDM model to account for variability in the meteorology over an annual period is to consider discrete bands of wind direction, wind speed and stability.

There are 16 wind directions (compass points), 6 wind speeds bands* and 5 stability classes. These are described in more detail in Appendix A.

For each combination of these bands (480), the relative frequency of occurrence is computed using historical weather data. Tables 2.3-2.7, show these frequencies for 1968 data. For a given receptor the average concentration is then calculated by summing all concentrations (one corresponding to each of the 480 combinations) weighted by the frequency of each combination. The 1968 weather data was used for the calibration of the model while a 15-year summary of data was used in developing regulations.

* 0-3, 4-6, 7-10, 11-16, 17-21, >21 knots.

Table 2.3
ILLINOIS - CHICAGO REGION

METEOROLOGICAL INPUT DATA FOR THE ANNUAL SEASON

AMBIENT TEMPERATURE = 283.8 K 51.4 F

MIXING DEPTH = 1300. METERS

AMBIENT PRESSURE = 993. MILLIBARS

STABILITY CLASS 1		WINDSPEED CLASS				
WIND DIRECTION	1	2	3	4	5	6
N	0.0000	0.0000	0.0	0.0	0.0	0.0
NNE	0.0000	0.0000	0.0	0.0	0.0	0.0
NE	0.0000	0.0002	0.0	0.0	0.0	0.0
ENE	0.0001	0.0002	0.0	0.0	0.0	0.0
E	0.0000	0.0002	0.0	0.0	0.0	0.0
ESE	0.0000	0.0001	0.0	0.0	0.0	0.0
SE	0.0000	0.0002	0.0	0.0	0.0	0.0
SSE	0.0000	0.0001	0.0	0.0	0.0	0.0
S	0.0000	0.0001	0.0	0.0	0.0	0.0
SSW	0.0000	0.0000	0.0	0.0	0.0	0.0
SW	0.0000	0.0002	0.0	0.0	0.0	0.0
WSW	0.0000	0.0001	0.0	0.0	0.0	0.0
W	0.0001	0.0001	0.0	0.0	0.0	0.0
WNW	0.0000	0.0001	0.0	0.0	0.0	0.0
NW	0.0000	0.0001	0.0	0.0	0.0	0.0
NNW	0.0	0.0000	0.0	0.0	0.0	0.0

ILLINOIS - CHICAGO REGION

METEOROLOGICAL INPUT DATA FOR THE ANNUAL SEASON

AMBIENT TEMPERATURE = 283.8 K 51.4 F

FIXING DEPTH = 1300. METERS

AMBIENT PRESSURE = 993. MILLIBARS

STABILITY CLASS 2

WINDSPEED CLASS

WIND DIRECTION	1	2	3	4	5	6
N	0.0003	0.0004	0.0003	0.0	0.0	0.0
NNE	0.0002	0.0004	0.0006	0.0	0.0	0.0
NE	0.0004	0.0012	0.0013	0.0	0.0	0.0
ENE	0.0003	0.0013	0.0019	0.0	0.0	0.0
E	0.0006	0.0016	0.0016	0.0	0.0	0.0
ESE	0.0003	0.0006	0.0006	0.0	0.0	0.0
SE	0.0005	0.0009	0.0006	0.0	0.0	0.0
SSE	0.0003	0.0008	0.0005	0.0	0.0	0.0
S	0.0005	0.0010	0.0009	0.0	0.0	0.0
SSW	0.0003	0.0007	0.0010	0.0	0.0	0.0
SW	0.0005	0.0012	0.0012	0.0	0.0	0.0
WSW	0.0003	0.0009	0.0008	0.0	0.0	0.0
W	0.0008	0.0010	0.0009	0.0	0.0	0.0
WNW	0.0004	0.0009	0.0007	0.0	0.0	0.0
NW	0.0007	0.0011	0.0007	0.0	0.0	0.0
NNW	0.0002	0.0004	0.0003	0.0	0.0	0.0

Table 2.5

ILLINOIS - CHICAGO REGION

METEOROLOGICAL INPUT DATA FOR THE ANNUAL SEASON

AMBIENT TEMPERATURE = 283.8 K 51.4 F

MIXING DEPTH = 1300. METERS

AMBIENT PRESSURE = 993. MILLIBARS

STABILITY CLASS 3

WINDSPEED CLASS

WIND DIRECTION	1	2	3	4	5	6
N	0.0003	0.0006	0.0017	0.0003	0.0000	0.0
NNE	0.0002	0.0005	0.0023	0.0007	0.0001	0.0
NE	0.0005	0.0013	0.0049	0.0009	0.0000	0.0
ENE	0.0004	0.0018	0.0059	0.0007	0.0	0.0
E	0.0007	0.0019	0.0058	0.0004	0.0	0.0
ESE	0.0004	0.0007	0.0014	0.0001	0.0	0.0
SE	0.0008	0.0010	0.0017	0.0001	0.0	0.0
SSE	0.0005	0.0008	0.0021	0.0002	0.0	0.0
S	0.0007	0.0013	0.0035	0.0007	0.0000	0.0000
SSW	0.0006	0.0011	0.0045	0.0011	0.0002	0.0000
SW	0.0007	0.0018	0.0067	0.0019	0.0003	0.0000
WSW	0.0005	0.0011	0.0045	0.0012	0.0001	0.0000
W	0.0009	0.0017	0.0047	0.0011	0.0001	0.0000
WNW	0.0006	0.0012	0.0034	0.0007	0.0001	0.0000
NW	0.0008	0.0014	0.0038	0.0008	0.0001	0.0000
NNW	0.0002	0.0005	0.0019	0.0002	0.0000	0.0000

ILLINOIS - CHICAGO REGION

METEOROLOGICAL INPUT DATA FOR THE ANNUAL SEASON

AMBIENT TEMPERATURE = 283.8 K 51.4 F

MIXING DEPTH = 1300. METERS

AMBIENT PRESSURE = 993. MILLIBARS

STABILITY CLASS 4

WINDSPEED CLASS

WIND DIRECTION	1	2	3	4	5	6
N	0.0005	0.0025	0.0089	0.0111	0.0017	0.0004
NNE	0.0008	0.0041	0.0113	0.0116	0.0017	0.0002
NE	0.0018	0.0069	0.0147	0.0106	0.0010	0.0002
ENE	0.0011	0.0062	0.0137	0.0080	0.0006	0.0001
E	0.0018	0.0069	0.0119	0.0052	0.0004	0.0000
ESE	0.0008	0.0037	0.0060	0.0027	0.0002	0.0
SE	0.0013	0.0056	0.0098	0.0042	0.0002	0.0000
SSE	0.0006	0.0043	0.0113	0.0070	0.0008	0.0001
S	0.0009	0.0065	0.0206	0.0191	0.0028	0.0006
SSW	0.0005	0.0051	0.0197	0.0265	0.0045	0.0010
SW	0.0009	0.0064	0.0183	0.0240	0.0036	0.0007
WSW	0.0004	0.0035	0.0130	0.0211	0.0047	0.0015
W	0.0010	0.0044	0.0141	0.0264	0.0072	0.0026
WNW	0.0007	0.0043	0.0121	0.0227	0.0059	0.0018
NW	0.0010	0.0065	0.0154	0.0272	0.0070	0.0019
NNW	0.0004	0.0031	0.0100	0.0164	0.0035	0.0008

ILLINOIS - CHICAGO REGION

METEOROLOGICAL INPUT DATA FOR THE ANNUAL SEASON

AMBIENT TEMPERATURE = 283.8 K 51.4 F

MIXING DEPTH = 1300. METERS

AMBIENT PRESSURE = 993. MILLIBARS

STABILITY CLASS 5

WINDSPEED CLASS

WIND DIRECTION	1	2	3	4	5	6
N	0.0014	0.0026	0.0023	0.0	0.0	0.0
NNE	0.0015	0.0037	0.0027	0.0	0.0	0.0
NE	0.0039	0.0063	0.0026	0.0	0.0	0.0
ENE	0.0031	0.0064	0.0020	0.0	0.0	0.0
E	0.0061	0.0097	0.0020	0.0	0.0	0.0
ESE	0.0030	0.0049	0.0008	0.0	0.0	0.0
SE	0.0056	0.0085	0.0019	0.0	0.0	0.0
SSE	0.0026	0.0077	0.0033	0.0	0.0	0.0
S	0.0054	0.0145	0.0095	0.0	0.0	0.0
SSW	0.0036	0.0131	0.0099	0.0	0.0	0.0
SW	0.0041	0.0139	0.0094	0.0	0.0	0.0
WSW	0.0017	0.0066	0.0058	0.0	0.0	0.0
W	0.0033	0.0075	0.0086	0.0	0.0	0.0
WNW	0.0023	0.0063	0.0062	0.0	0.0	0.0
NW	0.0043	0.0097	0.0088	0.0	0.0	0.0
NNW	0.0011	0.0032	0.0043	0.0	0.0	0.0

2.5 Air Quality Data

The basis of the model calibration is the air quality data measured at various stations throughout the CMAQCR. Tables 2.8 and 2.9 list the monitoring data available for the 1968 annual averages of particulates and SO_2 (also shown in Fig 2.14). These data are based on compilations of 24-hour averaging times and are derived from hi-vol samplers for particulates and West-Gaeke or equivalent methods for sulfur dioxides.

For security reasons, monitoring equipment is generally housed on municipal buildings, schools, or similar installations. Sampling occurs therefore at heights of 30 to 200 ft above ground level.

As indicated by the high values, the distribution of sampler sites is representative of polluted areas; however, as noted in Section 2.2, it may be desirable to provide for clean, control stations in outlying areas for purposes of estimating background levels.

The AQDM can evaluate concentrations at up to 237 points in the region. These may or may not be coincident with actual measuring sites; however, comparisons with short-term standards (e.g., maximum 24-hour averages) require the standard geometric deviation of measured values so these must be located at measuring sites (there is a limit in AQDM of 12 locations at which the shorter term standards can be evaluated). The 12 output receptors selected for the evaluation of short-term regulations represent the most polluted areas. If the short-term Illinois standards are achieved at these 12, then the air quality in the rest of the region will likely be acceptable. Figures 2.15 and 2.16 show isopleth maps depicting the annual geometric means calculated at 225 points by the calibrated dispersion model using the emission inventory with no regulations applied. Also shown are the 12 receptors used as control points.

SUSPENDED PARTICULATE MONITORING STATIONS

STATION	LOCATION (MILES)		MEASURED VALUE OF ANNUAL ARITHMETIC MEAN CONCENTRATION (MICROGRAMS/METER ³)	STANDARD GEOMETRIC DEVIAT (24HR. AVERAGING TIME)
	X	Y		
1. Chicago # 1	37.70	57.20	101	1.7
2. Chicago # 2	44.00	55.20	137	1.7
3. Chicago # 3	37.90	53.85	102	1.7
4. Chicago # 4	45.40	51.70	168	1.7
5. Chicago # 6	45.90	49.45	155	1.7
6. Chicago # 7	43.10	49.75	141	1.7
7. Chicago # 8	39.00	50.40	133	1.7
8. Chicago # 9	46.20	46.85	112*	1.7
9. Chicago #10	42.30	45.65	131	1.7
10. Chicago #11	43.55	43.15	125	1.7
11. Chicago #12	47.80	43.10	128	1.7
12. Chicago #13	40.30	40.85	134	1.7
13. Chicago #14	44.55	40.65	131	1.7
14. Chicago #15	48.47	40.14	134	1.7
15. Chicago #16	45.20	37.00	125	1.7
16. Chicago #17	47.00	34.40	152	1.7
17. Chicago #18	49.80	34.35	127	1.7
18. Chicago #20	44.00	58.30	110	1.7
19. Cook Cty. # 1	25.10	66.50	80	2.0657
20. Cook Cty. # 2	35.00	61.30	93	2.0091
21. Cook Cty. # 3	42.30	64.30	77	1.8156
22. Cook Cty. # 4	33.70	54.40	95	1.7285
23. Cook Cty. # 5	36.50	50.80	111	1.7462
24. Cook Cty. # 6	31.75	50.00	99	1.6888
25. Cook Cty. # 7	39.70	48.95	132	1.4806

*1969 Data

TABLE 2.8 (cont.)

STATION	LOCATION (MILES)		MEASURED VALUE OF ANNUAL ARITHMETIC MEAN CONCENTRATION (MICROGRAMS/METER ³)	STANDARD GEOMETRIC DEVIATION (24 HR. AVERAGING TIME)
	X	Y		
26. Cook Cty. # 8	36.75	42.80	147	1.4806
27. Cook Cty. # 9	33.80	34.20	94	1.7326
28. Cook Cty. #10	42.70	34.80	119	1.6106
29. Cook Cty. #11	41.20	31.00	93	1.6859
30. Cook Cty. #12	44.40	31.70	107	1.7257
31. Cook Cty. #13	50.00	31.50	113	1.6507
32. Cook Cty. #14	42.25	26.90	74	1.7580
33. Cook Cty. #15	44.55	24.75	76	1.6569
34. Bedford Pk. #1	39.00	42.80	148	1.5732
35. Bedford Pk. #2	39.00	42.50	119	1.5620
36. Chicago Heights	45.85	25.25	236	2.1080
37. Skokie	39.62	60.48	119	1.7687
38. Island Lake	16.40	77.80	88	1.9778
39. Crystal Lake	10.80	75.50	49*	1.6253
40. Joliet-Rivals Pk.	21.80	27.85	96	1.6877
41. Joliet-Gompers Schl.	20.40	26.35	114	1.4706
42. Lockport	23.80	30.65	89	1.9083
43. Mokena	32.20	26.40	76	1.4887
44. Monee	39.40	18.20	77	1.4579
45. Rockdale	20.45	24.80	151	1.6190
46. Romeoville	22.10	34.55	123	1.9577
47. Wilmington	18.95	12.40	98	1.3221
48. Joliet-Rialto Bldg.	22.25	26.15	156	1.4644

*1969 Data

TABLE 2.8 (cont.)

STATION	LOCATION (MILES)		MEASURED VALUE OF ANNUAL ARITHMETIC MEAN CONCENTRATION (MICROGRAMS/METER ³)	STANDARD GEOMETRIC DEVIATION (24 HR. AVERAGING TIME)
	X	Y		
49. Bensenville	30.10	55.05	139	1.6913
50. Morton Grove	38.55	60.80	95	1.6946
51. Winnetka	40.20	65.25	91	1.7782
52. McCook	35.30	44.60	113*	1.5050
53. Addison	26.90	55.95	132	1.7313
54. Downers Grove	24.20	44.55	114	1.9428
55. Elmhurst	29.85	51.57	139	1.5520
56. Wheaton	21.45	49.25	86	1.7925
57. Aurora	10.25	42.45	118	1.5324
58. Elgin	13.00	62.50	105	1.6075
59. Lake Bluff	35.50	77.25	59	1.6494
60. North Chicago	35.50	80.80	98	3.2689+
61. Waukegan	35.75	83.25	85	1.6295
62. #1 Fire Station)	60.70	30.50	203.1	1.88
63. Airport)	56.90	31.80	143.5	1.61
64. Kuny School)	61.40	25.30	83.5	1.74
65. Wirt School) Gary	65.40	31.50	98.8	1.89
66. Ivanhoe School)	55.90	29.60	156.7	1.99
67. Williams School)	62.00	29.20	112.0	1.14
68. Taft School)	59.3	17.7	83.5	1.7
69. Fire Station) Lake	52.80	36.05	143.1	1.7
70. So. Side School) Cty.	52.95	35.25	148.0	1.7

*1969 Data

+Only nine samples - questionable value

TABLE 2.8 (cont.)

STATION	LOCATION (MILES)		MEASURED VALUE OF ANNUAL ARITHMETIC MEAN CONCENTRATION (MICROGRAMS/METER ³)	STANDARD GEOMETRIC DEVIATION (24 HR. AVERAGING TIME)
	X	Y		
71. City Hall)	51.85	30.90	122.0	1.7
72. Goldblatts) Hammond	51.10	31.75	112.5	1.7
73. Water Works)	52.15	37.10	180.9	1.7
74. Marktown)	54.10	34.70	188.5	1.7
75. Fire Station)	54.10	33.20	180.0	1.7
76. Franklin School) East	55.30	33.00	132.4	1.7
77. Roxanna School) Chicago	54.60	31.30	94.8	1.7
78. South Haven)	75.70	18.40	77	1.7
79. Ogden Dunes)	68.00	32.90	75	1.7
80. Chesterton) Porter	75.20	32.20	60	1.7
81. Kouts) Cty.	76.20	11.10	79	1.7
82. Flint Lake)	75.60	24.60	57	1.7

TABLE 2.9

SULFUR DIOXIDE MONITORING STATIONS

STATION	LOCATION (MILES)		MEASURED VALUE OF ANNUAL ARITHMETIC MEAN CONCENTRATION (MICROGRAMS/METER ³)	STANDARD GEOMETRIC DEVIATION (24 HR. AVERAGING TIME)
	X	Y		
1. Chicago # 1	37.70	57.20	47.5	2.90
2. Chicago # 2	44.00	55.20	92.5	1.83
3. Chicago # 3	37.90	53.85	45.0	2.59
4. Chicago # 4	45.40	51.70	89.9	3.12
5. Chicago # 6	45.90	49.45	161.3	1.76
6. Chicago # 7	43.10	49.75	66.1	1.82
7. Chicago # 8	39.00	50.40	119.0	1.87
8. Chicago # 9	46.20	46.85	66.1	2.3
9. Chicago #10	42.30	45.65	79.4	2.12
10. Chicago #11	43.55	43.15	135.0	2.01
11. Chicago #12	47.80	43.10	84.6	1.89
12. Chicago #13	40.30	40.85	68.8	2.63
13. Chicago #14	44.55	40.65	50.3	1.95
14. Chicago #15	48.47	40.14	50.2	2.31
15. Chicago #16	45.20	37.00	15.8	1.94
16. Chicago #17	47.00	34.40	60.9	1.82
17. Chicago #18	49.80	34.35	50.2	2.38
18. Chicago #20	44.00	58.30	116.3	1.74
19. Camp Station	46.00	49.70	309.0	1.7
20. Bedford Park #1	39.00	42.80	140.4	1.76
21. Bedford Park #2	39.00	42.50	88.5	2.17
22. Cook Cty. # 3	42.30	64.30	68.8	2.19
23. Cook Cty. # 6	31.75	50.00	74.0	2.47
24. Cook Cty. # 7	39.70	48.95	105.9	2.13

TABLE 2.9 (cont.)

59

STATION	LOCATION (MILES)		MEASURED VALUE OF ANNUAL ARITHMETIC MEAN CONCENTRATION (MICROGRAMS/METER ³)	STANDARD GEOMETRIC DEVIATION (24 HR. AVERAGING TIME)
	X	Y		
25. Cook Cty. # 8	36.75	42.80	148.0	2.31
26. Cook Cty. #12	44.40	31.70	74.0	2.18
27. Cook Cty. #13	50.00	31.50	113.9	2.08
28. Cook Cty. #15	44.55	24.75	57.8	2.28
29. Elgin	13.00	62.50	29.1	2.4
30. Wheaton	21.45	49.25	27.8	2.4
31. North Chicago	35.50	80.80	29.1	2.4
32. Waukegan	35.75	83.25	34.4	2.4
33. Chicago Heights	45.85	25.25	55.5	2.4
34. South Haven)	75.70	18.40	0.010)	2.4
35. Ogden Dunes)	68.00	32.90	0.011)	2.4
36. Chesterton)	75.20	32.20	0.008)	2.4
37. Flint Lake)	75.60	24.60	0.008)	2.4
38. NASN)	56.50	33.20	0.028)	2.3
E. Chicago				

PPM

Figure 2.14
Monitoring Sites in the CMAQCR

Figure 2.15

Expected Particulate Annual Geometric Means*
(Uncontrolled Emission Inventory) and
12 Selected Receptors

* $\mu\text{g}/\text{m}^3$

COOK COUNTY

DUPAGE COUNTY

125

100

COOK COUNTY

125

WILL COUNTY

LAKE COUNTY

100

Figure 2.16

Expected Sulfur Dioxide Annual Geometric Mean,
(Uncontrolled Emission Inventory) and
12 Selected Receptors

* $\mu\text{g}/\text{m}^3$

COOK COUNTY

DUPAGE COUNTY

COOK COUNTY

WILL COUNTY

LAKE COUNTY

3.0 The Strategy Model

3.1 Control Philosophy

The heart of an implementation plan is its emission control regulations, which set forth requirements for prevention, abatement, and control of a given type of air pollutant and establish a timetable for obtaining compliance with those requirements. These control regulations are written around an emission control strategy, which is a collection of emission limitations. Ideally the emission control strategy is the product of a comprehensive assessment of the nature and extent of the pollution in the region—including a review of existing levels of that type of pollution, the types of sources and their emissions, the techniques available for their control, and the probable increase in source emissions due to urban and economic growth. This latter problem is not directly confronted in the development of "per source" regulations as described in this report but will be the primary objective of "per unit area" regulations to be developed as the next step in the planning program.

The terms emission standard, control strategy, and control regulation are used repeatedly in discussing the development of implementation plans. An emission standard is a limitation placed on each category of the sources of a particular pollutant. The general categories of sources emitting sulfur oxides and particulate matter for which emission standards have been developed are shown in Table 3.1. Stumph and Duprey, 1969, have discussed the various types of emission standards presently in use. An emission control strategy is composed of the various emission standards selected for the different categories of sources. For example, an emission control strategy for particulate matter would include emission standards for combustion sources, industrial process sources, and solid waste disposal sources. After an emission control strategy is developed into a legally enforceable requirement, it is called an

EMISSION STANDARDS	
SULFUR OXIDES	PARTICULATE MATTER
INDUSTRIAL PROCESSES	INDUSTRIAL PROCESSES
FUEL COMBUSTION	FUEL COMBUSTION
	SOLID WASTE DISPOSAL

Table 3.1 General classification of emission standards by sources.

emission control regulation. Control regulations then are the control strategies written with appropriate legal structure and terminology. No attempt is made here to provide this legal description. The objective is rather to present the technical implications of alternate control strategies.

The approach taken in the development of per source strategies is based on NAPCA-developed techniques that are best described by Farmer et al (1970). A compilation of emission standards which are the basis for the control strategies is shown in Tables 3.2 and 3.3, with accompanying Figs 3.1-3.9.* These represent a selection of state-of-the-art methods that were derived from a document prepared by the NAPCA Regional Office by Ken Axetell (now of Division of Control Agency Development). The strategies tested at Argonne are combinations of the standards.

* These will be discussed in Section 4.0

Table 3.2

PARTICULATE MATTER EMISSION CONTROL STANDARDS

Fuel Combustion

- 1* American Society of Mechanical Engineers (ASME) standard number APS-1, first edition, 1966, (modified to maximum of .6 lb-Dust/10⁶Btu instead of .8 lb-Dust/10⁶Btu), Fig. 3.1
- 3. Missouri curve of heat input vs. allowable emissions, Fig. 3.2
- 14. Chicago curve of heat input vs. allowable emissions, Fig. 3.3
- 17. ASME standard APS-1, first edition, Fig. 3.4.
- 18. Curve of heat input vs. allowable emissions, Fig. 3.5

Process Sources

- 7* Bay Area process weight-rate curve, Fig. 3.6
- 15. Limit of .1 grains/SCF in exhaust gas

Incineration

- 11* Incinerators greater than 1000 lb/hr limited to .2 grains/SCF in exhaust gases; all others limited to .35 grains/SCF
- 13. Limit of .1 grain/SCF in exhaust gas
- 16. Limit of .2 grains/SCF in exhaust gas

NOTE: A "London Law" i.e., no particulate emissions from space heating can be applied along with any combination of particulate regulations and is indicated by adding 100 to the regular index number.

* These regulations are an approximation of the proposed Illinois State Regulations.

+ Numbers used to index the emission control standards correspond to a table prepared by K. Axetell, of NAPCA.

Table 3.3

SULFUR DIOXIDE EMISSION CONTROL STANDARDS

Fuel Combustion

- 1.*+ Limit of 2.5 pounds SO_2 per 10^6 BTU input for power plants
 - 1 % sulfur limit in fuels for space heating
 - 1.5% sulfur limit in fuels for all other sources
- 4. 1% sulfur limit in fuels for all sources
- 8. 1.5% sulfur limit in fuels for all sources
- 11. ASME standard APS-1 first edition curve for particulates used for SO_2 with 2 times the allowable emission rate, Fig. 3.7
- 12. Same as 11 except use the same limits for SO_2 as particulates, Fig. 3.8
- 13. Same as 11 except use .6 times the allowable emission rate, Fig. 3.9
- 17. 2% sulfur limit in fuel for all sources
- 18. Same as 1 except power plants limited to 2% sulfur fuels

Process Sources

- 6* Limit SO_2 in exhaust gas to 1500 ppm
- 9. Same as 6 with 1000 ppm limit
- 15. Same as 6 with 500 ppm limit

NOTE: A "London Law" i.e., no sulfur dioxide emissions from space heating can be applied along with any combination of sulfur dioxide regulations. and is indicated by adding 100 to the regular index number.

* These regulations are an approximation of the proposed Illinois State Regulations.

+ Numbers used to index the emission control standards correspond to a table prepared by K. Axetelli, of NAPCA.

Figure 3.1 Particulate Standard - 1
American Society of Mechanical
Engineers, Standard APS-1,
first edition (modified to
.6 lb-Dust/10⁶Btu instead of
.8 lb-Dust/10⁶Btu).

Figure 2.15 Particulate Standard - 3
Missouri Curve of heat input vs.
allowable particulate emissions

Figure 3.3 Particulate Standard - 14
City of Chicago curve of heat
input vs. allowable particulate
ssi

Figure 3.4 Particulate Standard - 17
ASME, APS-1 first edition

Figure 3.5 Particulate Standard - 18
Curve of heat input vs. allowable
particulate emissions

Figure 3.6 Particulate Standard - 7
Bay Area process weight
rate curve

Figure 3.7 Sulfur Dioxide Standard - 11
 APS-1 curve used for sulfur
 dioxide with 2 times the allow-
 able emission rates as those
 for lat

Figure 3.8 Sulfur Dioxide Standard - 12
ASME APS-1 curve used for sulfur
dioxide with same limits as
particulates

Figure 3.9 Sulfur Dioxide Standard - 13
ASME APS-1 curve used for sulfur
dioxide with .6 times the allow-
able emissions rate as those
for particulates

3.2 The Strategy Model Operation

The strategy model consists of a set of computer routines coupled directly to the AQDM model. Through a simplified input technique (a set of numbers corresponding to the emission standards for a given pollutant - Tables 3.2 and 3.3) a strategy can be formulated from a library of emission standards that are built into the code. When a given strategy is selected (many strategies can be tested in a single computer run), the strategy model selectively scans the emission inventory, applies the emissions standard to the designated source type and classes, modifies their emission rates and passes the "regulated" emission inventory to AQDM for air quality evaluation. An example strategy might be:

1-7-11 for particulate

1-6 for sulfur dioxide

These are in fact, the strategies used to approximate the proposed Illinois rules. In combination with strategies based on the emissions regulations given in the table, a "London Law", i.e., no SO₂ or particulate emissions from space heating, can be evaluated.

For each strategy the computerized analysis produces the following:*

1. A regional map of isopleths of the annual geometric mean.
2. A table of revised emissions for each point and area source.*
3. The regionwide reduction and % reduction in emissions from all point sources and from all area sources.

*8-1/2 x 11 copies of this extensive output are not included in this report. An indexed volume of computer output, including these tables, will be provided to the State.

*See Appendix B for a sample set of Computer Output.

4. A comparison at 12 selected points of 24-hour averages with the 1% and maximum-single-day standards for Illinois.+
5. Of the 12 selected dose points, the five worst are identified and a table of all sources, point or area, contributing more than 1% of the estimated concentration is printed

+The 1 hr/day SO_2 standard cannot be evaluated by the Larsen statistical model. This standard, however, should be used to govern emissions and stack-height requirements for major point sources by providing a legal limit to peak, hourly-average ground level concentrations (see Sec 4.5).

3.3 Area Source Calculations

For a given control strategy the emission inventory is processed applying the standard as appropriate. When an area source is encountered, certain simplifying assumptions are made to approximate the effect of the strategy on the numerous sources comprising the area emissions. This section describes how area sources are treated by the strategy model.

Part of the preprocessing of the inventory conducted at Argonne was the resolution of each area source emission into contributions from two source categories; residential-commercial and industrial. This breakdown facilitates the evaluation of selective control by source class.

The following procedures and assumptions were employed for area source evaluation:

1. The sulfur oxide or particulate emission rates are used to calculate thermal rates assuming:
 - a. Both residential and industrial emissions are due to fuel combustion
 - b. The percent of the thermal requirement (calculated from emissions) for each area source, satisfied by coal is approximately 60%. The balance being supplied by oil (Peoples Gas, Light and Coke Co., 1967 residential/commercial survey). The same division is assumed for both residential/commercial and industrial components.
 - c. Assumed fuel properties for area sources are:

		Coal	Oil
heating value	(Btu/lb)	11,000	18,500
sulfur content	(S)	3%	1.5%
ash content	(A)	9%	---
emission factor SO ₂	(Duprey, 1968)	$38 \times S \frac{\text{lb-SO}_2}{\text{ton-coal}}$	$157 \times S \frac{\text{lb-SO}_2}{1000 \text{ gal.oil}}$
emission factor particulate	(Duprey, 1968)	$16 \times A \frac{\text{lb-part.}}{\text{ton-coal}}$	$19 \frac{\text{lb-part.}}{1000 \text{ gal.oil}}$

- d. With the above ratio of coal use and fuel characteristics, the emission contributions for each pollutant are:

	SO ₂	Particulate
coal	83%	96%
oil	17%	4%

That is, for every pound of SO₂ emitted by an area source, .83 lb SO₂ are assumed to come from combustion of coal.

- e. Area source emissions from incineration are not included in the emission inventory and are therefore not considered in the control strategy. Only large incinerators (point sources) are controlled.
- f. The typical size of burning equipment within an area source is assumed to be less than 10×10^6 Btu/hr.

The area-source, control procedure for various emission standard types is summarized as follows:

Particulates

1. Thermal input standard - the assumption that all units are smaller than 10×10^6 Btu/hr input implies a fixed emission limit. For example, the limit for standard 16 would be .15 lb/ 10^6 Btu. This value would be used for all area sources based on the total area thermal rate.
2. London Law - the particulate emissions from residential-commercial portion would simply be zeroed.

SO₂

1. Fuel sulfur limitation - the area source emissions are con-

trolled in proportion to the assumed 3% and 1.5% sulfur content in coal and oil respectively. Selective limitations can be applied to each of the two categories.

2. Thermal input standard - the application of this type of limit in SO_2 is similar to the handling of the thermal input standard for particulates.
3. London Law - the SO_2 emissions for the residential-commercial portion is zeroed.

4.0 Emission Control Standards

4.1 Introduction*

Early Concepts

Early emission standards limited the concentration of pollutants in the effluent gas stream in such terms as pounds per thousand pounds, grains per standard cubic foot, parts per million, and micrograms per standard cubic meter. Concentrations based on pollutant mass per unit gas volume vary with temperature and pressure so correction to standard temperature and pressure is necessary, usually 60°F and 14 pounds per square inch absolute. To prevent circumvention of standards by diluting pollutants with large quantities of air, concentration standards have to be standardized. This is usually accomplished by correcting flue-gas volumes to a percentage of the theoretical quantity of air required for complete combustion of fuel. Because early emission standards were primarily intended for coal-burning boiler plants, pollutant concentrations were corrected to 50% excess air which, for most bituminous coals, results in a carbon dioxide concentration of approximately 12% in the dry flue gas. Unfortunately, emission standards of this type have the following deficiencies:

1. Pollutant concentration, by itself, does not indicate total pollutant discharge, because flue-gas volumes vary considerably.
2. An emission standard specifying a single concentration requires essentially the same degree of control for large and small sources, whereas large sources emit more pollutants and are usually capable of purchasing and operating more efficient collectors.

*This section taken largely from [Stumph and Duprey, 1969].

3. Standardization with respect to percent excess air is meaningful only for pure combustion processes where no other materials are contacted by the fuel or its combustion products.

The first emission standards were derived for coal-fired equipment, but were occasionally applied to incinerators and industrial processes. Emission limits applied to coal-fired equipment were not related to the emission rates of incinerators and industrial processes, and standardization for excess combustion air raised special problems for each.

Collection-efficiency standards are similar to concentration standards in that they (1) do not directly limit total emissions, (2) usually specify a single degree of control regardless of source size, and (3) are subject to circumvention. Regarding the last point, collection efficiency is determined by measuring pollutant flow rate both before and after the collector. The efficiency of many types of collectors increases with the quantity of material passing through them because of the attendant increase in particle size. Some methods of increasing pollutant flow rate include recirculating collected solids and entrainment of larger particles from the process by increasing gas-flow rates. Although these practices often increase collection efficiency, they are usually accompanied by increased emission rates.

New Concepts

The deficiencies associated with concentration and collection-efficiency standards have led to development of more meaningful standards that restrict total emission rate in units such as in pounds per hour. This type of standard eliminates the possibility of circumvention and

directly limits total pollutant discharge to the atmosphere. Another feature of newer standards is that sources with large potential for pollution are being more strictly controlled because they (1) usually contribute a greater pollution load to the atmosphere and (2) can usually afford and maintain more expensive and efficient control devices, due to economics of size. Parameters that reflect source size are also approximate measures of pollution potential. Thus, emission limits for fuel-burning equipment usually vary on the basis of total heat input in millions of Btu per hour, whereas some incinerator standards are based on the total weight of refuse charged in pounds per hour. Many emission standards for industrial processes vary with process-weight rates; others vary with potential-emission rate. Whenever an emission standard applies to a specific industry, any convenient measure of source size usually correlates with pollution potential.

4.2 Fossil Fuel Availability*

Introduction

Fuel switching will be the most widely used method for controlling both particulate and SO_2 emissions from fuel combustion. This results from the fact that the large number of small sources cannot economically control emissions of these pollutants any other way. Furthermore, a recent NAPCA paper implies that no economical control devices for removing SO_2 from flue gas are available to either large or small sources (NAPCA, 1969). Therefore, the feasibility and cost of any control regulation will be affected by the availability of clean fuels. The supply of these fuels to a region is, among other things, a function of prices consumers are willing to pay, the site and location of known reserves, the past investments in exploration by fuel suppliers, and technological advances.

This section is a description of the short-run (1-3 year) supply of low-sulfur fossil fuels in Illinois. Low, medium and high sulfur fuels are defined in here as having $S \leq 1\%$, $1\% < S \leq 3\%$, and $S > 3\%$ respectively, where S is the sulfur content of the fuel. Ash contents of fuels are not discussed in detail in this section. Control devices are available to large and intermediate sources for controlling particulate emissions.

Coal

Coal reserves in the United States represents about 83% of the potential energy from fossil fuels. Estimates of domestic coal reserves on January 1, 1965 indicated that about two-thirds of the coal in the ground is low-sulfur coal. However, bituminous coal, which is the most widely used coal, has only about 30% of its reserves in the low-sulfur category (NAPCA, 1969). This represents about a 200 year supply of low-sulfur bituminous coal based on a 50% recovery rate and 1969 levels of demand (Petkus, E. J., 1970). For electrical power

*The discussion which follows relies heavily on the work done by Jack A. Simon and Hubert E. Risser of the Illinois State Geological Survey and Edward J. Petkus of the Department of Environmental Control, Chicago, Illinois.

generation, the lower rank subbituminous and lignite coals can be used. This increases the potential supply of low-sulfur coals.

Although sufficient reserves of low-sulfur coal exist, there is presently a nationwide shortage of this coal. Many factors have created this shortage. Some of the more important facts are listed below:

1. There is a nationwide shortage of all types of coal. The coal industry experienced a peak demand in 1947, and until the late 50's had a declining market. As a result new mines were not developed substantially. During the 60's the market has expanded considerably. The industry has been unable to adjust to this sudden change because of the lack of capital expenditures and mine development in the 50's. As a result in 1969, as in 1968, demand for coal exceeded production by 20 million tons.
2. The railroad industry did not make investments in new cars for transporting coal during the slump. As a result a shortage in transportation facilities now exist.
3. Very little mine development of lower rank coals has occurred because of the very low demand for this coal.
4. The two largest bituminous coal fields are the Illinois-Indiana-West Kentucky and the Appalachian (primarily, West Virginia) fields. The Illinois field has a limited reserve of low-sulfur coal and most of the low-sulfur coal in the Appalachian field is tied up in long-term contracts to manufacturers of metallurgical coke. At present, the production of low-sulfur coals from this field is not sufficient to meet present demands. The increased demands due to air pollution control can not be supplied by the Appalachian field.

In Illinois about two-thirds of the coal used is consumed by the utilities. Because of mining efficiencies and low transportation costs, the Illinois coal field is the major supplier. Unfortunately, most of the Illinois coal has a high or medium sulfur content. Only about 1% of the reserves in the Illinois field can be classified as low-sulfur coal. Therefore, if low-sulfur coal is to be used the bulk of it will have to be supplied from outside the state.

At the present time the only substantial uncommitted low-sulfur coal reserves are located in Wyoming, Montana and North Dakota (Risser, H. E., 1970). The coal from these fields are lower rank subbituminous and lignite coals. Because little demand for these coals existed in the past, new mines will have to be developed. About three years are required to get a mine in full-scale operation (Simon, J. A., 1970). Furthermore, additional investments by the railroad industry will have to be made in order to transport sufficient quantities of the western coal to Illinois.

From the Illinois mines a substantial supply of medium-sulfur coal is presently available. This coal is either found naturally in the ground or is obtained by washing higher-sulfur coal. The reserves of this medium-sulfur coal is quite large. For active mines it is estimated that a 25 to 30 year supply of this coal can be recovered (Simon, J. A., 1970)

The facts presented above can be summarized in relation to the short-run supply of coal in Illinois as:

1. The short-run supply of low-sulfur coal is quite small.
2. As much as three years will be required to obtain sufficient low-sulfur coal supplies.
This coal will come from outside the state

and would be lower rank coal.

3. A sufficient supply of high rank bituminous, medium-sulfur Illinois coal now exists.

It should also be mentioned that technological improvements in coal desulfurization and gasification are not expected to be sufficient to change the short-run supply picture.

Some Implications Associated with the Use of
Low-Sulfur Coal in Illinois

There are many implications that the use of low-sulfur coal has on the air quality. It is usually assumed that the use of low-sulfur coal will decrease sulfur dioxide emission from coal burning sources to 1/2 or 1/3 of present emission levels. However, the low-sulfur coal available to Illinois is the lower rank subbituminous and lignite coals. These generally have lower heating values (Btu/Ton) than bituminous coal. As a result it may take as much as 1.3 times as much low-sulfur coal to generate the same heat as for medium-sulfur bituminous coal. This implies the 1% low-sulfur coal is equivalent to a 1.3% medium-sulfur coal in terms of emissions of SO₂ per therm of input. It should be pointed out that some of the low-sulfur coals in Wyoming, Montana and North Dakota have the same heat values as Illinois coal and anticipated SO₂ emission reductions would occur.

In addition, if lower heat valued coal is used, the total amount of particulate emission may increase. The argument (regarding ash content) is similar for sulfur dioxides. However, particulate emissions will be affected in another way. The efficiencies of electrostatic precipitators, used to catch particulate matter in flue gas, are known to decrease as the sulfur content of the fuel used decreases because of decreased flue gas conductivity. Therefore, higher particulate emissions can be expected if low-sulfur coal is used.

The economic impact on the state can be quite significant. The coal industry in Illinois is quite dependent on Illinois utilities. Not only is approximately 50% of the coal produced in Illinois sold to the Illinois utilities, but the utility market in Illinois and neighboring states represents the major cause of expansion in the coal market.

It is estimated that "for every one million tons of Illinois coal displaced from the utility market, there will be a subsequent loss of employment of coal miners and a \$10 to \$15 million loss to the State's economy can be anticipated" (Risser, H. E., 1970). Furthermore, utilities tend to make long-term (20 year) contracts with fuel suppliers. Therefore, any loss of demand will probably be irreversible even if Illinois fields can supply sufficient quantities of low-sulfur coal in the future.

Some direct costs associated with using low-sulfur coal from Western sources can be estimated. About a 50% increase in the cost of coal per ton can be expected (Risser, H. E., 1970). This is about \$4 per ton. Assuming an equivalent heat value for the low-sulfur coal and consumption equal to 1968 figures would result in approximately a \$100 million increase in the cost of coal to the Illinois utilities. This cost does not include conversion costs associated with boilers, electrostatic precipitators and storage facilities. The increased costs to other coal users has not been estimated.

Oil

The availability of low-sulfur fuel oil is dependent on the availability of crude oil with lower sulfur contents, import quotas and market conditions. The most critical factors, for Illinois, are the market conditions. Specifically, these represent the relative prices consumers are willing to pay for the different petroleum products refined from crude oil. These include residual oil, distillates, petroleum coke and gasoline.

Residual oils are classified as grades 4, 5 and 6. Grade 4 oil is presently classified as a residual oil for import purposes, but is a blend of distillate and residual oils. Both grade 4 and 5 are used for heating commercial and industrial establishments. Grade 6, heavy oil, is used by public utilities and industrial and commercial consumers. The sulfur content of these fuels range from .5 to 5.0% by weight. However, the majority of the fuel ranges from .75 to 2.5% sulfur (NAPCA, 1969).

It is important to note that based on emissions per therm of input 1.7% sulfur residual oil is equivalent to 1% sulfur coal. To make this calculation a 21×10^6 Btu/Ton heat value for coal and 6.3×10^6 Btu/Bbl* heat value for oil were used. If the lower average heat value for lower rank coals is used in the calculation, the 1% sulfur coal would be equivalent to 2.3% sulfur residual oil.

Distillate fuel oil, grades 1 and 2, are always low in sulfur. They range from .04 to .35% sulfur by weight. These fuels are primarily used for space heating in small residences and commercial buildings.

In the past residual oils in this area, as well as other parts of the country, were considered a by-product of refining crude oil. The market was

* (1 bbl = 42 gal)

such that many refineries turned away from residual oil production to making other petroleum products. In 1957, 14% of domestic crude was made into residual oils. Presently, only 7% is being made into these grades (NAPCA, 1969).

The reason for this trend can be easily explained. Crude oil is refined, among other things, into both residual and distillate fuel oils. The residual oil can be further processed into petroleum coke, gasoline, distillates, etc. Because the markets for these products is much better than the residual market, less residual is made. Therefore, the supply of residual oils can be easily increased if the demand for them increases relative to the demand of the other petroleum products.

Given the right market conditions, considerable supplies of residual oil can be generated by simply shutting down coking plants. This practice has been done by some local petroleum firms to meet the increased demand for residual oil in the Chicago area.

The ultimate availability of fuel oils in Illinois will depend on the availability of lower sulfur content crude oil. Imports of crude into the area are limited because of the water transport system into Illinois; often shipment cannot be made in the winter because of frozen rivers. To further complicate the situation, low-sulfur residual oil imported into Illinois is regulated by the federal government (Risser, H. E., 1970).

For the 1970-71 winter months, it is estimated that a 41×10^3 bbl. per day shortage of fuel oil will exist in Cook and Lake Counties, Illinois, and Lake County, Indiana (Petkus, 1970). This represents about 40% of the daily market. It is felt, however,

that this storage can be satisfied as the market situation changes and the petroleum industry adjusts. The adjustment period is very fast because of the flexibility in production discussed above.

For the State of Illinois the availability of low-sulfur fuel oils can be summarized as:

1. Supplies are very sensitive to market conditions and will increase as demands increase.
2. For the immediate future sufficient supplies exist. However, if a rapid increase in oil utilization occurs (i.e., coal users converting to oil) the presently tight supply situation will be aggravated and a shortage may occur.
3. The long-run situation is more dependent on low-sulfur crude oil supplies than is the short-run situation. Some crudes can be desulfurized which will increase the national supply. However, the Illinois supply is further constrained by poor water transportation routes.

Some Economic Implications

As mentioned above, the short-run supply situation of low-sulfur residual oil is very sensitive to its market price. Unlike coal, residual oil is sold as a by-product of the refining process. Therefore, to increase the supply of residual oil, with a constant supply of crude, a trade-off must be made. If the market, say for petroleum coke, is large enough, the price of both residual oil and coke will rise together. If the coke price increases relative to residual oil prices the supply of residual oil may decrease. Because of this increased competition for oil products, prices will rise regardless of the change in residual oil supplies.

Natural Gas

Natural gas is the cleanest of all fossil fuels. Its sulfur content is almost negligible. Usually, the sulfur content is naturally low; however, if significant amounts of sulfur exist they are easily reduced. The particulate content, although not as small as sulfur, is less than both coal and oil. On a pounds of particulate emission per therm basis, fuels are ranked in decreasing order as, coal in pulverized unit (.76*), coal in hand-fired equipment (.095), residual oil (.015), distillate oil (.011), and natural gas (.0017).

Unfortunately, natural gas is the least abundant fossil fuel. If all potential reserves of gas in the United States are recoverable, there would be only a 50-year supply at the present consumption rate. As more and more natural gas is used for pollution control, the supply will deplete even faster.

The Federal Power Commission regulates the distribution and interstate prices of natural gas. If intrastate prices are high relative to the set interstate prices, regional shortages of natural gas may exist. Since the natural reserves of gas in Illinois represent less than 1% of the national total, gas supplies in Illinois are quite dependent on the Federal Power Commission's price setting policy.

Illinois supplies are also affected by pipeline and storage capacities of the local gas utilities. A considerable time lag would result before existing capacities could be increased.

Presently the Chicago region's natural gas supply is just sufficient to meet existing winter demands. Some gas companies have long waiting lists of potential customers signifying a present gas shortage.

* a 10% ash content assumed.

To increase the winter supply of natural gas for space heating, the gas companies will have to increase their pipeline and storage capacities. The storage areas, usually underground caves, are filled in the summer when demands are low. If the pipeline vs. storage capacity ratio is reduced, then less gas may be available in the summer months. Therefore, those industries and power plants which usually purchase gas on an interruptible basis may not have as much gas available to them. This would result in increased emissions from these sources in the summer months.

The above discussion can be summarized as follows:

1. Both short and long-term supplies of natural gas are limited.
2. Short-term gas supplies could be increased for winter months by increasing storage facilities. However, this may reduce summer supplies. Furthermore, a considerable time lag may be required to increase pipeline and/or storage capacities.
3. Both Federal Power Commission and import policies will affect the supply of natural gas in Illinois.
4. Although gas is naturally clean, it can be expected that prices will rise as demands increase and supplies decrease.

4.3 Description of Particulate Emission Standards*

The collection of standards built into the strategy model is described in this section. While there are many standards currently in use, those included here are representative of those known to produce effective control.

Fuel Combustion Particulate Standards

In 1966 the ASME issued a new model entitled "Recommended Guide for the Control of Dust Emission - Combustion for Indirect Heat Exchangers" commonly known as ASME Standard APS-1. The new ASME model limits the mass-emission rate of particulate matter rather than the in-stack concentration used in the 1949 model. For small-to-medium sources, the maximum emission is .8 lb dust/MBtu. More stringent controls are applied to major sources along with stack height provisions. This is Standard 17 in Table 3.2. A modified version similar in structure but limiting the maximum emission to .6 lb/MBtu (Standard 1 in Table 3.2) has been proposed for Illinois: Both APS-1 versions require a varying degree of control dependent on plant size and stack height. The original ASME Standard APS-1 has had only limited acceptance by state and local air pollution control agencies perhaps due to the following limitations:

1. It is based on meteorological dispersion equations applicable only to single source emissions located on essentially flat terrain. Maximum allowable ground-level concentrations are based on the "critical wind speed" with no consideration for inversion and possible fumigation conditions. Obviously, these assumed conditions do not exist in urban areas nor in areas where irregular terrain or adjacent building negate the theoretical benefits of dispersion.

* This section is taken largely from Stumph and Duprey (1969).

2. Allowable mass-emission rate is dependent on the stack height. Increased stack height can be used to meet the standard in lieu of emission control, although there is no minimum stack-height requirement.
3. The use of a taller stack does not reduce the total quantity of pollutants discharged but merely disperses the effluent over a wider area, perhaps degrading the air elsewhere.
4. The control requirements of the standard are generally lenient compared to other modern regulations and to the degree of control now being applied to new fuel-burning installations. The standard can be restrictive for a plant with a large number of short stacks. However, the trend is to build large plants with a single tall stack, principally for dispersing sulfur dioxide emissions. Any unit burning pulverized coal with 10% ash and 13,000 Btu per pound can comply with the most stringent ASME provision with a collection efficiency of only 87% merely by erecting a tall stack. For example, a 500-megawatt plant with a 700-foot stack can comply with an 87% efficient collector.

Most urban areas, many states, and the Federal government (Federal facilities) use what is commonly known as the sliding scale concept to regulate particulate-matter emissions from fuel-burning equipment. Standard numbers 3,14,18 (Table 3.2) illustrate three of the more restrictive standards that are currently in use. These are the State of Missouri, City of Chicago, and a curve similar to Chicago's but slightly less stringent.

It is common practice to compare collector performance using collection efficiency rather than total pollutant-emission rate. Keeping with this

practice, collection-efficiency requirements for each of the five standards are presented in Table 4.1 for various types and sizes of equipment, based on coal with an average heat content of 11,000 Btu per pound and an ash content of 10%. The efficiency requirements of a sliding scale standard increase with increasing size of the installation and also with increasing emission potential of the source. There is some justification for more restrictive standards, at least for new installations, since the emission standards shown have not yet reached the limits of technical feasibility and are, perhaps, unnecessarily lenient for installations greater than 10,000 million Btu per hour. Plants with even greater capacities are being designed.

Standards based on potential emissions such as the Pennsylvania standard could not be evaluated with the current IPP emission inventory because of insufficient information regarding present control devices and collection efficiencies.

Process Equipment

About 20 years ago, the Los Angeles County Air Pollution Control District developed the so-called process-weight^{table} which restricted total particulate-matter emission rates from industrial processes as a function of the process-weight rate. Process weight is, generally, the total weight of all materials, except gases, introduced into a process. This approach removed dilution as a factor in meeting emission standards and assured increasingly strict control of larger source operations.

The Los Angeles County process-weight regulation was derived after a thorough study of the many metallurgical industries located there. Well-controlled and well-operated plants served as the basis for determining the

TABLE 4.1

Required Collection Efficiencies for Coal-Burning Installations^a

Type of Unit (Emission Factors) ^b	Size 10 ⁶ Btu/hr	Required Collection Efficiency, %, for Various Particulate Control Standards				
		1* +	3	14	17*	18
Pulverized (16A)	100	91.8	94.5	95.6	89.0	94.5
	1,000	93.8, 91.8	97.1	96.7	94.5, 89.0	95.9
	10,000	98.9, 96.8	98.4	97.5	99.0, 97.3	97.3
Pulverized with fly ash reinjection (24A)	100	94.5	96.3	97.0	92.6	96.3
	1,000	95.9, 94.5	98.1	97.8	96.3, 92.6	97.2
	10,000	99.3, 97.9	98.9	98.3	99.4, 98.2	98.2
Spreader stoker with reinjection (20A)	50	93.4	95.1	95.8	91.2	94.7
	100	93.4	95.6	96.4	91.2	95.6
	1,000	95.1, 93.4	97.7	97.4	95.6, 91.2	96.7
Traveling grate stoker (5A)	10	73.9	73.9	78.3	65.2	73.9
	50	73.9	80.4	83.5	65.2	79.1
	100	73.9	82.4	85.6	65.2	82.6
Hand-fired (20)	10	34.0	34.0	45.1	12.1	34.0
	50	34.0	50.5	58.2	12.1	47.3
	100	34.0	56.0	63.7	12.1	56.0

a. Basis: 10% ash, A, and 11,000 Btu/lb

b. Duprey, R. L., Compilation of Air Pollutant Emission Factors, 1968.

* If two numbers appear, the first is for a 150 ft stack and the second for a 300 ft stack. If one number appears, it is independent of stack height.

+ Proposed Illinois Standard.

degree of control that was technically and economically feasible. The application of this regulation also demonstrated that many types of industries, regardless of the specific nature of their products, can comply with the emission limits. The maximum-allowable emission limit was set at 40 pounds per hour.

In 1959, the Bay Area Air Pollution Control District in San Francisco developed still another process-weight standard based on well-controlled process industries found there. They included some of the larger mineral-based operations not found in Los Angeles County. Consequently, the Bay Area Regulation is comparable to the Los Angeles County Regulation in the lower range, but allowable emissions increase at a reduced rate above 40 pounds per hour with increasing size of operation. This standard (No. 7-Fig 2.19) is perhaps more reasonable for a wider-range of source types than the Los Angeles County Regulation and, therefore, has been more widely accepted. It has been proposed for Illinois.

In addition to the Bay Area Standard, a concentration standard of .1 grains/standard cubic foot (#15 in Table 3.2) is considered because it is a traditional statement and can be enforced by stack sampling without detailed knowledge of the time-dependent, process-weight-rate.

Incinerator Particulate Standards

Emission standards specific for incinerators are relatively new and are undergoing revision. Los Angeles County has for many years enforced a concentration standard of 0.3 grain per standard dry cubic foot, corrected to 12% carbon dioxide, without the contribution of auxiliary fuel. This was a level felt to be attainable with well-designed, multiple-chamber incinerators, without control equipment. In 1966, the Federal government applied this standard to its incinerators smaller than 200 pounds per hour and required larger units to meet a standard of 0.2 grain per standard dry cubic foot. These particular standards have been adopted by many other control agencies in the past few years. The State of New Jersey requires that incinerators with capacities greater than 2000 pounds per hour meet a standard of 0.1 grain per standard dry cubic foot, and smaller ones a standard of 0.2 grain per standard dry cubic foot.

Incineration standards available to the strategy model are the proposed Illinois standard (11) and two concentration standards .1 gr/SCF(13) and .2 gr/SCF(16).

4.4 Sulfur Dioxide Emission Control Standards

The fuel combustion standards for SO_2 emissions listed in Table 3.3 can be classified as sulfur-content or process-heat regulations. The two sets are, respectively {1,4,8,17,18} and {1,11,12,13}. Note that standard 1 is a combination of the two types of ordinances.

If standard 1 is ignored for the moment, an a priori ranking of the elements in each standard set by most effective to least effective can be made. It is obvious that a 1-percent sulfur content ordinance, 4, is more effective than a 1.5% ordinance, 3, which is more effective than a 2% ordinance, 17. It is also obvious that standard 18 is more effective than standard 17 but less effective than standard 4. However, the a priori rank of 8 to 18 is not clear. For these regulations a trade-off between power plant emissions and space heating emissions is made. Therefore, the a priori ranked set is {4, (8-18), 17}. The process-heat standards are easily ranked because they are proportional to each other. The ranked set is {13,12,11}.

If a 21×10^6 Ecu/Ton heat value for coal and a 6.3×10^6 Btu/Bbl heat value for residual oil is assumed, an equivalent sulfur-content ordinance for standard 1 can be generated. It would be stated as:

- 1.4% sulfur limit for coal for power plants*
- 2.4% sulfur limit for oil for power plants
- 1% sulfur limit for all fuels for space heating, and
- 1.5% sulfur limit for all fuels for all other sources.

Therefore, for a power plant, coal standard 1 is more effective than standards 8 or 18. For oil-burning power plants, the ranking is not clear.

* $(2.5 \text{ lbs } \text{SO}_2 / 10^6 \text{ Btu})(21 \times 10^6 \text{ Btu/Ton Coal}) / (38 \text{ lbs } \text{SO}_2 / \text{Ton Coal} - \% \text{ Sulfur}) = 1.38\% \text{ sulfur.}$

Since most fossil fuel burning power plants in the Chicago region presently use coal, it should be expected that the short-term ranking will be {4,1,(8-18),17} for the sulfur-content standards.

Because the process-heat* standards have a maximum allowable emission rate per 10^6 Btu input, an equivalent maximum sulfur-content can be calculated in the same manner as the process-heat portion of standard 1 was done.

These equivalent values are:

- 13. A maximum of .27% sulfur for coal
A maximum of .46% sulfur for oil
- 12. A maximum of .44% sulfur for coal
A maximum of .76% sulfur for oil
- 11. A maximum of .88% sulfur for coal
A maximum of 1.5% sulfur for oil

From these results it becomes obvious that standards 13 and 12 are more effective than a 1% ordinance, 4. In addition, all the process-heat standards are more effective than control, 1, for all sources except for oil burning space heating. An a priori ranking between 4 and 11 cannot be made.

From the above results it should be expected that the ranked set of all the fuel combustion emission standards would be {13,12,(4-11),1,(8-18),17}.

The process source standards like the process heat standards are all proportional to each other, making a priori rankings easy. The ranked set is {15,9,6}.

Although an ordinal ranking of all the standards can be made, the degree of effectiveness cannot be obtained without a dispersion model. The dispersion model is also capable of combining standards to determine multiple effects.

* Same as sliding scale or sometimes called thermal input standards.

For example, the 'London Law' can be used in conjunction with any of the above standards. The results of the dispersion model analysis is presented in Section 5.

Before concluding this section some comments concerning the feasibility and flexibility of some of the potential standards are desirable. The feasibility of any of these emission standards will be dependent on the availability of low-sulfur fuels as discussed in Section 4.2 or upon the engineering and economic practicality of sulfur removal techniques. If 1% sulfur coal is required to meet the standards, then the lower rank Western United States coal will have to be used. Since these have lower average heat values than Eastern coal, the maximum sulfur limits equivalent to standards 13, 12, and 11 would be reduced. In any case, the sulfur limits associated with standards 13 and 12 makes the use of coal virtually impossible, thus requiring a shift to oil, natural gas, or nuclear/electric power. The maximum equivalent sulfur limits for oil for standards 13 and 12 are also sufficiently stringent to prevent any significant use of oil since the sulfur content of residual oil normally ranges from .75 to 2.5% by weight. Finally, there is no excess supply of natural gas to allow all coal and oil burners to switch to gas. These facts indicate that, based on fuel availability, neither standard 13 nor 12 is a feasible means for controlling SO_2 emissions. In terms of untapped reserves, standards 11 and 4 are feasible but near-term compliance will be quite difficult for many pollution sources.

Process-heat type standards are important because they explicitly state maximum output per unit thermal input and thus are dependent upon the level of plant operation and not influenced by the choice of fuel. For

example, if 1% Illinois coal with a heat value at 21×10^6 Btu/Ton is burned, 1.8 lbs. of sulfur dioxides are emitted for every 10^6 Btu used.

On the other hand, if 1% Western United States coal with a heat value of 15×10^6 Btu/Ton is burned, 2.5 lbs of sulfur dioxides are emitted per 10^6 Btu's.

4.5 A Control Strategy for the Short Term (1 Hr/Day) Sulfur Dioxide Air Quality Standard

Regional isopleth maps depicting annual geometric means of SO_2 are generally insensitive to emissions from isolated, large sources such as electric utilities. This can be understood by envisioning the elevated plumes as relatively high intensity beams which, depending upon wind speed and direction, touch down and affect a very limited portion of the region. For example, the .2 ppm isopleth due to a major, elevated source may cover from 0-100 square miles of the 5,000 square miles in the region. Since the calculation of annual means reflects not only the intensity of the sources but also the frequency distribution of significant meteorological parameters, the percentage contribution to annual SO_2 means at any given dose point of fossil-fired electric generating stations, which consume over 60% of the coal in the region, may be in the range of 5-15%, especially in the more polluted areas.

Figure 4.1 depicts this situation for one day in January, 1967. The Argonne integrated puff dispersion model was used to describe the transient conditions on the day in question. The total concentration at TAM3* (solid line on first strip chart) is decomposed into contributions from electric power plants, industry, and residential/commercial sources. The importance of a concentrated zone of residential/commercial sources is quite evident and substantiates the effectiveness of a London Law. Utilities are responsible for about 10% of the daily average. Nevertheless, one or more power plants were responsible for a 1-hour peak of .4 ppm, a peak which, while of short duration at TAM3, probably existed elsewhere in the region throughout the 24-hour period.

* Telemetered Air Quality Monitoring Station at Roosevelt Road and State Street operated by the City of Chicago Department of Environmental Control.

FIGURE 4.1

HOURS BEGINNING 1 AM - JANUARY 15 1967

From the foregoing, it is evident that analyses of control strategies based on long-term averages will not be affected significantly by controls on utilities. However, the Illinois air quality standards specify a short-term limit on SO_2 concentrations:

A 1-hour average SO_2 concentration of .42 ppm cannot be exceeded for more than 1 hour per day.

This then is likely to be the governing air quality standard for control of major point sources, in particular utilities.

A per source emission regulation such as listed in Table 3.3 coupled with a stack-height requirement can be written to ensure that this short-term standard is unlikely to be violated. The maximum, 24-hour, SO_2 average, If this 24-hour standard is achieved and permissible 1 day per year, is .17 ppm, if power plants are controlled so that their peak ground-level concentrations are less than .2 ppm, it will be unlikely that the .42 ppm, 1-hour limit will be reached.

An extensive analysis of this problem, while warranted, has not been performed. Nevertheless, some idea of a suitable control strategy can be obtained by considering existing power plants in the region. For convenience, these have been divided into two classes: plants with high stacks and large thermal output per stack (e.g., Will, Crawford, Fisk) and plants (such as Ridgeland) characterized by less advantageous plume-rise conditions.

A representative worst case for dispersion (i.e., likely maximum ground-level concentrations) downwind of plants in the Chicago region with large stacks and plume rise occurs when the plumes are trapped beneath a lid at 1,000 feet. A similar situation for Ridgeland (6 stacks, each 213 feet high) occurs for plumes trapped beneath a lid at 500 feet. (It is assumed that buoyant plumes from large stacks will penetrate a lid at 500 feet and thereby have little influence on regional air quality.) A wind speed of 10 mph is used in both cases.

Curves of peak ground-level concentrations of SO_2 (1-hour averages) as functions of SO_2 emissions are shown for each of these representative worst cases in Figure 4.2. The arrows indicate present SO_2 emissions (IPP inventory) from several power plants in the CMAQCR. It is clear that the suggested .2 ppm threshold is violated at Will County and Crawford (use lower line) and at Ridgeland (use upper line).

The coal burned at Will County and Crawford has a sulfur content of approximately 3%. According to Figure 4.2, a reduction to 1.5% will satisfy the proposed criterion of .2 ppm.

Ridgeland presently burns residual fuel oil. The emission rate of 7,000 lbs. SO_2 /hr is based on the generation of 700 MWelectric at 30% plant efficiency using fuel oil with a sulfur content of .9% by weight. Because of the undesirable stack arrangement at this plant, the peak downwind concentration will occasionally be in the range of .4 ppm. Thus use of low sulfur oil (<.5% by weight) is indicated.

Figure 4.2 Peak SO_2 Concentrations for
Two Meteorological Conditions

5.0 Results and Analysis

5.1 Introduction

Considering the large number of strategies which have been simulated by the control strategy model, it is evident that some efficient method of comparing the relative effectiveness of the different strategies with respect to the air quality they produce had to be developed in conjunction with the isopleth maps which display the air quality corresponding to each individual control strategy (included in Appendices C and D). Specifically, 5 questions regarding the relative control strategy effectiveness must be answered by such comparisons.

1. Do the various measures of air quality which have been generated by the program (amount of land area exceeding each of the standards, number of receptors in excess of the standards) correlate so that only one measure of air quality can be used to rank the effectiveness of the regulations?
2. Which laws generate sufficiently good air quality according to this measure to be able to state that the air quality standards (Table 5.1) have essentially been met?
3. How sensitive is the air quality to reductions in process source emissions vs. combustion source emissions?
4. How sensitive is the air quality to the total amount of emission reduction that each control strategy produces?
5. How sensitive is the air quality to reductions in small source emissions vs. reductions in large source emissions?

AIR QUALITY STANDARDS

Suspended Particulates (24 hour samples)

Standard to be reached by January 1, 1972

Maximum annual geometric mean - 75 micrograms per cubic meter

Maximum concentration of 200 micrograms per cubic meter not to be exceeded more than 1% of the days per year.

Maximum concentration of 260 micrograms per cubic meter not to be exceeded more than 1 day per year.

Sulfur Dioxide

Standard to be reached by January 1, 1972

Maximum geometric mean - 0.015 ppm (24 hour samples) (40 micrograms per cubic meter)

24 hr. concentration of 0.10 ppm not to be exceeded more than 1% of the days per year. (265 micrograms per cubic meter)

24 hr. concentration of 0.17 ppm not to be exceeded more than 1 day/yr. (450 micrograms per cubic meter)

1 hr. concentration of 0.42 ppm not to be exceeded more than 1 hr/day (1100 micrograms per cubic meter)

NOTE: Standards are applicable at each sampling station.

Sulfur Dioxide values may be converted to $\mu\text{g}/\text{M}^3$ using the conversion factor $2645 \mu\text{g}/\text{M}^3 = 1 \text{ ppm}$ at 70°F and 14.7 psia .

In comparing air quality at a particular location in an area to the standard, the calculated expected value based on real air quality data and the Larson Model shall be used to determine if the standard was met or exceeded. (1)

The sampling procedure for suspended particulates shall use the High Volume Sampler. The sampling procedure for sulfur dioxide is the modified West-Gaeke method or the conductivity method calibrated using the modified West-Gaeke method.

TABLE 5.1

In order to answer these questions and to clearly show the significant statistics on each control strategy, Tables 5.2 and 5.4 were developed which list the following information for SO₂ and particulates for each control strategy:

1. The total % reduction of emissions effected by control strategy.
2. The area source (small source) emission reduction.
3. The point source emission reduction.
4. The number of selected receptors exceeding each of the air quality standards, together with the maximum amount that the standard is exceeded.
5. A land area index*.

The last two sets of data are alternate measures of the air quality produced by the control strategy. It should be noted in using these indices that the land area violation measure includes Indiana and the area over Lake Michigan so that in some sense the absolute value of these numbers is open to interpretation. The relative contribution of land area violation over Indiana and the Lake, however, seems to be stable from one control strategy to the next so that the value of land area index as a relative index of effectiveness in achieving Illinois air quality is not hampered.

The receptor violation index is not weakened by the lake problem but one of the receptors is in Indiana. From an examination of the data, this receptor point is frequently in violation. The use of the receptor index is more sensitive to estimation errors in the model. This would seem to indicate that receptor violations in two, or even three, areas may not mean that the control strategy is not necessarily strict enough for compliance with

*The land area index is a measure of the ground level area polluted to a given concentration threshold. The index value is the number of grid points (of a possible 237 in the region) that are contained within this level.

the air quality standards. The combination of these indices provides a sufficiently consistent air quality measure to answer the questions posed above.

A copy of the control strategy table and definitions is included immediately after the control strategy performance table for ease of reference.

Particulate Regulations	Uncontrolled	Controlled	Total Percent Reduction	Area Source Percent Reduction	Point Source Percent Reduction	Number of Selected Receptors ^a Exceeding Annual Geometric Mean Standard	Maximum Violation for Annual Geometric Mean Standard (75) ^b	Number of Selected Receptors Exceeding 1 day Standard	Maximum Violation of 1 day Standard (265)	Number of Selected Receptors Exceeding 1% of the days/yr Standard	Maximum Violation of 1% of the days/yr Standard (200)	Land Area Index for Exceeding Annual Geometric Mean of 75 but Less Than 100	Land Area Index for Exceeding Annual Geometric Mean of 100 but Less Than 125	Land Area Index for Exceeding Annual Geometric Mean of 125
	111	Ch1	1597 ^d	366 ^d	1231 ^d	12	68	12	368	12	313	176	50	9
	114	107	71	52	76	10	17	11	144	11	131	37 ^c	0	0
	103	107	83	90	81	1	13	3	128	4	117	4 ^c	0	0
	118	115	80	89	77	1	14	6	131	9	120	4 ^c	0	0
	117	107	79	88	86	2	14	8	130	9	119	13 ^c	0	0
	14	7	76	59	73	7	15	8	135	11	123	28	0	0
	14	15	76	59	81	8	16	10	140	11	127	29	0	0
	14	15	76	59	81	8	16	10	139	11	126	29	0	0
	3	7	70	59	75	10	20	11	157	11	141	42	0	0
	3	15	69	59	75	10	19	11	154	11	139	46	0	0
	3	15	69	59	75	10	19	11	154	11	139	46	0	0
	13	7	68	51	73	10	21	11	160	11	143	47	0	0
	13	15	69	51	74	10	20	11	156	11	140	48	0	0
	18	7	62	37	70	11	28	11	192	11	142	65	4	0
	17	7	62	37	69	11	28	11	192	11	141	66	4	0
	17	11	61	37	68	11	28	11	190	11	142	69	4	0

- a Twelve receptor throughout the region are selected for detailed analysis.
b This is for the 12 selected receptors
c The majority of the area in violation is outside Illinois.
d Total daily emissions in tons.

TABLE 5.2

TABLE 5.3

PARTICULATE MATTER EMISSION CONTROL STANDARDS

Fuel Combustion

- 1*+ American Society of Mechanical Engineers (ASME) standard number APS-1, first edition, 1966, (modified to maximum of .6 lb-Dust/10⁶Btu instead of .8 lb-Dust/10⁶Btu), Fig. 3.1
- 3. Missouri curve of heat input vs. allowable emissions, Fig. 3.2
- 14. Chicago curve of heat input vs. allowable emissions, Fig. 3.3
- 17. ASME standard APS-1, first edition, Fig. 3.4.
- 18. Curve of heat input vs. allowable emissions, Fig. 3.5

Process Sources

- 7* Bay Area process weight-rate curve, Fig. 3.6
- 15. Limit of .1 grains/SCF in exhaust gas

Incineration

- 11* Incinerators greater than 1000 lb/hr limited to .2 grains/SCF in exhaust gases; all others limited to .35 grains/SCF
- 13. Limit of .1 grains/SCF in exhaust gas
- 16. Limit of .2 grains/SCF in exhaust gas

NOTE: A "London Law" i.e., no particulate emissions from space heating can be applied along with any combination of particulate regulations and is indicated by adding 100 to the regular index number.

* These regulations are an approximation of the proposed Illinois State Regulations.

+ Numbers used to index the emission control standards correspond to a table prepared by K. Axetell, of NAPCA.

Sulfur Oxide Regulations		Uncontrolled		Total Percent Reduction		Area Source Percent Reduction		Point Source Percent Reduction		Number of Selected Receptors ^a Exceeding Annual Geometric Mean Standard		Maximum Violation for Annual Geometric Mean Standard (40) ^b		Number of Selected Receptors Exceeding 1 day Standard		Maximum Violation of 1 day Standard (450)		Number of Selected Receptors Exceeding 1% of the days/yr Standard		Maximum Violation of 1% of the days/yr Standard (260)		Land Area Index Exceeding Annual Geometric Mean of 40 but Less Than 60		Land Area Index Exceeding Annual Geometric Mean of 60 But less Than 80		Land Area Index Exceeding Annual Geometric Mean of 80		
111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139
111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139
Ind	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
4957 ^d	62	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	
716 ^d	57	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	
4241 ^d	63	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	
11	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
69	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
653	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
540	65	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	
31	12	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
31	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

a Twelve receptor throughout the region are selected for detailed analysis.

b This is for the 12 selected receptors.

c The majority of the area in violation is outside Illinois.

d Total daily emissions in tons.

a Twelve receptor throughout the region are selected for detailed analysis.
b This is for the 12 selected receptors.
c The majority of the area in violation is outside Illinois.
d Total daily emissions in tons.

TABLE 5.4

TABLE 5.5

SULFUR DIOXIDE EMISSION CONTROL STANDARDS

Fuel Combustion

- 1.*+ Limit of 2.5 pounds SO_2 per 10^6 BTU input for power plants
 - 1 % sulfur limit in fuels for space heating
 - 1.5% sulfur limit in fuels for all other sources
- 4. 1% sulfur limit in fuels for all sources
- 8. 1.5% sulfur limit in fuels for all sources
- 11. ASME standard APS-1 first edition curve for particulates used for SO_2 with 2 times the allowable emission rate, Fig. 3.7
- 12. Same as 11 except use the same limits for SO_2 as particulates, Fig. 3.8
- 13. Same as 11 except use .6 times the allowable emission rate, Fig. 3.9
- 17. 2% sulfur limit in fuel for all sources
- 18. Same as 1 except power plants limited to 2% sulfur fuels

Process Sources

- 6* Limit SO_2 in exhaust gas to 1500 ppm
- 9. Same as 6 with 1000 ppm limit
- 15. Same as 6 with 500 ppm limit

NOTE: A "London Law" i.e., no sulfur dioxide emissions from space heating can be applied along with any combination of sulfur dioxide regulations, and is indicated by adding 100 to the regular index number.

* These regulations are an approximation of the proposed Illinois State Regulations.

+ Numbers used to index the emission control standards correspond to a table prepared by K. Axetell, of NAPCA.

5.2 The Effect of Indiana Sources

In order to make realistic evaluations of the regional air quality with emphasis on the Illinois portion, an estimate of the contribution from Indiana sources is necessary. The diffusion model was run to compare the expected regional air quality with and without Indiana sources. This comparison is based on the uncontrolled emission inventory. Figures 5.1 and 5.3 show the regional isopleth maps reflecting contributions from all sources while Figures 5.2 and 5.4 were produced with the Indiana sources removed.

It is evident that there is an effect and indeed it works in both directions. The contributions from Indiana sources are produced by rather infrequent NE to SE winds (about 15-20% of the time on an annual basis). The most significant effects are the general increase in overall levels throughout the region and the production of a $125 \mu\text{g}/\text{m}^3$ area in the downtown Chicago area. This is undoubtedly caused by driving this area from slightly below to slightly above this threshold. By the same token, the Illinois sources contribute to the overall background level in the northern parts of Lake and Porter Counties, Indiana. Here the levels are increased to above $75 \mu\text{g}/\text{m}^3$ (about twice the normal background). A comparison of the two cases at the 12 control receptors is presented in Table 5.6.

The evaluation of various strategies presented later assumes, in all cases, that the following approximation to the proposed Indiana regulations:

Particulates	17-7-11
SO ₂	12-6

is always in effect.

Figure 5.1

Expected Particulate Annual Geometric Means
(Uncontrolled Emission Inventory)
and Control Receptors

Figure 5.2

Expected Particulate Annual Geometric
(Uncontrolled Emission
Inventory with Indiana
Sources Removed)

Figure 5.3

Expected Sulfur Dioxide Annual Geometric Means
(Uncontrolled Emission Inventory)
and Control Receptors

Figure 5.4

Expected Sulfur Dioxide Annual Geometric Mean
(Uncontrolled Emission Inventory with Indiana
Sources Removed)

Table 5.6 Expected Annual Geometric Mean (micrograms/cubic meter)
for All Sources and Illinois Sources Only

Receptor*	Number	Particulate		Receptor*	Number	SO ₂	
		all sources	Ill sources			all sources	Ill sources
62	7	132	117	18	2	63	59
28	7	102	114	19	2	76	72
1	28	101	96	24	19	65	90
48	1	98	98	25	24	64	61
74	48	144	95	11	64	71	57
11	74	117	99	10	64	64	59
4	11	125	111	26	71	44	26
17	4	116	122	27	64	58	20
26	17	115	102	38	58	109	15
34	26	111	112	Joliet	44	35	33
13	34	124	108	15	62		50

*See Tables 2.8 and 2.9 and Figure 2.12.

5.3 Selection of a Single Index for Comparison of Alternate Control Strategies - The Annual Geometric Mean of 24-hr Averages

The Illinois Air Quality Standards specify three criteria for each of the pollutants under study here:

1. Annual geometric mean of 24-hour averages
2. 99th percentile of 24-hour averages
3. Maximum 24-hour average to be exceeded at most one day per year.

The two sets of alternate control strategies (28 for SO₂ and 15 for particulates) must be compared with all three of these criteria unless one is sufficiently stringent to ensure compliance with the other two. This is approximately so for the annual geometric mean.

Figures 5.5 and 5.6 show the Illinois Standards on log-probability paper. The three points indicate the geometric mean, 99th percentile, and one-day-per-year values. Note that the one-day-per-year value is plotted at the percentile:

$$100\%[1 - (\frac{1 - .4}{365})] = 99.84\%$$

rather than at

$$100\%[1 - \frac{1}{365}] = 99.73\%$$

This occurs because the distribution of 24-hour values in a single year is discrete, i.e., not continuous. From Figures 5.5 and 5.6, it is evident that the standards satisfy log-normal distributions. The geometric standard deviations (ratio of value at 84th percentile to that at 50th percentile) are 2.3 for SO₂ and 1.5 for particulates. These measure the steepness of the log-normal distribution.

ILLINOIS AIR QUALITY STANDARDS
for PARTICULATES
(24-hr averages)

Figure 5.5

Particulate Concentration (micrograms/cubic meter)

PERCENTILE

SO₂ (ppm)

ILLINOIS AIR QUALITY STANDARDS
 FOR SO₂
 (24-hr averages)
 Figure 5.6

For the 12 selected monitor sites representative of worst conditions in the region, the geometric standard deviations of observed data are all less than or equal to 2.3 for SO_2 and all less than or equal to 1.7 for particulates. Thus, for SO_2 any site which meets the required annual geometric mean (50th percentile) will automatically meet the 1% and max-day standards since we assume the log-normal distribution is valid for our estimates. For particulates, a site which has an annual geometric mean of $75 \mu\text{g}/\text{m}^3$ may exceed the 1% standard of $200 \mu\text{g}/\text{m}^3$ by 30% and the max-day standard of $260 \mu\text{g}/\text{m}^3$ by 38%.

We choose to rank initially all regulations according to the annual geometric mean. This criterion, if satisfied for SO_2 , will ensure compliance with the other two criteria. For particulates, the ranking by geometric mean will parallel that for 1% and max-day values. If the first criterion is satisfied, the estimated levels for the other two will be reasonably close to the standards and can be used subsequently for a more refined ranking.

The degree to which a given strategy meets the requisite annual geometric mean can be assessed by either the area within isopleths greater than this standard or by the number or percentage of the 12 selected receptors which exceed the standard. When considering the areal measure, one is tempted to neglect that portion of the affected area that lies over Lake Michigan or over Indiana. Twenty-four hour average exposure of yachtsmen is probably negligible. The control standards affecting Indiana sources are the same for all computer runs regardless of the strategy being tested in Illinois..

5.4 Control Strategies Yielding Acceptable Air Quality

In this section the tabular (Tables 5.2 and 5.4) and graphical (Appendices C and D) results are reviewed. The term "acceptability" is defined here to mean that the area with concentrations in excess of the standard for annual geometric mean is less than 50 square miles (1% of the total land area in the region).

The order in Tables 5.2 and 5.4 corresponds to that in Appendices C and D. The labels "Ill", "Chi", and "Ind" imply that that line describes results using proposed Illinois and Indiana and existing Chicago strategies. These three abbreviations are not column headings. The first three columns represent the control standard for fuel combustion, process, and incineration which, in combination, form the control strategy.

Indiana sources are always assumed to be controlled by the proposed Indiana regulations, regardless of the strategy being tested in Illinois.

Particulate Control Strategies

All the strategies tested seemed to have roughly the same effect in terms of total emission reductions (maximum of 83% to a minimum of 61% in Table 5.2). However, the obvious success of the laws controlling space heating sources are an indication of the origins of high particulate levels. The four strategies tested that included the London Law reduced area source emissions by about 90%, whereas the next best strategy with no London Law reduced area sources by only 59%. This point is best exemplified by the isopleth maps. Three of the four London Law maps (almost identical) have no areas in Illinois with concentrations exceeding the standard.

Emission reductions to point sources are fairly uniform for all strategies and range from 68% to 86%.

The sensitivity of the various strategies in terms of the Area Index is shown in Figure 5.7. The strategies with the London Law, with one exception, are clustered at an Area Index of about 5. The remainder of the strategies are distributed somewhat linearly and correspond to significantly higher indices (25-45).

Strategies 14-7-13 through 18-15-13 (Table 5.2) seem to produce about the same level of control with the only differences probably due to the fuel combustion standards. It is also significant to note here that air contamination for both particulates and SO_2 is largely produced by fuel combustion. The proposed Illinois strategy (1-7-11) is considerably worse than the several mentioned above. For this proposed regulation, all of the City of Chicago is above $75 \mu\text{g}/\text{m}^3$ with the downtown area above 100. This is also true for the last two strategies tested.

The strategy simulating independent control in Illinois, Chicago, and Indiana produces an area index of 37 indicating about 20% of the region exceeding the annual standard (mostly in the City of Chicago).

In summary, it is evident that only the London Law, in combination with the more commonly accepted industrial fuel combustion and process standards will satisfy the Illinois Air Quality Standards in the CMAQCR. This is discussed further in the next subsection.

REGIONAL PERCENT REDUCTION IN EMISSIONS

FIGURE 5.7 LAND AREA INDEX IN VIOLATION
OF ANNUAL STANDARD

Sulfur Dioxide

A scan of the first figure in Appendix D or of the three "Land Area Index" columns in the first line of Table 5.4 indicates that present emissions cause over 25% of the region to be in violation of the standard. Twenty-five square miles in the central city exceed $80 \mu\text{g}/\text{m}^3$ (twice the standard). The peak in Will County is caused primarily by emissions from the Joliet Arsenal and not local power plants (see comments in Section 3.5 on electric generating stations).

The second figure shows that the presently proposed SO_2 emission control regulations for Illinois and Indiana, coupled with the existing, more stringent, City of Chicago ordinance, are very effective in reducing pollutant concentrations. Nevertheless, over 40 square miles in Chicago are above the standard. That this would be the case was predicted in an Argonne report to the Chicago Department of Environmental Control.* A principal conclusion of that document was that the high density of coal-burning, residential and commercial, space-heating sources in the City bear a disproportionate share of ground level contamination considering that they consume less than 20% of the high-sulfur fuel in the region.

Each member of the next set of 10 strategies employs the London Law (indexed by adding 100 to the usual number for the fuel-combustion standard) with various combinations of standards for industry and utilities. These strategies are successful in all cases.

As pointed out in Section 4.4 concerning the availability of low-sulfur fuels, the heat-rate-based regulations 11, 12 and 13 derived from the ASME APS-1 particulate standard (Figs 3.7-3.9) are quite stringent. In fact, it was felt that regulations 12 and 13 were unfeasible without employment of sulfur removal systems. As expected, these two, if applied to

* Roberts, J. J., and Croke, E. J., "A Preliminary Evaluation of the Proposed Chicago Coal-Sulfur Limitations, April 14, 1970.

fuel combustion sources in the region, result in acceptable air quality. The results for Standard 11 are borderline and probably unacceptable.

All other fuel combustion standards, independent of the accompanying process standard, are unacceptable. Even a 1% sulfur limit is in this category.

In summary, the control of sulfur emissions from residential and commercial fuel-burning sources seems to be a prerequisite for achieving the air quality standards. This is dramatized by scanning a few of the columns in Table 5.2. The "Land Area Index for the 40-60 $\mu\text{g}/\text{m}^3$ range shows a sharp rise when fuel combustion Standard 11 is used, and thereafter. Nevertheless, the "Total Percent Reduction" of emissions for the region as well as the "Point Source Percent Reduction" do not show as pronounced a downward trend with decreasing effectiveness of the strategies. In contrast, the Area Source Percent Reduction does drop significantly below the lines 13 in Table 5.4.

The effectiveness of the London Law is expected and in a sense fortunate. From the standpoint of fuel availability, it is a feasible solution in contrast to the extremely stringent, regionwide limits implied by Standard 13 (see Section 4.4). It can be successfully coupled with the proposed Illinois regulations to achieve all three 24-hour standards and, in all likelihood, the maximum 1-hour-per-day standard (see Sec. 4.5). This report does not contain an assessment of the regional cost for conversion of space heating sources to clean fuels, although pertinent data has been acquired by organizations such as the Chicago DEC, the gas utility, and the Environmental Pollution Committee of the Hyde Park-Kenwood Community Council. In any case, a decision to employ a London Law must be made with an understanding of the associated economic penalty which will be especially burdensome in older, urban neighborhoods.

APPENDIX A

DESCRIPTION OF DISPERSION AND STATISTICAL MODELS

APPENDIX A

A.1 DIFFUSION

The Air Quality Display Model (AQDM) is based upon a diffusion model developed by Martin and Tikvart [1968]. The basic output of the AQDM is in the form of calculated average annual pollutant concentrations at ground level. Concentrations for shorter periods are estimated by means of a statistical technique developed by Larsen [1969] and discussed in Section A.2.

Sutton [1932] and Bosanquet [1936] provided the first point source diffusion equations. Sutton's equations were widely used to estimate downwind concentrations from single sources until the early 1960's. Because the mixing and dilution of airborne trace substances are accomplished primarily by atmospheric turbulence, no exact or general solution of an atmospheric diffusion equation is possible. Sutton and Bosanquet expressed downwind concentrations as solutions to appropriate diffusion equations, but the coefficients of diffusion employed ("eddy mixing coefficients") were derived from vertical wind profiles obtained during field experiments.

Later, Pasquill [1961] presented a method for estimating concentrations when wind profiles are not available. This method expresses the vertical and horizontal angular spread of a diffusion plume as functions of downwind distance, mean local wind speed, and atmospheric stability. Gifford [1961] converted Pasquill's formulation into expressions based upon the lateral and vertical standard deviations (σ_y and σ_z) of plume concentration distributions. The Pasquill-Gifford plume formulation, now widely used, is described in detail in a recent summary by Turner [1961].

The Martin-Tikvart model calculates concentrations downwind from a set of point and area sources on the basis of the Pasquill-Gifford point source formulation. A description of this process follows;

The stack in the illustration on page A-2 represents a typical elevated point source. The coordinate system for this source has its origin at ground level at the base of the stack (i.e., directly below the effective point of emission). The X-axis extends horizontally in the mean wind

direction. The Y-axis is horizontal in the cross-wind (and cross-plume) direction. The Z-axis is vertical.

The "effective stack height" (or effective height of emission release) is the height at which the plume center line becomes horizontal. The effective stack height is the sum of the physical stack height and an incremental factor related to the buoyancy and vertical momentum of the effluent.

The concentration, χ , at a position (x,y,z) for substances emitted at $(0,0,h)$ is given by

$$\chi(x,y,z; h) = \frac{10^6 Q}{2\pi\sigma_y\sigma_z u} \exp \left[-\frac{1}{2} \left(\frac{y}{\sigma_y} \right)^2 \right] \left\{ \exp \left[-\frac{1}{2} \left(\frac{z-h}{\sigma_z} \right)^2 \right] + \exp \left[-\frac{1}{2} \left(\frac{z+h}{\sigma_z} \right)^2 \right] \right\} \quad (A.1)$$

where:

$\chi(x,y,z; h)$ = pollutant concentration at point x,y,z for an effective stack height h , micrograms/meter³

Q = emission rate, grams/sec.

u = mean wind speed, meters/sec.

σ_y, σ_z = standard deviation of the plume concentration distribution in the cross-plume and vertical directions, meters. (σ_y and σ_z are given as functions of downwind distance and atmospheric stability.)

Equation (A.1) is based upon several assumptions, including:

- (a) Total reflection of the plume takes place at the earth's surface.
- (b) The plume description represents conditions averaged over a time period of several minutes. The "instantaneous" behavior of the plume, particularly during unstable atmospheric conditions, is more complex.
- (c) The effluent has neutral buoyancy in the atmosphere; no fall-out or buoyancy rise is modeled by Equation (A.1). In the case of actual effluents, all contaminant gases and most particles with equivalent diameters less than 20 microns satisfy this assumption. For larger particulate material, the simple plume description must be modified to include a fall-out effect.
- (d) The time-averaged plume exhibits a Gaussian distribution of concentrations in the cross-plume and vertical dimensions. The measures of the spread in both directions (the standard deviations) are considered to be a function of downwind distance and atmospheric stability only.
- (e) The plume is a steady-state phenomenon resulting from a constant, continuous emission source, and none of the effluent "disappears" (by chemical change or by absorption on the ground surface, for example). Thus, an area integration of the plume concentration in any plane perpendicular to the center line is constant, regardless of the downwind distance.

Ground-level concentration estimates are obtained by setting $z = 0$ in Equation (A.1), resulting in

$$X(x, y, z; h) = \frac{10^6 Q}{\sigma_y \pi \sigma_z u} \exp \left[-\frac{1}{2} \left(\frac{y}{\sigma_y} \right)^2 \right] \exp \left[-\frac{1}{2} \left(\frac{h}{\sigma_z} \right)^2 \right] \quad (A.2)$$

For a source which emits at a constant rate from hour to hour and day to day, Equation (A.2) can be modified to yield estimates of annual average concentrations if applicable stability wind rose data are available. A wind rose tabulates the frequency of occurrence for each wind direction and wind speed class during a standard climatological period.

A stability wind rose contains the same information, but it is further divided according to atmospheric stability classes.

Although the change in wind direction is a continuous function over the long-term period, for computation purposes discrete wind directions are specified with respect to a 16-point compass, corresponding to 22.5-degree circular sectors. For annual periods it is often assumed that all wind directions within a given 22.5-degree sector occur with equal frequency. Thus the effluent could be assumed to be uniformly distributed in the horizontal within the sector. However, this assumption would result in discontinuities in calculated concentrations at sector boundaries. A more reasonable distribution is obtained by using a linear interpolation between sector center lines. Thus, the concentration at a given receptor location is composed of proportional contributions from both the sector containing the receptor and from the nearest adjacent sector. The linear interpolation term is given by $(c-y)/c$, where y is the crosswind distance between the receptor and the sector center line, and c is the sector width at the receptor location. This concept is illustrated in the following sketch. Note that a SSW wind affects the receptor to the NNE of the source.

Use of the linear crosswind distribution changes the form of Equation (A.2) to the univariate Gaussian distribution:

$$\chi = \frac{2 \times 10^6 Q(c-y) / c}{u \sigma_z \sqrt{2\pi} (2\pi \times /16)} \exp \left[-\frac{1}{2} \left(\frac{h}{\sigma_z} \right)^2 \right] \quad (A.3)$$

Vertical plume rise is inhibited by the existence of a stable atmospheric layer having a base lower than the effective stack height (the layer elevation will generally range between 100 and 3,000 feet). The rate of vertical mixing is greatly reduced in such a layer, and the base of the layer can thus be considered as an effective "lid" on vertical transport of pollutants.

When an elevated stable layer occurs locally, the estimated pollutant concentrations can be calculated with the assumption that all the effluent remains within a mixing layer depth L , defined as the vertical distance from the ground to the base of the stable layer. For the model calculations, σ_z is considered to increase in the downwind direction until it reaches a distance X_L at which $\sigma_z = 0.47L$. At this distance, pollutant concentration at the base of the stable layer will be one-tenth that at the plume center line. Up to this distance, the Gaussian vertical distribution is assumed, and Equation (A.3) is appropriate. At distance X_L the trapping effect of the elevated stable layer begins to be effective, and uniform mixing below the base of the stable layer is assumed to occur at downwind distance $2X_L$. For distances $X \geq 2X_L$, the average concentration is calculated with the assumption of full mixing in the mixing layer:

$$\chi = \frac{10^6 Q(c-y) / c}{Lu(2\pi x/16)} \quad (A.4)$$

For distances between X_L and $2X_L$, χ is determined by a linear interpolation between Equation (A.3), evaluated at X_L , and Equation (A.4), evaluated at $2X_L$.

For a specific source-receptor configuration, an estimate of χ is obtained by choosing a representative wind speed for each wind speed class and solving the appropriate equation for all wind speed and stability classes appropriate for the time period in the geographical area of interest. The average concentration, $\bar{\chi}$, is obtained by summing all concentrations and weighting each one according to its frequency for the particular wind direction, wind speed class, and stability class. The average concentration is:

$$\bar{X} = \sum_{\theta} \sum_N \sum_S F(\theta, N, S) \chi(\theta, N, S) \quad (A.5)$$

where:

$F(\theta, N, S)$ = normalized frequency during the period of interest for wind direction interval θ , wind speed class N , and stability class S .

$\bar{\chi}(\theta, N, S)$ = average ground-level concentration calculated from (A.3) or (A.4) as appropriate.

The total concentration at a specific receptor is obtained by summing the results of Equation (A.5) over all sources. For each of the 16 wind direction intervals, wind speed is defined in 6 categories and stability class in 5 categories. Thus a three-dimensional array of 480 categories is established. (However, only a few wind directions result in non-zero contributions for specific source-receptor pairs. Thus the computation time is reduced significantly.) Vertical variations in wind speed and wind direction are not accounted for in the present model.

The representative speeds associated with the six climatological wind speed categories (0-3, 4-6, 7-10, 11-16, 17-21 and >21 knots), are given by the five mid-interval values of 0.67, 2.46, 4.47, 6.93 and 9.61 meters per second, and by 12.52 meters per second (= 25.5 knots) for the >21 knots category.

The five stability categories ($S = 1, 2, 3, 4$ and 5 , in order of increasing atmospheric stability) are defined on the basis of the criteria stated by Turner [1964]. Stability in the lowest part of the atmosphere is determined primarily by the radiative flux divergence and local wind speed. Turner's classification is based upon ground-level meteorological observations only (surface wind speed, cloud cover, ceiling), supplemented by solar elevation data (latitude, time of day, and time of year); thus the stability estimates can be obtained for any Weather Bureau station at which continuous observations have been made. No vertical sounding data (available from principal stations only) is needed.

The values of $\sigma_z(X, S)$ used in the program are those of Pasquill [1961] and Gifford [1961]. For computation these are represented in the form $\sigma_z = aX^b + c$, where a , b and c are constants for each stability class, as shown in the following table. No a , b and c values are stated for $S = 5$ in the table. Class 5 is associated with nighttime, surface inversion

conditions, and the σ_z values for this case are the smallest normally used. However, because of the thermal and mechanical influences of urban areas, the lowest part of the typical urban atmosphere is less stable than its rural counterpart. Since the diffusion model is intended for use in urban regions, the σ_z values for $S = 4$ are always used when the meteorological criteria indicate $S = 5$.

The minimum value of X used in calculating σ_z is 100 meters. If $X < 100$ meters, X is set equal to 100 meters prior to the σ_z calculation.

Stability Class (S)	a	b	c
1 ~ Very Unstable	.001	1.890	9.6
2 ~ Moderately Unstable	.048	1.110	2.0
3 ~ Slightly Unstable	.119	.915	0.0
4 ~ Neutral	X > 1000 meters	2.610	.450
	X ≤ 1000 meters	.187	.755
			-25.5
			- 1.4

The mixing layer depth, L , varies greatly from season to season, day to day, and diurnally. Since it is impractical to account for all these variations, a procedure reflecting only major changes is used in the model. The procedure determines an effective mixing depth by modifying the average afternoon mixing depth values, as tabulated by Holzworth [1964], according to the stability class being considered. Stability classes $S = 1, 2$ and 3 are afternoon conditions, with $S = 1$ corresponding to very unstable conditions. When $S = 1$, the value of L is assumed to be 50% greater than the climatological value tabulated by Holzworth; when $S = 2$ or 3 , the climatological value is adopted. According to Turner's criteria, $S = 5$ can occur only when nighttime ground-based inversion conditions exist. Since a shallow layer of neutral or weak lapse conditions has been found to occur over urban areas (even with strong nocturnal surface inversions in the surrounding rural areas), a mixing depth of $L = 100$ meters is adopted for stability class $S = 5$, when this class is indicated by the objective criteria. The 100-meter value is based upon observations of Clarke [1969]. Stability class $S = 4$ is a neutral stability condition which occurs either with high wind speeds during the day or with high negative net radiation

during the night. To find the mixing depth for the transition period, average the nighttime and afternoon mixing depth values for 2/5 of the class $S = 4$ occurrences. The remaining 3/5 of the class $S = 4$ occurrences utilizes the climatological value.

The effective stack height, appearing in Equation (A.3), is defined as the height of the plume centerline when it becomes horizontal. Thus $h = h^* + \Delta h$, where h^* is the physical stack height and Δh is the plume rise. The effective stack height does not appear in Equation (A.4) because the height of emission is immaterial after vertical mixing is complete.

The plume rise equation used in the program (when actual point sources are being considered) is due to Holland [1953], and is given by

$$\Delta h = \frac{V_s d}{u} \left[1.5 + 2.68 \times 10^{-3} P \left(\frac{T_s - T_a}{T_s} \right) d \right] \quad (A.6)$$

where:

V_s = stack gas-exit velocity (meters/sec.)

d = stack exit diameter (meters)

u = mean wind speed (meters/sec.)

P = atmospheric pressure (mb)

T_s = stack gas-exit temperature ($^{\circ}\text{K}$)

T_a = ambient air temperature ($^{\circ}\text{K}$)

Since this equation is appropriate for the neutral stability condition, it must be modified for application over a range of stability conditions. The following modification is used to allow for a range of from 1.3 Δh for very unstable conditions to Δh for neutral stability.

$$h = h^* + \Delta h(1.4 - 0.1S)$$

The plume rise equation (A.6) frequently underestimates the effective height of emission; thus its use often provides a slight "safety" factor. For some point sources (e.g., power plants with tall stacks), the effective emission height will be above the mixing depth when the mixing depth is low. Based on the assumption that the plume will not disperse downward through the stable layer, these cases are identified and eliminated from

consideration by the program. For area sources an average effective height of emission must be estimated.

The program handles area sources by converting them to equivalent or "virtual" point sources. In the conversion process, both the downwind distance and source strength are dependent on the particular source-receptor configuration.

If the total emission is calculated as though at the center of the source area, concentrations downwind tend to be overcalculated, especially for nearby receptors. Since uniform spread across the sector is assumed, it is logical to proceed a step further and assume a virtual point source at such a distance upwind that the 22.5-degree sector used subtends the area width. This concept is illustrated in the following sketch. Here the program would use X instead of X_p as the source-receptor downwind distance in Equation (A.3) or (A.4). The vertical spread, as measured by σ_z , is still calculated using X_p , the actual downwind distance.

In a similar manner, nearby receptors are affected by emissions from only a portion of the source area and, therefore, would be overcalculated if the total area emission value were used. To correct this, the source emission rate is multiplied by an "area utilization" factor, Q^* , which is the ratio of that portion of the source area lying within a 22.5-degree sector upwind of the receptor (A') to the total area (A). For example, in the sketch on the following page, Receptor 1 would use the total

area-emission value, Q , while Receptor 2 would use the proportional amount, $QQ^* = Q(A'/A)$. Note that in this figure the virtual point source would be defined by the reduced area width, W .

A.2 STATISTICAL SEGMENT

Larsen [1969] has developed a mathematical model for the expression of air pollution concentration as a function of averaging time and frequency, and has demonstrated how the model can be used to relate air quality criteria to air quality standards and emission standards. The model is employed here to convert arithmetic average concentrations to expected maximum concentrations and expected geometric mean concentrations for various averaging times, under the assumption that the standard geometric deviations are known. Output therefore will consist of the following:

- (a) Geometric mean concentrations for various averaging times.
- (b) Maximum expected concentrations for various averaging times.

The Larsen model was constructed on the basis of the following characteristics, as observed from analysis of seven pollutants for six cities over a three-year period:

- (a) Concentrations are approximately lognormally distributed for all pollutants in all cities for all averaging times.
- (b) The median concentration (50 percentile) is proportional to averaging time to an exponent.

If air quality data for the major cities are plotted on log-probability paper (for given averaging times), the resulting curves are

nearly straight lines. This suggests that, to a good approximation, the distribution of samples follows a lognormal curve. The sketch below represents such a curve, with the logarithm of concentrations plotted on the horizontal axis and the number of samples obtained for each concentration (for a given averaging time) plotted on the vertical axis. The curve follows the familiar, bell-shaped probability distribution, the only difference being that the logarithm of concentration is plotted rather than the concentration itself. The center of such a curve falls not on the arithmetic-mean but on the geometric-mean (50-percentile) concentration. This is the concentration which divides equally the area under the curve: half of the samples will lie above this value and half will lie below it. As with the normal probability curve, the standard deviation is a measure of the "spread" of the curve. However, for the lognormal distribution, it is called the standard geometric deviation, and is the ratio of the concentration which is exceeded by 16% of the samples to that which is exceeded by 50% of the samples.

Since only two parameters are needed to define the shape of this distribution, it is possible, once these parameters are known, to calculate the concentration for any percentile. In addition, since a specified averaging period corresponds to a fixed number of samples over a year, the highest sample will correspond to a particular percentile. Thus, it is also possible to calculate the expected maximum concentration for the year.

Equation (A.7) is a general relationship for calculating the concentration at any point along the curve as a function of the geometric-mean and standard-geometric deviation.

$$C = M_g (s_g)^z \quad (A.7)$$

where:

C = concentration corresponding to the desired percentile and averaging time,

s_g = standard geometric deviation of samples (at the desired averaging time),

M_g = geometric mean of samples (at the desired averaging time),

z = plotting position which corresponds to the desired percentile.

The parameters M_g and s_g are obtained from the actual distribution of sample data, while z is the number of standard deviations on a normal probability curve that correspond to the desired percentile and may be obtained from statistical tables [c.f., Pearson and Hartley, 1966]. The table below shows the values of z for several selected percentiles. In the program the z values are obtained by an approximation technique which involves solving the normal, cumulative-probability density function:

$$P = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{+z} e^{-x^2/2} dx$$

Values of z For Various Frequencies

<u>Highest Percentile</u>	<u>z</u>
50.0%	0.00
30.0%	0.52
15.0%	1.04
10.0%	1.28
5.0%	1.64
1.0%	2.33
0.1%	3.09

Since a particular percentile is associated with the maximum concentration in any set of samples for a specified averaging time, a similar table may be prepared in which the values of z correspond to the maximum concen-

tration for selected averaging times. Such values are listed below and, when used in Equation (A.7), they permit calculation of the expected maximum concentration in a distribution of samples (for a single averaging time) where M_g and s_g are known.

Values of z For Calculating
the Maximum Concentration

Averaging Time	z
1 year	0.00
1 month	1.64
24 hours	2.94
8 hours	3.26
4 hours	3.46
2 hours	3.63
1 hour	3.81

The geometric mean for a given set of samples may be calculated from the arithmetic mean and the standard geometric deviation for that same set of samples in a relatively straightforward manner, as shown in Equation (A.8).

$$M_g = \bar{x} / (s_g)^{(1/2 \ln s_g)} \quad (A.8)$$

where:

$\bar{x}$ = arithmetic mean

M_g = geometric mean for a set of samples

s_g = standard geometric deviation for the same set of samples

$\ln$ = the natural logarithm to the base e .

If s_g is for the desired averaging time, Equation (A.7) and Equation (A.8) may be used to provide the desired output. If the desired averaging time is different from the one associated with the input s_g , then s_g must be translated to the desired averaging time. It is assumed that the input s_g corresponds to a 24-hour averaging time.

Larsen proposes a method to change averaging times by assuming that the median concentration is proportional to averaging time to an exponent. The standard geometric deviations for different averaging times may be related as shown in Equation (A.9).

$$s_{g_n} = (s_{g_{24}})^k \quad (A.9)$$

where:

$$k = \sqrt{\frac{\ln 8760/n}{\ln 8760/24}}$$

and

s_{g_n} = standard geometric deviation at averaging period of n hours

$s_{g_{24}}$ = standard geometric deviation of 24-hour samples

The statistical relationships described above, along with the annual arithmetic mean concentration computed by the diffusion model, allow the user to estimate the expected maximum and geometric mean pollutant concentration at various averaging times.

EMISSION CONTROL REGULATION RUN

IPJ	TYPE	REGULATION CLASS 1,2,3		
1	SC2	1	9	0

APPENDIX B

SAMPLE OUTPUT FROM THE
COMPUTER CODE FOR
EVALUATING STRATEGIES

ILLINOIS - CHICAGO REGION

CONTROLLED SOURCE DATA

SOURCE NUMBER	SOURCE LOCATION (MILES)		SOURCE AREA SQUARE MILES	ANNUAL SOURCE EMISSION RATE (TONS/DAY)		STACK DATA				SOURCE CLASS
	HORIZONTAL	VERTICAL		SO2	PART	HT (M)	DIAM (M)	VEL (M/SEC)	TEMP (DEG. K)	
1	35.7	43.0	0.0	0.0	0.0	33.6	2.7	1.5	288.	2040.
2	9.9	46.3	0.0	0.0	0.0	18.3	0.9	5.6	589.	2600.
3	17.1	17.1	0.0	0.0	0.0	18.3	0.5	0.8	395.	2800.
4	17.1	17.1	0.0	22.863	0.0	22.9	0.3	2.0	395.	2800.
5	36.9	82.1	0.0	0.0	0.0	4.6	3.0	1.3	366.	2818.
6	50.1	24.7	0.0	0.0	0.0	17.0	3.0	1.3	366.	2818.
7	22.0	24.4	0.0	1.631	0.0	33.5	0.9	11.9	366.	2819.
8	43.7	35.2	0.0	4.703	0.0	7.3	1.2	12.0	366.	2819.
9	17.0	20.4	0.0	0.0	0.0	23.2	1.8	1.0	322.	2911.
10	23.8	35.1	0.0	0.0	0.0	55.5	3.7	3.6	550.	2911.
11	23.8	31.5	0.0	0.0	0.0	59.5	3.7	4.9	550.	2911.
12	44.5	28.5	0.0	0.0	0.0	11.6	3.7	2.3	329.	2911.
13	17.9	24.5	0.0	0.0	0.0	19.2	2.2	3.9	390.	2951.
14	26.5	37.1	0.0	0.0	0.0	13.4	2.2	6.3	390.	2951.
15	34.1	43.4	0.0	0.0	0.0	12.2	5.0	1.0	355.	2951.
16	25.2	81.9	0.0	0.0	0.0	9.1	2.2	6.3	390.	2951.
17	33.0	83.4	0.0	0.0	0.0	6.1	2.2	6.3	390.	2951.
18	12.3	67.2	0.0	0.0	0.0	9.1	2.2	5.2	390.	2951.
19	41.8	59.7	0.0	0.0	0.0	10.7	2.2	4.7	390.	2951.
20	42.2	60.4	0.0	0.0	0.0	12.8	2.2	6.3	390.	2951.
21	18.7	23.6	0.0	0.0	0.0	16.8	2.2	6.2	422.	2952.
22	22.4	28.2	0.0	0.0	0.0	19.5	0.0	0.0	288.	2952.
23	22.4	28.2	0.0	0.0	0.0	21.4	0.0	0.0	288.	2952.
24	11.7	52.2	0.0	0.0	0.0	9.9	2.2	6.2	422.	2952.
25	45.4	23.6	0.0	0.0	0.0	19.8	1.7	9.0	811.	3200.
26	34.5	42.9	0.0	0.0	0.0	22.9	3.7	5.5	1005.	3270.
27	37.4	85.4	0.0	0.0	0.0	15.3	1.6	7.0	330.	3270.
28	46.6	28.5	0.0	0.0	0.0	22.9	5.9	2.4	505.	3274.
29	34.5	44.3	0.0	0.0	0.0	16.3	1.6	8.0	480.	3274.
30	13.3	23.7	0.0	0.0	0.0	12.0	0.3	12.5	372.	3295.
31	22.4	28.2	0.0	0.0	0.0	18.0	1.9	1.0	288.	3295.
32	46.1	25.2	0.0	0.0	0.0	30.0	6.7	7.2	408.	3312.
33	45.2	24.2	0.0	0.0	0.0	15.3	3.3	3.9	408.	3312.
34	37.6	83.9	0.0	3.000	0.0	76.3	1.8	5.8	300.	3312.
35	45.9	24.7	0.0	0.0	0.0	18.3	0.9	9.2	1033.	3321.
36	40.3	58.9	0.0	0.0	0.0	18.3	1.4	10.0	372.	3321.
37	38.5	66.2	0.0	0.0	0.0	12.2	1.8	6.0	523.	3321.
38	31.3	55.5	0.0	0.0	0.0	24.4	2.7	2.0	377.	3321.
39	12.3	61.6	0.0	0.0	0.0	19.8	1.4	12.0	372.	3321.
40	35.6	82.2	0.0	0.0	0.0	12.2	1.8	10.7	377.	3321.
41	0.0	76.8	0.0	0.0	0.0	9.1	1.2	2.0	523.	3321.
42	11.7	52.5	0.0	0.0	0.0	12.2	0.2	10.0	1033.	3321.
43	9.8	53.6	0.0	0.0	0.0	21.4	1.0	10.0	494.	3322.
44	46.1	24.3	0.0	0.0	0.0	10.2	1.5	9.9	332.	3323.
45	40.3	51.3	0.0	0.0	0.0	15.0	1.5	11.0	332.	3323.
46	34.6	44.0	0.0	0.0	0.0	12.5	1.5	11.0	332.	3323.
47	46.3	23.8	0.0	0.0	0.0	9.1	0.5	5.3	811.	3361.
48	10.4	44.1	0.0	0.0	0.0	13.7	1.8	9.0	520.	3361.
49	35.1	44.8	0.0	0.0	0.0	19.8	1.8	3.0	450.	3361.
50	46.2	24.7	0.0	0.097	0.0	19.3	0.9	18.0	922.	3362.
51	25.0	35.4	0.0	0.0	0.0	20.0	3.7	1.5	312.	3440.
52	38.3	60.5	0.0	0.0	0.0	12.3	6.9	0.8	350.	3450.
53	40.3	48.1	0.0	0.0	0.0	20.4	0.9	9.0	866.	3900.
54	37.3	84.1	0.0	0.0	0.0	13.7	1.1	18.3	203.	3900.
55	34.5	43.1	0.0	0.0	0.0	10.0	0.6	1.0	554.	3900.

56	50.0	30.6	0.0	0.0	0.0	21.3	2.8	6.0	811.	3900.
57	38.7	45.7	0.0	0.0	0.0	49.7	4.3	3.1	308.	4953.
58	17.1	17.1	0.0	27.400	0.0	5.0	0.8	6.5	504.	4953.
59	44.5	50.9	0.0	0.0	0.0	50.0	3.8	4.0	289.	2040.
60	50.4	39.2	0.0	0.0	0.0	53.4	3.7	4.0	285.	2040.
61	49.4	36.4	0.0	0.0	0.0	53.4	3.6	2.0	303.	2040.
62	50.1	38.8	0.0	0.0	0.0	62.5	3.7	4.0	303.	2040.
63	48.0	35.3	0.0	0.0	0.0	50.0	3.7	6.1	303.	2040.
64	50.0	38.1	0.0	0.0	0.0	62.5	3.7	4.0	285.	2040.
65	43.9	47.6	0.0	0.0	0.0	62.5	3.7	4.0	285.	2040.
66	48.2	35.3	0.0	0.0	0.0	72.8	3.7	4.2	282.	2040.
67	45.5	46.2	0.0	0.0	0.0	32.5	0.8	55.7	339.	2040.
68	51.3	38.2	0.0	0.0	0.0	30.0	0.5	2.2	285.	2082.
69	49.4	35.8	0.0	0.0	0.0	21.4	0.5	16.2	300.	2092.
70	39.4	52.7	0.0	0.0	0.0	43.2	0.5	3.1	295.	2092.
71	42.9	46.8	0.0	0.0	0.0	64.7	1.6	5.8	365.	2099.
72	42.1	46.9	0.0	0.0	0.0	22.5	1.8	5.0	422.	2200.
73	43.4	50.7	0.0	0.0	0.0	7.0	0.7	10.0	285.	2500.
74	43.9	53.4	0.0	0.0	0.0	15.0	0.6	5.8	300.	2500.
75	40.9	40.1	0.0	0.0	0.0	15.0	1.8	9.1	285.	2500.
76	44.7	50.8	0.0	0.0	0.0	20.0	2.2	5.0	285.	2500.
77	43.5	49.9	0.0	0.0	0.0	7.0	0.7	10.0	285.	2500.
78	45.4	50.9	0.0	0.0	0.0	20.0	1.3	3.1	321.	2711.
79	40.4	53.9	0.0	0.0	0.0	11.3	0.5	6.7	322.	2711.
80	44.7	49.9	0.0	0.0	0.0	14.6	0.4	8.0	300.	2711.
81	43.4	52.5	0.0	0.0	0.0	20.0	1.3	2.2	321.	2711.
82	46.6	34.3	0.0	0.0	0.0	5.0	3.5	0.6	340.	2800.
83	44.7	52.0	0.0	0.0	0.0	15.0	0.4	0.4	300.	2800.
84	41.8	46.4	0.0	0.0	0.0	13.4	0.9	8.9	523.	2800.
85	47.0	34.0	0.0	0.0	0.0	42.0	0.3	16.0	380.	2819.
86	47.0	34.0	0.0	0.0	0.0	50.0	0.3	16.0	450.	2819.
87	44.3	52.8	0.0	0.0	0.0	5.2	0.4	10.6	322.	2822.
88	42.3	47.5	0.0	0.0	0.0	22.9	0.3	3.8	289.	2841.
89	46.9	36.6	0.0	0.0	0.0	15.0	0.7	5.1	450.	2851.
90	43.9	47.8	0.0	0.0	0.0	15.0	1.6	10.0	530.	2951.
91	41.7	57.9	0.0	0.0	0.0	15.0	2.0	8.0	530.	2951.
92	30.1	57.0	0.0	0.0	0.0	18.3	1.8	7.0	530.	2951.
93	50.0	35.3	0.0	0.0	0.0	30.2	0.2	7.6	577.	2952.
94	46.1	24.6	0.0	0.0	0.0	22.5	0.9	18.3	644.	3210.
95	50.4	38.3	0.0	0.0	0.0	22.9	5.9	2.4	505.	3274.
96	47.4	35.8	0.0	0.0	0.0	5.0	10.0	1.0	285.	3295.
97	34.6	45.0	0.0	0.0	0.0	3.0	25.0	1.0	288.	3295.
98	49.9	37.4	0.0	0.0	0.0	35.0	3.0	10.5	530.	3312.
99	49.9	37.4	0.0	0.0	0.0	40.0	3.5	10.0	530.	3312.
100	49.9	37.4	0.0	0.0	0.0	52.0	4.5	15.0	450.	3312.
101	49.9	27.4	0.0	0.0	0.0	20.0	5.0	1.0	300.	3312.
102	49.9	36.4	0.0	0.0	0.0	35.0	3.0	10.5	530.	3312.
103	49.9	36.4	0.0	0.0	0.0	20.0	5.0	1.0	300.	3312.
104	49.9	36.4	0.0	0.0	0.0	35.0	3.0	10.0	650.	3312.
105	49.9	36.4	0.0	0.0	0.0	52.0	3.0	6.1	700.	3312.
106	50.7	40.1	0.0	0.0	0.0	33.0	3.0	10.5	530.	3312.
107	50.7	40.1	0.0	0.0	0.0	52.0	5.0	15.0	450.	3312.
108	50.7	40.1	0.0	0.0	0.0	35.0	3.0	10.0	650.	3312.
109	50.7	40.1	0.0	0.0	0.0	52.0	3.0	6.1	700.	3312.
110	49.6	37.6	0.0	0.0	0.0	52.0	3.0	10.5	530.	3312.
111	49.6	37.6	0.0	0.0	0.0	52.0	3.2	10.0	530.	3312.
112	49.6	37.6	0.0	0.0	0.0	52.0	3.0	15.0	450.	3312.
113	49.6	37.6	0.0	0.0	0.0	20.0	5.0	1.0	300.	3312.
114	44.8	52.5	0.0	0.0	0.0	18.3	0.9	10.0	1033.	3321.
115	43.3	46.7	0.0	0.0	0.0	12.2	1.6	7.2	533.	3321.
116	44.7	36.1	0.0	0.0	0.0	18.3	1.6	7.3	532.	3322.
117	44.8	36.8	0.0	0.0	0.0	10.0	1.5	5.0	332.	3323.
118	45.4	48.1	0.0	0.0	0.0	20.0	0.9	2.0	372.	3332.
119	40.4	51.8	0.0	0.0	0.0	18.0	1.4	8.0	920.	3361.
120	43	44	0.0	0.0	0.0	18.0	1.4	8.0	920.	3361.
121	45	44	0.0	0.0	0.0	18.0	1.4	8.0	920.	3361.

122	42.1	45.1	0.0	0.0	0.0	20.0	0.8	12.0	394.	3411.
123	42.1	41.4	0.0	0.0	0.0	11.0	0.6	11.4	320.	3419.
124	44.1	53.0	0.0	0.479	0.0	82.0	3.9	9.7	644.	4953.
125	44.5	46.3	0.0	0.713	0.0	82.0	4.9	10.3	533.	4953.
126	49.0	38.3	0.0	0.524	0.0	82.0	3.9	7.3	561.	4523.
127	35.8	50.4	0.0	0.353	0.0	15.8	1.9	2.4	464.	3450.
128	37.3	84.8	0.0	0.570	0.0	55.5	1.5	3.7	492.	3900.
129	11.2	65.0	0.0	0.290	0.0	45.8	1.8	2.6	464.	2500.
130	36.5	81.7	0.0	0.225	0.0	30.5	2.6	0.3	464.	3900.
131	22.6	27.2	0.0	1.295	0.0	38.1	2.5	8.0	464.	3900.
132	36.4	82.4	0.0	2.317	0.0	56.3	2.1	6.0	464.	3220.
133	37.3	84.1	0.0	0.350	0.0	11.3	1.7	14.9	464.	3900.
134	33.9	83.3	0.0	0.070	0.0	15.3	1.2	8.0	492.	3900.
135	32.0	52.5	0.0	0.059	0.0	30.5	2.2	5.0	464.	3400.
136	19.5	23.7	0.0	5.415	0.0	23.8	3.5	5.3	464.	3900.
137	11.0	42.8	0.0	0.190	0.0	25.3	1.5	2.3	492.	3900.
138	11.7	43.1	0.0	0.0	0.0	30.5	1.5	4.5	492.	3500.
139	30.3	78.1	0.0	0.160	0.0	13.7	1.5	3.5	464.	3900.
140	4.2	81.4	0.0	1.140	0.0	62.3	1.8	7.3	464.	3900.
141	40.3	48.1	0.0	0.0	0.0	76.3	3.7	17.5	433.	3500.
142	32.8	42.1	0.0	0.660	0.0	28.1	3.7	1.3	464.	3900.
143	47.0	24.1	0.0	1.405	0.0	24.4	1.8	5.0	464.	3900.
144	42.4	61.3	0.0	0.032	0.0	9.1	1.1	2.4	492.	3500.
145	22.4	25.6	0.0	0.142	0.0	18.3	1.1	4.4	492.	3900.
146	49.9	30.6	0.0	0.005	0.0	10.1	0.8	0.7	492.	3900.
147	12.3	43.2	0.0	0.0	0.0	45.6	1.2	3.1	492.	3900.
148	34.5	44.4	0.0	5.572	0.0	29.3	3.8	4.5	464.	3900.
149	45.5	32.2	0.0	0.339	0.0	21.0	1.7	4.7	464.	3900.
150	27.2	38.8	0.0	2.320	0.0	46.4	3.9	1.7	464.	3500.
151	9.7	43.0	0.0	0.167	0.0	38.1	1.1	2.1	492.	3900.
152	37.2	42.7	0.0	0.209	0.0	9.1	0.8	10.5	464.	3900.
153	38.9	42.7	0.0	0.113	0.0	62.3	2.1	3.4	255.	2500.
154	39.9	42.8	0.0	0.648	0.0	43.0	1.0	7.9	527.	3900.
155	20.5	24.0	0.0	57.090	0.0	137.3	4.1	40.5	464.	4911.
156	20.5	24.0	0.0	31.010	0.0	75.6	2.5	13.4	464.	4511.
157	20.0	24.0	0.0	204.480	0.0	168.0	5.3	35.6	464.	4911.
158	41.1	66.5	0.0	1.410	0.0	75.3	3.2	11.4	450.	9349.
159	38.0	45.2	0.0	85.000	0.0	65.0	3.0	34.6	464.	4511.
160	37.8	85.1	0.0	123.806	0.0	125.0	4.3	29.6	464.	4911.
161	23.4	33.6	0.0	64.018	0.0	106.5	4.0	18.3	464.	4911.
162	23.4	33.6	0.0	136.726	0.0	145.6	4.7	27.5	464.	4911.
163	39.4	67.7	0.0	0.010	0.0	22.9	0.6	1.3	533.	9900.
164	35.4	79.9	0.0	5.180	0.0	55.0	4.5	3.1	464.	9900.
165	39.8	73.6	0.0	0.705	0.0	55.0	2.3	1.8	464.	9900.
166	46.1	50.1	0.0	0.409	0.0	100.0	1.3	8.1	464.	9900.
167	32.8	58.2	0.0	0.448	0.0	23.0	1.7	3.7	464.	9900.
168	15.4	8.4	0.0	0.203	0.0	12.2	0.9	3.8	492.	9900.
169	12.3	60.4	0.0	1.881	0.0	68.7	2.8	2.8	464.	9900.
170	21.6	17.2	0.0	1.094	0.0	67.0	2.0	3.3	464.	9900.
171	22.7	27.6	0.0	0.100	0.0	38.1	1.2	1.6	464.	9900.
172	12.6	60.5	0.0	1.465	0.0	38.1	1.3	14.2	492.	2010.
173	28.3	50.9	0.0	1.017	0.0	48.8	1.8	4.3	464.	2020.
174	15.2	51.1	0.0	0.118	0.0	21.2	1.1	1.3	477.	2040.
175	35.8	43.1	0.0	25.878	0.0	81.5	3.3	7.4	439.	2640.
176	45.1	31.9	0.0	0.091	0.0	33.5	2.2	1.2	492.	2500.
177	11.7	43.3	0.0	0.770	0.0	30.5	1.8	10.3	464.	2600.
178	10.4	53.5	0.0	0.030	0.0	45.8	0.9	1.0	492.	2600.
179	36.9	42.8	0.0	0.280	0.0	12.8	1.2	7.3	561.	2600.
180	39.8	42.6	0.0	0.134	0.0	21.4	1.0	1.5	497.	2600.
181	0.0	53.4	0.0	0.268	0.0	19.8	0.9	12.1	492.	2916.
182	45.1	24.7	0.0	1.015	0.0	67.0	1.9	2.2	464.	2818.
183	14.2	50.9	0.0	0.300	0.0	36.6	1.8	6.7	464.	2918.
184	36.9	81.4	0.0	6.910	0.0	34.1	3.7	5.0	464.	2818.
185	39.9	59.6	0.0	0.430	0.0	15.6	2.2	6.9	464.	2818.
186	32.5	79.8	0.0	0.190	0.0	24.4	2.4	1.2	464.	2818.
187	43.7	35.2	0.0	0.140	0.0	27.5	1.0	2.2	492.	2819.

188	48.9	33.3	0.0	0.0	0.0	38.1	2.0	2.1	464.	2819.
189	38.2	42.8	0.0	0.496	0.0	18.9	1.1	8.1	539.	2819.
190	17.1	17.1	0.0	13.737	0.0	38.2	1.8	7.6	439.	2800.
191	37.7	42.8	0.0	0.440	0.0	45.0	1.5	3.8	577.	2820.
192	33.8	70.5	0.0	0.130	0.0	16.5	1.8	2.0	464.	2820.
193	7.7	40.9	0.0	0.0	0.0	18.9	2.4	8.2	464.	2841.
194	41.9	34.8	0.0	21.360	0.0	33.5	1.8	6.1	533.	2911.
195	22.3	61.8	0.0	0.125	0.0	9.1	1.5	10.5	492.	2911.
196	23.8	35.1	0.0	9.700	0.0	30.5	5.1	5.0	464.	2911.
197	23.8	31.5	0.0	17.860	0.0	30.5	6.1	7.8	464.	2911.
198	35.1	43.5	0.0	0.274	0.0	19.3	1.1	5.9	492.	2951.
199	46.3	24.8	0.0	0.235	0.0	15.3	2.4	2.1	492.	2952.
200	37.4	85.4	0.0	1.890	0.0	61.5	3.7	1.6	464.	3270.
201	34.5	44.3	0.0	1.850	0.0	19.3	3.8	4.8	464.	3275.
202	22.3	28.2	0.0	3.904	0.0	32.3	2.2	7.9	464.	3297.
203	22.3	28.2	0.0	0.070	0.0	53.3	1.8	1.1	464.	3297.
204	8.8	53.7	0.0	0.616	0.0	30.5	1.0	14.0	492.	3322.
205	46.2	24.2	0.0	0.320	0.0	47.0	1.2	6.2	492.	3312.
206	37.5	83.9	0.0	0.260	0.0	68.7	1.2	3.7	492.	3312.
207	39.3	59.0	0.0	0.560	0.0	19.8	2.1	3.6	464.	3341.
208	44.1	32.8	0.0	5.500	0.0	47.6	4.0	7.6	464.	3391.
209	39.0	42.8	0.0	0.230	0.0	15.2	2.4	3.5	490.	3391.
210	40.2	48.8	0.0	0.0	0.0	52.4	2.8	1.5	464.	3392.
211	45.4	29.3	0.0	0.210	0.0	12.3	1.4	4.9	492.	3399.
212	39.4	42.7	0.0	0.430	0.0	45.8	1.8	4.2	533.	3411.
213	43.9	53.8	0.0	0.215	0.0	40.0	1.7	4.1	464.	9500.
214	40.4	49.8	0.0	0.111	0.0	40.0	1.3	4.0	492.	9900.
215	45.7	50.4	0.0	0.176	0.0	40.0	1.5	4.2	464.	9900.
216	47.7	40.6	0.0	0.126	0.0	40.0	1.4	3.9	492.	9900.
217	42.0	47.2	0.0	0.122	0.0	40.0	1.3	4.2	492.	9900.
218	47.6	40.6	0.0	0.130	0.0	40.0	1.3	3.8	492.	9900.
219	46.1	43.9	0.0	0.152	0.0	40.0	1.5	3.8	464.	9900.
220	44.8	36.1	0.0	0.237	0.0	40.0	1.8	3.9	464.	9900.
221	40.6	49.1	0.0	0.094	0.0	40.0	1.2	3.7	492.	9900.
222	45.6	52.6	0.0	0.093	0.0	40.0	1.2	3.7	492.	9900.
223	40.9	53.2	0.0	0.104	0.0	40.0	1.1	4.2	492.	9900.
224	43.2	45.4	0.0	0.077	0.0	40.0	1.0	3.7	492.	9900.
225	37.2	53.0	0.0	0.103	0.0	40.0	1.3	3.9	492.	9900.
226	49.8	35.8	0.0	0.203	0.0	40.0	1.7	4.0	464.	9900.
227	46.3	49.8	0.0	0.069	0.0	40.0	1.0	3.9	492.	9900.
228	40.2	45.8	0.0	0.080	0.0	40.2	1.1	4.1	492.	9900.
229	44.6	49.1	0.0	0.082	0.0	40.0	1.1	3.8	492.	9900.
230	44.4	36.3	0.0	0.195	0.0	10.0	1.5	4.5	464.	9900.
231	43.0	47.7	0.0	0.194	0.0	40.0	1.5	4.6	464.	9900.
232	40.8	45.8	0.0	0.078	0.0	40.0	1.0	4.3	492.	9900.
233	44.4	46.5	0.0	0.075	0.0	40.0	1.0	4.1	492.	9900.
234	46.2	48.2	0.0	0.125	0.0	40.0	1.8	4.3	464.	9900.
235	45.0	46.5	0.0	0.087	0.0	40.0	1.2	3.6	492.	9900.
236	46.7	50.8	0.0	0.087	0.0	40.0	1.2	3.6	492.	9900.
237	44.7	46.7	0.0	0.086	0.0	40.0	1.2	3.6	492.	9900.
238	45.7	46.1	0.0	0.062	0.0	40.0	0.9	3.4	492.	9900.
239	40.3	52.7	0.0	0.086	0.0	40.0	1.2	3.6	492.	9900.
240	44.1	48.1	0.0	0.112	0.0	40.0	1.3	3.2	492.	9900.
241	42.4	50.5	0.0	0.082	0.0	40.0	1.1	4.0	492.	9900.
242	44.5	46.5	0.0	0.065	0.0	40.0	1.0	3.8	492.	9900.
243	47.2	38.9	0.0	0.108	0.0	10.0	1.3	3.9	492.	9900.
244	38.9	49.3	0.0	0.170	0.0	10.0	1.5	4.3	464.	9900.
245	45.0	36.1	0.0	0.156	0.0	40.0	1.4	3.8	492.	9900.
246	42.1	48.0	0.0	0.077	0.0	40.0	1.1	4.2	492.	9900.
247	44.0	54.0	0.0	0.151	0.0	40.0	1.5	3.6	492.	9900.
248	40.2	51.9	0.0	0.100	0.0	40.0	1.2	3.8	492.	9900.
249	44.5	45.5	0.0	0.075	0.0	40.0	1.0	4.1	492.	9900.
250	40.3	51.9	0.0	0.100	0.0	40.0	1.2	3.8	492.	9900.
251	45	52	0.0	0.096	0.0	40.0	1.2	3.8	492.	9900.
252	46	0	0.0	130	0.0	1	3.9	92.	92.	990
253	44.5	22.7	0.0	0.092	0.0	1	4.1	92.	92.	990

254	38.6	52.6	0.0	0.000	0.0	40.0	1.1	4.1	492.	9900.
255	49.2	35.1	0.0	0.093	0.0	40.0	1.2	3.7	492.	9900.
256	40.9	51.2	0.0	0.069	0.0	40.0	1.0	4.0	492.	9900.
257	40.4	51.6	0.0	0.143	0.0	40.0	1.3	4.0	492.	9900.
258	45.0	48.4	0.0	0.068	0.0	40.0	1.0	4.0	492.	9900.
259	40.4	48.4	0.0	0.068	0.0	10.0	1.0	4.0	492.	9900.
260	43.1	48.7	0.0	0.074	0.0	10.0	1.0	4.0	492.	9900.
261	44.7	47.9	0.0	0.053	0.0	40.0	0.9	3.7	492.	9900.
262	43.0	48.6	0.0	0.047	0.0	40.0	0.8	2.9	492.	9900.
263	45.4	48.2	0.0	0.052	0.0	40.0	0.9	3.0	492.	9900.
264	40.4	48.7	0.0	0.022	0.0	40.0	0.8	2.5	492.	9900.
265	44.0	53.0	0.0	0.062	0.0	40.0	0.9	3.3	492.	9900.
266	45.1	51.9	0.0	0.036	0.0	40.0	0.8	2.6	492.	9900.
267	54.4	30.2	0.0	0.137	0.0	25.0	1.8	3.4	464.	2800.
268	54.5	33.1	0.0	11.271	0.0	43.1	3.4	9.8	464.	2800.
269	53.6	30.3	0.0	0.107	0.0	9.0	1.0	1.8	492.	2819.
270	54.5	33.2	0.0	11.257	0.0	45.0	3.0	9.1	464.	2820.
271	54.1	35.6	0.0	9.376	0.0	30.0	2.4	7.0	533.	2820.
272	52.1	37.1	0.0	0.695	0.0	46.0	2.1	2.4	464.	2841.
273	53.7	33.8	0.0	0.005	0.0	40.0	0.3	1.0	912.	2911.
274	53.5	34.1	0.0	0.021	0.0	30.0	1.0	0.3	611.	2911.
275	55.9	32.3	0.0	0.293	0.0	21.3	1.2	1.0	330.	2911.
276	53.9	35.3	0.0	0.583	0.0	40.0	2.3	1.0	530.	2911.
277	53.7	33.8	0.0	1.578	0.0	18.0	1.8	5.4	464.	2911.
278	53.1	33.5	0.0	0.110	0.0	12.2	1.5	3.6	492.	2911.
279	55.9	32.3	0.0	0.240	0.0	27.3	1.3	7.0	402.	2911.
280	53.5	34.1	0.0	15.307	0.0	50.0	2.5	5.0	464.	2911.
281	53.9	35.3	0.0	4.934	0.0	45.0	2.5	10.8	464.	2911.
282	55.9	32.3	0.0	1.648	0.0	45.7	2.1	5.0	464.	2911.
283	55.7	34.9	0.0	0.356	0.0	22.0	0.9	4.3	533.	3312.
284	55.9	35.1	0.0	0.537	0.0	44.0	3.1	0.9	464.	3312.
285	55.7	34.8	0.0	1.225	0.0	46.0	1.6	2.1	464.	3312.
286	55.5	34.9	0.0	0.126	0.0	46.6	2.0	7.6	464.	3312.
287	54.3	34.5	0.0	0.652	0.0	68.7	3.1	0.0	464.	3312.
288	54.9	34.5	0.0	0.188	0.0	68.7	3.1	0.1	464.	3312.
289	54.7	34.3	0.0	31.920	0.0	44.0	3.1	9.8	464.	3312.
290	54.9	34.5	0.0	5.800	0.0	70.5	3.4	0.3	492.	3312.
291	55.9	35.1	0.0	13.400	0.0	76.5	3.4	0.3	464.	3312.
292	54.9	34.5	0.0	2.140	0.0	45.8	1.8	7.5	464.	3312.
293	55.9	35.1	0.0	11.740	0.0	47.3	4.8	5.0	492.	3312.
294	55.2	34.6	0.0	3.550	0.0	45.0	2.4	15.5	464.	3312.
295	55.9	35.1	0.0	1.566	0.0	45.8	2.1	5.0	464.	3312.
296	54.9	34.5	0.0	0.170	0.0	45.9	3.4	14.0	492.	3312.
297	54.7	34.3	0.0	1.132	0.0	42.8	2.4	5.0	492.	3312.
298	55.9	35.3	0.0	3.132	0.0	44.0	2.1	14.0	464.	3312.
299	55.9	35.3	0.0	5.157	0.0	29.0	1.8	17.0	464.	3312.
300	55.7	34.9	0.0	0.699	0.0	20.0	3.0	4.0	492.	3312.
301	55.7	34.9	0.0	2.030	0.0	20.0	3.0	13.0	533.	3312.
302	55.5	34.9	0.0	0.137	0.0	20.0	3.0	1.7	533.	3312.
303	55.5	34.9	0.0	0.065	0.0	47.3	2.1	17.0	464.	3312.
304	55.5	35.3	0.0	9.538	0.0	37.8	3.4	11.6	464.	3312.
305	55.5	35.8	0.0	0.114	0.0	75.0	4.9	3.9	464.	3312.
306	54.9	34.8	0.0	0.038	0.0	20.0	0.5	10.0	492.	3312.
307	54.4	34.6	0.0	0.625	0.0	40.0	2.0	10.4	464.	3312.
308	55.0	35.1	0.0	4.200	0.0	52.0	2.6	16.9	464.	3312.
309	55.4	35.8	0.0	0.700	0.0	49.0	2.3	6.1	464.	3312.
310	55.0	35.3	0.0	0.425	0.0	47.0	2.0	12.4	464.	3312.
311	54.7	35.4	0.0	0.173	0.0	56.0	2.0	8.5	464.	3312.
312	54.9	35.3	0.0	0.463	0.0	54.0	2.0	2.0	464.	3312.
313	55.5	35.8	0.0	0.378	0.0	49.0	2.3	20.6	464.	3312.
314	54.6	35.6	0.0	0.767	0.0	82.0	3.0	11.0	464.	3312.
315	54.9	35.3	0.0	1.632	0.0	26.0	2.6	2.4	464.	3312.
316	54.9	34.9	0.0	5.230	0.0	88.6	3.4	10.3	285.	3312.
317	54.4	34.6	0.0	0.312	0.0	52.0	2.6	6.2	464.	3312.
318	55.0	35.1	0.0	0.003	0.0	52.0	2.6	22.2	464.	3312.
319	55.0	35.1	0.0	15.475	0.0	52.0	2.6	18.0	464.	3312.

320	60.3	32.1	0.0	30.850	0.0	48.0	3.1	5.0	464.	3312.
321	60.3	32.1	0.0	42.208	0.0	48.0	3.1	34.0	464.	3312.
322	69.5	33.3	0.0	4.570	0.0	72.0	3.4	10.2	464.	3312.
323	69.3	32.2	0.0	0.960	0.0	32.0	1.0	10.0	464.	3312.
324	51.3	32.5	0.0	0.781	0.0	18.0	1.2	6.8	492.	3312.
325	0.0	32.0	0.0	0.113	0.0	37.0	1.5	5.0	533.	3332.
326	51.2	33.5	0.0	0.078	0.0	33.6	1.4	1.7	533.	3391.
327	54.0	34.1	0.0	0.220	0.0	40.0	1.6	2.6	492.	3391.
328	62.0	30.3	0.0	0.297	0.0	21.0	1.1	5.5	492.	3450.
329	52.8	34.8	0.0	0.226	0.0	27.3	2.0	4.1	464.	3900.
330	51.2	38.4	0.0	169.697	0.0	116.0	7.3	5.5	464.	4211.
331	71.8	33.6	0.0	11.916	0.0	122.0	4.6	45.1	430.	4911.
332	57.2	33.5	0.0	96.615	0.0	72.0	6.0	24.9	416.	4911.
333	75.6	21.5	0.0	0.104	0.0	23.4	1.0	1.9	492.	9200.
334	44.7	45.3	0.0	0.114	0.0	52.8	2.6	0.2	492.	2010.
335	44.2	45.9	0.0	0.258	0.0	38.0	1.9	0.8	464.	2010.
336	45.5	46.1	0.0	0.693	0.0	45.6	2.2	2.3	492.	2010.
337	44.5	45.3	0.0	1.733	0.0	47.0	2.3	2.5	464.	2010.
338	44.2	45.8	0.0	2.422	0.0	64.7	3.9	1.2	464.	2010.
339	39.4	52.7	0.0	4.287	0.0	45.6	2.2	8.2	464.	2040.
340	44.7	52.3	0.0	0.174	0.0	12.0	0.7	8.0	464.	2040.
341	45.3	48.3	0.0	1.054	0.0	76.0	3.6	0.8	464.	2500.
342	42.2	51.2	0.0	0.376	0.0	55.0	2.6	0.7	492.	2500.
343	49.6	35.3	0.0	0.586	0.0	33.0	1.7	3.9	464.	2621.
344	40.4	53.9	0.0	0.442	0.0	58.0	2.8	0.8	492.	2711.
345	45.4	48.1	0.0	0.276	0.0	42.5	2.1	0.8	492.	2711.
346	49.8	36.8	0.0	0.573	0.0	33.0	1.7	2.6	492.	2800.
347	44.7	52.2	0.0	4.598	0.0	68.0	3.3	3.5	464.	2841.
348	46.9	36.6	0.0	2.922	0.0	60.1	3.7	3.1	492.	2851.
349	46.3	49.4	0.0	0.153	0.0	105.0	1.5	1.0	533.	2911.
350	50.4	38.3	0.0	5.880	0.0	33.0	1.7	5.0	464.	3200.
351	46.0	34.1	0.0	4.246	0.0	68.0	3.3	3.2	464.	3312.
352	49.9	37.4	0.0	1.815	0.0	18.0	1.0	16.6	464.	3312.
353	49.9	36.4	0.0	3.670	0.0	33.0	1.7	13.0	464.	3312.
354	50.7	40.1	0.0	5.000	0.0	45.6	2.2	28.1	464.	3312.
355	43.1	43.5	0.0	1.168	0.0	63.0	3.0	1.2	464.	3411.
356	41.1	48.0	0.0	0.363	0.0	48.5	2.4	1.3	492.	3900.
357	43.3	45.0	0.0	0.765	0.0	42.0	2.1	2.5	464.	3900.
358	40.6	47.1	0.0	0.240	0.0	45.6	2.2	1.0	492.	3900.
359	42.1	42.0	0.0	0.484	0.0	28.0	1.5	4.2	464.	3900.
360	45.1	45.4	0.0	0.290	0.0	45.6	2.2	1.5	492.	3900.
361	42.0	54.6	0.0	0.274	0.0	38.0	1.9	0.9	492.	3900.
362	44.7	51.7	0.0	0.282	0.0	33.0	1.7	1.5	492.	3900.
363	44.2	52.7	0.0	0.319	0.0	24.0	1.3	2.9	492.	3900.
364	45.7	51.8	0.0	0.310	0.0	41.0	2.0	1.7	492.	3900.
365	45.0	36.1	0.0	1.013	0.0	25.7	1.4	6.8	464.	3900.
366	52.1	41.6	0.0	0.294	0.0	52.0	2.6	0.6	492.	3900.
367	43.0	48.0	0.0	0.217	0.0	55.0	2.6	0.3	464.	3900.
368	40.3	51.7	0.0	1.031	0.0	60.0	2.9	1.7	464.	3900.
369	45.9	46.2	0.0	0.139	0.0	47.0	2.3	0.3	533.	3900.
370	40.4	48.2	0.0	0.0	0.0	78.0	3.6	2.9	464.	3900.
371	42.9	46.8	0.0	6.042	0.0	67.0	3.2	4.8	464.	3900.
372	41.3	53.5	0.0	2.021	0.0	45.6	2.2	3.4	464.	3900.
373	40.4	50.7	0.0	0.900	0.0	55.0	2.6	1.4	492.	3900.
374	46.5	50.7	0.0	0.219	0.0	36.1	1.8	0.9	492.	3900.
375	46.7	50.7	0.0	2.579	0.0	52.0	2.8	2.5	464.	3900.
376	45.0	51.3	0.0	1.875	0.0	60.0	2.9	2.6	464.	3900.
377	43.0	47.9	0.0	4.294	0.0	46.0	2.2	10.1	464.	3900.
378	42.7	37.8	0.0	3.030	0.0	33.0	1.7	12.4	464.	3900.
379	44.9	35.9	0.0	1.254	0.0	36.1	1.8	3.7	464.	3900.
380	42.7	54.4	0.0	0.0	0.0	100.0	4.3	6.5	464.	4911.
381	44.1	3	0	138	0.0	100.0	2.1	13.2	464.	4911.
382	44.1	3	0	131	0.0	100.0	2.1	3.0	464.	4911.
383	41.3	46.7	0.0	138.221	0.0	100.0	2.1	12.9	464.	4911.

385	40.2	55.2	0.0	2.343	0.0	93.4	3.7	1.4	464.	9349.
387	45.7	38.2	0.0	2.029	0.0	72.7	3.6	1.2	464.	9349.
388	41.4	49.2	0.0	1.952	0.0	78.7	3.6	1.2	464.	9349.
389	43.2	45.1	0.0	1.830	0.0	71.0	3.4	1.3	464.	9349.
390	38.0	46.2	0.0	2.115	0.0	52.8	2.6	5.0	492.	4953.
391	46.1	45.1	0.0	0.736	0.0	36.7	1.9	12.7	464.	9900.
392	44.6	49.5	0.0	0.774	0.0	61.0	2.8	4.3	464.	9900.
393	45.7	51.6	0.0	0.409	0.0	13.1	0.8	3.2	492.	5900.
394	49.3	37.8	0.0	0.908	0.0	52.5	2.5	12.3	492.	5900.
395	46.2	46.5	0.0	0.310	0.0	50.5	2.5	3.4	464.	9900.
396	45.1	47.8	0.0	0.252	0.0	24.6	1.4	5.6	464.	9900.
397	46.1	47.1	0.0	0.466	0.0	36.0	1.8	1.7	492.	9900.
398	43.7	53.7	0.0	0.226	0.0	44.3	2.2	1.5	464.	9900.
399	43.1	49.7	0.0	0.127	0.0	44.2	2.3	1.4	492.	9900.
400	47.5	34.3	0.0	0.106	0.0	23.0	1.3	2.3	492.	9900.
401	43.9	50.4	0.0	0.106	0.0	49.2	2.4	0.7	464.	9900.
402	45.7	48.3	0.0	0.090	0.0	33.8	1.7	0.9	492.	9900.
403	46.2	52.2	0.0	0.129	0.0	105.0	1.6	1.9	492.	9900.
404	43.9	50.7	0.0	0.520	0.0	82.0	3.9	0.3	464.	9900.
405	46.0	47.0	0.0	0.139	0.0	45.5	3.0	1.2	464.	9900.
406	45.8	50.7	0.0	0.420	0.0	125.0	2.7	1.5	464.	9900.
407	46.9	50.4	0.0	0.101	0.0	222.0	2.7	0.8	464.	9900.
408	46.2	50.0	0.0	1.270	0.0	65.0	2.1	3.5	464.	9900.
409	46.2	50.1	0.0	1.397	0.0	27.9	1.4	13.6	492.	9900.
410	47.7	43.8	0.0	2.151	0.0	52.5	2.5	4.1	464.	9900.
411	45.2	49.2	0.0	1.562	0.0	55.0	2.3	7.8	464.	9900.
412	46.8	51.1	0.0	1.082	0.0	60.0	2.0	3.5	464.	9900.
413	48.8	40.3	0.0	0.203	0.0	65.0	1.6	2.4	492.	9900.
414	31.9	57.4	0.0	0.0	0.0	100.0	0.0	0.0	0.	9900.
415	31.9	57.4	0.0	0.0	0.0	100.0	0.0	0.0	0.	9900.
416	31.9	57.4	0.0	0.0	0.0	100.0	0.0	0.0	0.	9900.
417	32.7	43.7	0.0	0.0	0.0	100.0	0.0	0.0	0.	9900.
418	32.7	43.7	0.0	0.0	0.0	100.0	0.0	0.0	0.	9900.
419	53.6	30.3	0.0	3.903	0.0	90.0	1.8	7.5	333.	2819.
420	54.5	31.3	0.0	0.137	0.0	23.0	0.4	5.0	530.	2819.
421	54.9	32.0	0.0	6.386	0.0	60.0	1.8	12.3	363.	2819.
422	54.1	35.6	0.0	0.0	0.0	35.0	1.6	5.0	450.	2820.
423	53.5	34.1	0.0	0.223	0.0	50.0	1.3	0.2	811.	2911.
424	53.9	35.3	0.0	1.421	0.0	62.0	2.6	2.9	811.	2911.
425	53.5	34.1	0.0	1.039	0.0	41.0	2.3	2.7	811.	2911.
426	55.9	32.3	0.0	0.630	0.0	22.5	1.2	8.3	810.	2911.
427	53.9	35.3	0.0	4.692	0.0	65.0	2.5	9.0	700.	2911.
428	53.5	35.6	0.0	78.195	0.0	55.0	2.6	12.2	420.	2911.
429	53.7	33.8	0.0	0.900	0.0	38.0	3.5	8.2	805.	2911.
430	55.9	32.3	0.0	0.027	0.0	27.2	1.5	2.1	300.	2911.
431	55.9	32.3	0.0	0.196	0.0	54.9	1.8	0.3	300.	2911.
432	56.6	33.4	0.0	38.500	0.0	100.0	4.5	16.0	475.	3241.
433	57.0	33.5	0.0	21.519	0.0	30.0	4.5	12.0	475.	3241.
434	55.0	35.3	0.0	0.0	0.0	39.0	1.6	8.0	300.	3312.
435	60.5	31.7	0.0	0.0	0.0	51.2	3.0	6.1	700.	3312.
436	54.9	35.4	0.0	0.0	0.0	33.0	1.3	10.0	500.	3312.
437	55.9	35.1	0.0	0.0	0.0	61.0	3.4	9.3	355.	3312.
438	54.7	34.3	0.0	0.0	0.0	36.6	4.0	10.7	355.	3312.
439	55.4	35.1	0.0	0.0	0.0	39.6	1.8	5.1	435.	3312.
440	54.9	34.5	0.0	0.0	0.0	10.0	5.0	3.1	285.	3312.
441	55.9	35.1	0.0	0.0	0.0	50.3	2.9	5.5	700.	3312.
442	54.9	35.3	0.0	0.0	0.0	33.0	1.3	10.0	500.	3312.
443	61.2	31.7	0.0	0.0	0.0	33.0	3.0	10.5	530.	3312.
444	61.0	31.8	0.0	0.0	0.0	45.3	5.2	2.5	353.	3312.
445	55.4	35.1	0.0	0.0	0.0	39.6	3.5	16.4	435.	3312.
446	62.0	31.5	0.0	0.0	0.0	10.0	2.8	11.7	283.	3312.
447	54.5	34.5	0.0	0.0	0.0	42.8	6.7	9.4	530.	3312.
448	55.9	35.1	0.0	0.0	0.0	32.0	4.8	2.2	320.	3312.
449	61.5	31.7	0.0	0.0	0.0	37.5	2.4	5.0	433.	3312.
450	54.7	31.5	0.0	0.0	0.0	11.3	0.8	4.8	533.	2227.
451	56.7	25.1	0.0	0.0	0.0	18.3	2.3	1.1	1030.	3321.

452	54.5	34.0	0.0	0.0	0.0	14.0	1.0	5.1	420.	3323.
453	54.5	34.0	0.0	0.0	0.0	15.0	1.0	2.6	300.	3323.
454	54.5	32.0	0.0	0.304	0.0	37.0	1.5	20.8	391.	3332.
455	54.4	32.8	0.0	0.0	0.0	15.3	0.3	30.4	320.	3361.
456	54.4	32.8	0.0	0.0	0.0	15.3	1.4	3.2	700.	3361.
457	53.0	35.8	0.0	0.0	0.0	91.4	2.7	6.5	505.	3362.
458	54.9	34.1	0.0	0.0	0.0	40.0	2.5	1.3	464.	3371.
459	54.9	34.1	0.0	0.0	0.0	40.0	2.5	1.3	464.	3371.
460	46.2	51.2	1.01	2.340	0.0	40.0	0.0	0.0	0.	9999.
461	45.2	51.2	1.01	3.388	0.0	40.0	0.0	0.0	0.	9999.
462	44.2	51.2	1.01	2.430	0.0	40.0	0.0	0.0	0.	9999.
463	43.2	51.2	1.01	2.089	0.0	40.0	0.0	0.0	0.	9999.
464	42.2	51.2	1.01	1.710	0.0	10.0	0.0	0.0	0.	9999.
465	46.2	50.2	1.01	2.874	0.0	40.0	0.0	0.0	0.	9999.
466	45.2	50.2	1.01	5.017	0.0	40.0	0.0	0.0	0.	9999.
467	44.2	50.2	1.01	2.941	0.0	40.0	0.0	0.0	0.	9999.
468	43.2	50.2	1.01	2.177	0.0	40.0	0.0	0.0	0.	9999.
469	42.2	50.2	1.01	2.130	0.0	10.0	0.0	0.0	0.	9999.
470	46.2	49.2	1.01	1.954	0.0	40.0	0.0	0.0	0.	9999.
471	45.2	49.2	1.01	2.970	0.0	40.0	0.0	0.0	0.	9999.
472	44.2	49.2	1.01	2.845	0.0	40.0	0.0	0.0	0.	9999.
473	43.2	49.2	1.01	2.136	0.0	40.0	0.0	0.0	0.	9999.
474	42.2	49.2	1.01	2.116	0.0	10.0	0.0	0.0	0.	9999.
475	46.3	48.2	1.01	1.904	0.0	40.0	0.0	0.0	0.	9999.
476	45.2	48.2	1.01	1.495	0.0	40.0	0.0	0.0	0.	9999.
477	44.2	48.2	1.01	2.617	0.0	40.0	0.0	0.0	0.	9999.
478	43.2	48.2	1.01	1.724	0.0	40.0	0.0	0.0	0.	9999.
479	42.2	48.2	1.01	2.013	0.0	10.0	0.0	0.0	0.	9999.
480	46.2	47.2	1.01	1.701	0.0	40.0	0.0	0.0	0.	9999.
481	45.2	47.2	1.01	2.016	0.0	40.0	0.0	0.0	0.	9999.
482	44.2	47.2	1.01	0.915	0.0	40.0	0.0	0.0	0.	9999.
483	43.2	47.2	1.01	0.765	0.0	40.0	0.0	0.0	0.	9999.
484	42.2	47.2	1.01	1.423	0.0	40.0	0.0	0.0	0.	9999.
485	47.2	46.2	1.01	0.496	0.0	10.0	0.0	0.0	0.	9999.
486	46.2	46.2	1.01	2.162	0.0	40.0	0.0	0.0	0.	9999.
487	45.2	46.2	1.01	1.293	0.0	40.0	0.0	0.0	0.	9999.
488	44.2	46.2	1.01	2.982	0.0	40.0	0.0	0.0	0.	9999.
489	43.2	46.2	1.01	0.629	0.0	40.0	0.0	0.0	0.	9999.
490	42.2	46.2	1.01	0.979	0.0	10.0	0.0	0.0	0.	9999.
491	44.2	54.2	4.04	8.725	0.0	10.0	0.0	0.0	0.	9999.
492	42.2	54.2	4.04	5.799	0.0	10.0	0.0	0.0	0.	9999.
493	40.2	54.2	4.04	4.731	0.0	10.0	0.0	0.0	0.	9999.
494	44.2	52.2	4.04	10.252	0.0	40.0	0.0	0.0	0.	9999.
495	52.2	52.2	4.04	6.789	0.0	10.0	0.0	0.0	0.	9999.
496	46.2	52.2	4.04	6.692	0.0	10.0	0.0	0.0	0.	9999.
497	40.2	50.2	4.04	5.088	0.0	10.0	0.0	0.0	0.	9999.
498	46.2	48.2	4.04	8.829	0.0	10.0	0.0	0.0	0.	9999.
499	46.2	46.2	4.04	2.654	0.0	40.0	0.0	0.0	0.	9999.
500	46.2	44.2	4.04	9.922	0.0	10.0	0.0	0.0	0.	9999.
501	44.2	44.2	4.04	4.210	0.0	10.0	0.0	0.0	0.	9999.
502	42.2	44.2	4.04	5.365	0.0	10.0	0.0	0.0	0.	9999.
503	40.2	44.2	4.04	3.268	0.0	10.0	0.0	0.0	0.	9999.
504	48.2	52.2	4.04	4.052	0.0	10.0	0.0	0.0	0.	9999.
505	46.2	42.2	4.04	8.319	0.0	10.0	0.0	0.0	0.	9999.
506	44.2	42.2	4.04	5.065	0.0	10.0	0.0	0.0	0.	9999.
507	52.2	42.2	4.04	2.466	0.0	10.0	0.0	0.0	0.	9999.
508	46.2	42.2	4.04	1.224	0.0	10.0	0.0	0.0	0.	9999.
509	50.2	39.2	4.04	0.313	0.0	40.0	0.0	0.0	0.	9999.
510	50.2	37.1	4.04	0.671	0.0	40.0	0.0	0.0	0.	9999.
511	30.1	87.4	100.88	0.962	0.0	10.0	0.0	0.0	0.	9999.
512	20.1	87.4	100.88	0.962	0.0	10.0	0.0	0.0	0.	9999.
513	10.0	87.4	100.88	0.207	0.0	10.0	0.0	0.0	0.	9999.
514	0.0	87.4	100.88	0.207	0.0	10.0	0.0	0.0	0.	9999.
515	0.0	7.3	1	1.20	0.0	0.0	0.0	0.0	0.	9999.
516	0.0	17.3	100.88	3.96	0.0	10.0	0.0	0.0	0.	9999.
517	10.0	77.3	100.88	0.207	0.0	10.0	0.0	0.0	0.	9999.

518	0.0	77.3	100.88	0.261	0.0	10.0	0.0	0.0	0.0	9999.
519	30.1	67.3	100.88	0.962	0.0	10.0	0.0	0.0	0.0	9999.
520	20.1	67.3	100.88	0.962	0.0	10.0	0.0	0.0	0.0	9999.
521	10.0	67.3	100.88	0.207	0.0	10.0	0.0	0.0	0.0	9999.
522	0.0	67.3	100.88	0.207	0.0	10.0	0.0	0.0	0.0	9999.
523	40.2	61.3	25.22	5.414	0.0	10.0	0.0	0.0	0.0	9999.
524	35.1	62.3	25.22	4.061	0.0	10.0	0.0	0.0	0.0	9999.
525	30.1	62.3	25.22	4.061	0.0	10.0	0.0	0.0	0.0	9999.
526	20.1	57.2	100.88	1.354	0.0	10.0	0.0	0.0	0.0	9999.
527	10.0	57.2	100.88	1.354	0.0	10.0	0.0	0.0	0.0	9999.
528	0.0	57.2	100.88	0.589	0.0	10.0	0.0	0.0	0.0	9999.
529	40.2	56.2	25.22	16.909	0.0	10.0	0.0	0.0	0.0	9999.
530	35.1	57.2	25.22	7.404	0.0	10.0	0.0	0.0	0.0	9999.
531	30.1	57.2	25.22	13.536	0.0	10.0	0.0	0.0	0.0	9999.
532	35.1	52.2	25.22	10.937	0.0	10.0	0.0	0.0	0.0	9999.
533	30.1	52.2	25.22	13.802	0.0	10.0	0.0	0.0	0.0	9999.
534	20.1	47.2	100.88	1.455	0.0	10.0	0.0	0.0	0.0	9999.
535	10.0	47.2	100.88	0.0	0.0	10.0	0.0	0.0	0.0	9999.
536	0.0	47.2	100.88	0.424	0.0	10.0	0.0	0.0	0.0	9999.
537	35.1	47.2	25.22	10.800	0.0	10.0	0.0	0.0	0.0	9999.
538	30.1	47.2	25.22	6.768	0.0	10.0	0.0	0.0	0.0	9999.
539	35.1	42.2	25.22	11.699	0.0	40.0	0.0	0.0	0.0	9999.
540	30.1	42.2	25.22	9.144	0.0	10.0	0.0	0.0	0.0	9999.
541	20.1	37.1	100.88	2.462	0.0	10.0	0.0	0.0	0.0	9999.
542	10.0	37.1	100.88	1.049	0.0	10.0	0.0	0.0	0.0	9999.
543	0.0	37.1	100.88	0.389	0.0	10.0	0.0	0.0	0.0	9999.
544	45.2	37.1	25.22	13.702	0.0	10.0	0.0	0.0	0.0	9999.
545	40.2	37.1	25.22	7.227	0.0	10.0	0.0	0.0	0.0	9999.
546	35.1	37.1	25.22	6.768	0.0	10.0	0.0	0.0	0.0	9999.
547	30.1	37.1	25.22	6.768	0.0	10.0	0.0	0.0	0.0	9999.
548	45.2	32.1	25.22	2.852	0.0	10.0	0.0	0.0	0.0	9999.
549	40.2	32.1	25.22	1.396	0.0	10.0	0.0	0.0	0.0	9999.
550	30.1	27.1	100.88	1.354	0.0	10.0	0.0	0.0	0.0	9999.
551	20.1	27.1	100.88	0.133	0.0	10.0	0.0	0.0	0.0	9999.
552	10.0	27.1	100.88	0.124	0.0	10.0	0.0	0.0	0.0	9999.
553	45.2	27.1	25.22	6.768	0.0	10.0	0.0	0.0	0.0	9999.
554	40.2	27.1	25.22	6.768	0.0	10.0	0.0	0.0	0.0	9999.
555	45.2	22.1	25.22	6.768	0.0	10.0	0.0	0.0	0.0	9999.
556	40.2	22.1	25.22	27.072	0.0	10.0	0.0	0.0	0.0	9999.
557	30.1	17.1	100.88	0.133	0.0	10.0	0.0	0.0	0.0	9999.
558	20.1	17.1	100.88	0.772	0.0	10.0	0.0	0.0	0.0	9999.
559	10.0	17.1	100.88	0.257	0.0	10.0	0.0	0.0	0.0	9999.
560	45.2	17.1	25.22	0.257	0.0	10.0	0.0	0.0	0.0	9999.
561	40.2	17.1	25.22	0.257	0.0	10.0	0.0	0.0	0.0	9999.
562	40.2	7.1	100.88	0.124	0.0	10.0	0.0	0.0	0.0	9999.
563	30.1	7.1	100.88	0.133	0.0	10.0	0.0	0.0	0.0	9999.
564	20.1	7.1	100.88	0.124	0.0	10.0	0.0	0.0	0.0	9999.
565	10.0	7.1	100.88	0.257	0.0	10.0	0.0	0.0	0.0	9999.
566	52.2	36.1	1.01	1.670	0.0	10.0	0.0	0.0	0.0	9999.
567	52.2	35.1	1.01	0.959	0.0	10.0	0.0	0.0	0.0	9999.
568	52.2	35.1	1.01	1.770	0.0	10.0	0.0	0.0	0.0	9999.
569	55.2	34.1	1.01	0.910	0.0	10.0	0.0	0.0	0.0	9999.
570	52.2	34.1	1.01	0.680	0.0	10.0	0.0	0.0	0.0	9999.
571	53.2	34.1	1.01	0.570	0.0	10.0	0.0	0.0	0.0	9999.
572	52.2	34.1	1.01	0.500	0.0	10.0	0.0	0.0	0.0	9999.
573	55.2	33.1	1.01	1.230	0.0	10.0	0.0	0.0	0.0	9999.
574	54.2	33.1	1.01	2.090	0.0	10.0	0.0	0.0	0.0	9999.
575	53.2	33.1	1.01	0.810	0.0	10.0	0.0	0.0	0.0	9999.
576	52.2	33.1	1.01	0.512	0.0	10.0	0.0	0.0	0.0	9999.
577	59.2	32.1	1.01	0.500	0.0	10.0	0.0	0.0	0.0	9999.
578	58.2	32.1	1.01	0.510	0.0	10.0	0.0	0.0	0.0	9999.
579	57.2	32.1	1.01	0.082	0.0	10.0	0.0	0.0	0.0	9999.
580	56.2	32.1	1.01	0.520	0.0	10.0	0.0	0.0	0.0	9999.
581	55.2	32.1	1.01	0.960	0.0	10.0	0.0	0.0	0.0	9999.
582	54.2	32.1	1.01	1.430	0.0	10.0	0.0	0.0	0.0	9999.
583	53.2	32.1	1.01	2.370	0.0	10.0	0.0	0.0	0.0	9999.

584	52.2	32.1	1.01	1.840	0.0	10.0	0.0	0.0	0.	9999.
585	61.3	31.1	1.01	0.510	0.0	10.0	0.0	0.0	0.	9999.
586	60.3	31.1	1.01	0.510	0.0	10.0	0.0	0.0	0.	9999.
587	59.2	31.1	1.01	0.640	0.0	10.0	0.0	0.0	0.	9999.
588	58.2	31.1	1.01	0.630	0.0	10.0	0.0	0.0	0.	9999.
589	57.2	31.1	1.01	0.520	0.0	10.0	0.0	0.0	0.	9999.
590	56.2	31.1	1.01	0.960	0.0	10.0	0.0	0.0	0.	9999.
591	55.2	31.1	1.01	4.520	0.0	10.0	0.0	0.0	0.	9999.
592	54.2	31.1	1.01	0.960	0.0	10.0	0.0	0.0	0.	9999.
593	53.2	31.1	1.01	0.940	0.0	10.0	0.0	0.0	0.	9999.
594	52.2	31.1	1.01	1.510	0.0	10.0	0.0	0.0	0.	9999.
595	50.2	37.1	4.04	0.300	0.0	10.0	0.0	0.0	0.	9999.
596	50.2	33.1	4.04	1.040	0.0	10.0	0.0	0.0	0.	9999.
597	50.2	32.1	4.04	1.400	0.0	10.0	0.0	0.0	0.	9999.
598	50.2	29.1	4.04	1.920	0.0	10.0	0.0	0.0	0.	9999.
599	52.2	29.1	4.04	4.850	0.0	10.0	0.0	0.0	0.	9999.
600	54.2	29.1	4.04	4.170	0.0	10.0	0.0	0.0	0.	9999.
601	56.2	29.1	4.04	3.110	0.0	10.0	0.0	0.0	0.	9999.
602	58.2	29.1	4.04	8.120	0.0	10.0	0.0	0.0	0.	9999.
603	60.3	29.1	4.04	7.560	0.0	10.0	0.0	0.0	0.	9999.
604	62.3	29.1	4.04	1.190	0.0	10.0	0.0	0.0	0.	9999.
605	50.2	27.1	4.04	0.720	0.0	10.0	0.0	0.0	0.	9999.
606	52.2	27.1	4.04	2.292	0.0	10.0	0.0	0.0	0.	9999.
607	54.2	27.1	4.04	3.390	0.0	10.0	0.0	0.0	0.	9999.
608	56.2	27.1	4.04	0.710	0.0	10.0	0.0	0.0	0.	9999.
609	58.2	27.1	4.04	1.410	0.0	10.0	0.0	0.0	0.	9999.
610	60.3	27.1	4.04	2.050	0.0	10.0	0.0	0.0	0.	9999.
611	62.3	27.1	4.04	1.230	0.0	10.0	0.0	0.0	0.	9999.
612	64.3	27.1	36.22	4.670	0.0	10.0	0.0	0.0	0.	9999.
613	70.3	22.1	100.88	3.620	0.0	10.0	0.0	0.0	0.	9999.
614	50.2	22.1	25.22	3.310	0.0	10.0	0.0	0.0	0.	9999.
615	55.2	22.1	25.22	4.670	0.0	10.0	0.0	0.0	0.	9999.
616	60.3	22.1	25.22	7.760	0.0	10.0	0.0	0.0	0.	9999.
617	65.3	22.1	25.22	1.500	0.0	10.0	0.0	0.0	0.	9999.
618	50.2	12.0	100.88	4.610	0.0	10.0	0.0	0.0	0.	9999.
619	60.3	12.0	100.88	1.160	0.0	10.0	0.0	0.0	0.	9999.
620	70.3	12.0	100.88	3.630	0.0	10.0	0.0	0.0	0.	9999.
621	50.2	2.0	100.88	1.170	0.0	10.0	0.0	0.0	0.	9999.
622	60.3	2.0	100.88	0.390	0.0	10.0	0.0	0.0	0.	9999.
623	70.3	2.0	100.88	0.830	0.0	10.0	0.0	0.0	0.	9999.
624	70.3	32.1	25.22	0.250	0.0	10.0	0.0	0.0	0.	9999.
625	75.3	32.1	25.22	0.490	0.0	10.0	0.0	0.0	0.	9999.
626	62.3	31.1	4.04	0.450	0.0	10.0	0.0	0.0	0.	9999.
627	54.2	35.1	1.01	0.450	0.0	10.0	0.0	0.0	0.	9999.
628	56.2	32.1	1.01	0.900	0.0	10.0	0.0	0.0	0.	9999.
PERCENT REDUCTION				49.586	100.000					
AREA SOURCE PERCENT REDUCTION				29.042	100.000					
PCINT SOURCE PERCENT REDUCTION				53.060	100.000					

ILLINOIS - CHICAGO REGION

RECEPTOR CONCENTRATION DATA

RECEPTOR NUMBER	RECEPTOR LOCATION		EXPECTED ARITHMETIC MEAN	
	(KILOMETERS)		(MICROGRAMS/CU. METER)	
	HORIZ	VERT	SO ₂	PARTICULATES
1	20.9	24.1	9.	0.
2	20.9	30.6	10.	0.
3	20.9	37.0	10.	0.
4	20.9	43.4	7.	0.
5	20.9	49.9	9.	0.
6	20.9	56.3	8.	0.
7	20.9	62.8	8.	0.
8	20.9	69.2	9.	0.
9	20.9	75.6	8.	0.
10	20.9	82.1	7.	0.
11	20.9	88.5	7.	0.
12	20.9	94.9	7.	0.
13	20.9	101.4	7.	0.
14	20.9	107.8	6.	0.
15	20.9	114.2	5.	0.
16	27.4	24.1	28.	0.
17	27.4	30.6	78.	0.
18	27.4	37.0	24.	0.
19	27.4	43.4	16.	0.
20	27.4	49.9	13.	0.
21	27.4	56.3	12.	0.
22	27.4	62.8	12.	0.
23	27.4	69.2	11.	0.
24	27.4	75.6	10.	0.
25	27.4	82.1	10.	0.
26	27.4	88.5	9.	0.
27	27.4	94.9	8.	0.
28	27.4	101.4	7.	0.
29	27.4	107.8	7.	0.
30	27.4	114.2	6.	0.
31	33.8	24.1	15.	0.
32	33.8	30.6	23.	0.
33	33.8	37.0	18.	0.
34	33.8	43.4	20.	0.
35	33.8	49.9	18.	0.
36	33.8	56.3	17.	0.
37	33.8	62.8	15.	0.
38	33.8	69.2	16.	0.
39	33.8	75.6	14.	0.
40	33.8	82.1	13.	0.

ILLINOIS - CHICAGO REGION

RECEPTOR CONCENTRATION DATA				
RECEPTOR NUMBER	RECEPTOR LOCATION		EXPECTED ARITHMETIC MEAN	
	(KILOMETERS)		(MICROGRAMS/CU. METER)	
	HORIZ	VERT	SO ₂	PARTICULATES
41	33.8	88.5	11.	0.
42	33.8	94.9	10.	0.
43	33.8	101.4	9.	0.
44	33.8	107.8	8.	0.
45	33.8	114.2	7.	0.
46	40.2	24.1	11.	0.
47	40.2	30.6	14.	0.
48	40.2	37.0	15.	0.
49	40.2	43.4	17.	0.
50	40.2	49.9	19.	0.
51	40.2	56.3	25.	0.
52	40.2	62.8	20.	0.
53	40.2	69.2	19.	0.
54	40.2	75.6	18.	0.
55	40.2	82.1	16.	0.
56	40.2	88.5	14.	0.
57	40.2	94.9	13.	0.
58	40.2	101.4	12.	0.
59	40.2	107.8	10.	0.
60	40.2	114.2	8.	0.
61	46.7	24.1	9.	0.
62	46.7	30.6	11.	0.
63	46.7	37.0	13.	0.
64	46.7	43.4	15.	0.
65	46.7	49.9	17.	0.
66	46.7	56.3	21.	0.
67	46.7	62.8	22.	0.
68	46.7	69.2	22.	0.
69	46.7	75.6	21.	0.
70	46.7	82.1	23.	0.
71	46.7	88.5	20.	0.
72	46.7	94.9	18.	0.
73	46.7	101.4	15.	0.
74	46.7	107.8	12.	0.
75	46.7	114.2	10.	0.
76	53.1	24.1	9.	0.
77	53.1	30.6	11.	0.
78	53.1	37.0	13.	0.
79	53.1	43.4	15.	0.
80	53.1	49.9	18.	0.

RECEPTOR CONCENTRATION DATA				
RECEPTOR NUMBER	RECEPTOR LOCATION		EXPECTED ARITHMETIC MEAN	
	(KILOMETERS)		(MICROGRAMS/CU. METER)	
	HORIZ	VERT	SO ₂	PARTICULATES
81	53.1	56.3	21.	0.
82	53.1	62.8	24.	0.
83	53.1	69.2	31.	0.
84	53.1	75.6	31.	0.
85	53.1	82.1	29.	0.
86	53.1	88.5	25.	0.
87	53.1	94.9	22.	0.
88	53.1	101.4	19.	0.
89	53.1	107.8	15.	0.
90	53.1	114.2	12.	0.
91	59.5	24.1	9.	0.
92	59.5	30.6	11.	0.
93	59.5	37.0	14.	0.
94	59.5	43.4	17.	0.
95	59.5	49.9	21.	0.
96	59.5	56.3	27.	0.
97	59.5	62.8	28.	0.
98	59.5	69.2	43.	0.
99	59.5	75.6	47.	0.
100	59.5	82.1	45.	0.
101	59.5	88.5	37.	0.
102	59.5	94.9	30.	0.
103	59.5	101.4	23.	0.
104	59.5	107.8	18.	0.
105	59.5	114.2	15.	0.
106	66.0	24.1	9.	0.
107	66.0	30.6	12.	0.
108	66.0	37.0	20.	0.
109	66.0	43.4	22.	0.
110	66.0	49.9	27.	0.
111	66.0	56.3	47.	0.
112	66.0	62.8	39.	0.
113	66.0	69.2	50.	0.
114	66.0	75.6	69.	0.
115	66.0	82.1	69.	0.
116	66.0	88.5	58.	0.
117	66.0	94.9	41.	0.
118	66.0	101.4	30.	0.
119	66.0	107.8	22.	0.
120	66.0	114.2	18.	0.

ILLINOIS - CHICAGO REGION

RECEPTOR CONCENTRATION DATA				
RECEPTOR NUMBER	RECEPTOR LOCATION		EXPECTED ARITHMETIC MEAN	
	(KILOMETERS)		(MICROGRAMS/CU. METER)	
	HORIZ	VERT	SO ₂	PARTICULATES
121	72.4	24.1	9.	0.
122	72.4	30.6	13.	0.
123	72.4	37.0	20.	0.
124	72.4	43.4	25.	0.
125	72.4	49.9	33.	0.
126	72.4	56.3	58.	0.
127	72.4	62.8	47.	0.
128	72.4	69.2	59.	0.
129	72.4	75.6	75.	0.
130	72.4	82.1	82.	0.
131	72.4	88.5	67.	0.
132	72.4	94.9	42.	0.
133	72.4	101.4	30.	0.
134	72.4	107.8	23.	0.
135	72.4	114.2	13.	0.
136	78.8	24.1	10.	0.
137	78.8	30.6	13.	0.
138	78.8	37.0	19.	0.
139	78.8	43.4	27.	0.
140	78.8	49.9	38.	0.
141	78.8	56.3	56.	0.
142	78.8	62.8	56.	0.
143	78.8	69.2	58.	0.
144	78.8	75.6	62.	0.
145	78.8	82.1	62.	0.
146	78.8	88.5	46.	0.
147	78.8	94.9	33.	0.
148	78.8	101.4	25.	0.
149	78.8	107.8	20.	0.
150	78.8	114.2	16.	0.
151	85.3	24.1	10.	0.
152	85.3	30.6	14.	0.
153	85.3	37.0	21.	0.
154	85.3	43.4	34.	0.
155	85.3	49.9	64.	0.
156	85.3	56.3	89.	0.
157	85.3	62.8	81.	0.
158	85.3	69.2	64.	0.
159	85.3	75.6	55.	0.
160	85.3	82.1	47.	0.

RECEPTOR CONCENTRATION DATA				
RECEPTOR NUMBER	RECEPTOR LOCATION		EXPECTED ARITHMETIC MEAN	
	(KILOMETERS)		(MICROGRAMS/CU. METER)	
	HORIZ	VERT	SO2	PARTICULATES
161	85.3	88.5	37.	0.
162	85.3	94.9	29.	0.
163	85.3	101.4	23.	0.
164	85.3	107.8	18.	0.
165	85.3	114.2	15.	0.
166	91.7	24.1	10.	0.
167	91.7	30.6	14.	0.
168	91.7	37.0	20.	0.
169	91.7	43.4	33.	0.
170	91.7	49.9	69.	0.
171	91.7	56.3	103.	0.
172	91.7	62.8	71.	0.
173	91.7	69.2	55.	0.
174	91.7	75.6	44.	0.
175	91.7	82.1	36.	0.
176	91.7	88.5	29.	0.
177	91.7	94.9	24.	0.
178	91.7	101.4	19.	0.
179	91.7	107.8	16.	0.
180	91.7	114.2	13.	0.
181	98.1	24.1	9.	0.
182	98.1	30.6	12.	0.
183	98.1	37.0	20.	0.
184	98.1	43.4	34.	0.
185	98.1	49.9	65.	0.
186	98.1	56.3	69.	0.
187	98.1	62.8	50.	0.
188	98.1	69.2	37.	0.
189	98.1	75.6	31.	0.
190	98.1	82.1	26.	0.
191	98.1	88.5	22.	0.
192	98.1	94.9	19.	0.
193	98.1	101.4	15.	0.
194	98.1	107.8	13.	0.
195	98.1	114.2	11.	0.
196	104.6	24.1	8.	0.
197	104.6	30.6	12.	0.
198	104.6	37.0	17.	0.
199	104.6	43.4	26.	0.
200	104.6	49.9	34.	0.

ILLINOIS - CHICAGO REGION

RECEPTOR CONCENTRATION DATA				
RECEPTOR NUMBER	RECEPTOR LOCATION		EXPECTED ARITHMETIC MEAN	
	(KILOMETERS)		(MICROGRAMS/CU. METER)	
	HORIZ.	VERT.	SO ₂	PARTICULATES
201	104.6	56.3	39.	0.
202	104.6	62.8	32.	0.
203	104.6	69.2	26.	0.
204	104.6	75.6	23.	0.
205	104.6	82.1	20.	0.
206	104.6	88.5	17.	0.
207	104.6	94.9	14.	0.
208	104.6	101.4	12.	0.
209	104.6	107.8	11.	0.
210	104.6	114.2	9.	0.
211	111.0	24.1	8.	0.
212	111.0	30.6	11.	0.
213	111.0	37.0	14.	0.
214	111.0	43.4	18.	0.
215	111.0	49.9	24.	0.
216	111.0	56.3	27.	0.
217	111.0	62.8	23.	0.
218	111.0	69.2	20.	0.
219	111.0	75.6	18.	0.
220	111.0	82.1	16.	0.
221	111.0	88.5	14.	0.
222	111.0	94.9	12.	0.
223	111.0	101.4	10.	0.
224	111.0	107.8	9.	0.
225	111.0	114.2	7.	0.
226	70.8	93.8	46.	0.
227	70.8	88.8	67.	0.
228	74.0	80.0	79.	0.
229	63.9	78.8	65.	0.
230	59.1	63.9	47.	0.
231	70.1	69.4	57.	0.
232	76.9	69.3	60.	0.
233	71.4	51.0	35.	0.
234	60.4	50.7	46.	0.
235	90.9	53.4	85.	0.
236	29.0	32.2	33.	0.
237	72.7	59.5	53.	0.

ILLINOIS - CHICAGO REGION

STATISTICAL DATA FOR SELECTED RECEPTORS

ANNUAL SO₂

MICROGRAMS PER CUBIC METER

AVERAGING TIME 24. HOURS

AIR QUALITY STANDARD 40.00

RECEPTOR NUMBER	EXPECTED ARITHMETIC MEAN	EXPECTED GEOMETRIC MEAN	0.0 PERCENT CONCENTRATION	STANDARD GEOMETRIC DEVIATION	AIR QUALITY STANDARD EXCEEDED
226	46.	39.	201.	1.74	0.0
227	67.	56.	329.	1.83	15.7
228	79.	68.	325.	1.70	28.2
229	65.	49.	451.	2.13	8.9
230	47.	33.	389.	2.31	0.0
231	57.	45.	350.	2.01	5.0
232	60.	49.	319.	1.89	9.1
233	35.	26.	257.	2.18	0.0
234	46.	35.	304.	2.08	0.0
235	85.	60.	692.	2.30	19.8
236	33.	28.	135.	1.70	0.0
237	53.	43.	301.	1.94	2.8

ILLINOIS - CHICAGO REGION

STATISTICAL DATA FOR SELECTED RECEPTORS

ANNUAL SO₂

MICROGRAMS PER CUBIC METER

AVERAGING TIME 24. HOURS

AIR QUALITY STANDARD 450.00

RECEPTOR NUMBER	EXPECTED ARITHMETIC MEAN	EXPECTED GEOMETRIC MEAN	0.3 PERCENT CONCENTRATION	STANDARD GEOMETRIC DEVIATION	AIR QUALITY STANDARD EXCEEDED
226	46.	39.	184.	1.74	0.0
227	67.	56.	298.	1.83	0.0
228	79.	68.	298.	1.70	0.0
229	65.	49.	399.	2.13	0.0
230	47.	33.	340.	2.31	0.0
231	57.	45.	313.	2.01	0.0
232	60.	49.	288.	1.89	0.0
233	35.	26.	226.	2.18	0.0
234	46.	35.	270.	2.08	0.0
235	85.	60.	605.	2.30	155.0
236	33.	28.	124.	1.70	0.0
237	53.	43.	270.	1.94	0.0

ILLINOIS - CHICAGO REGION

STATISTICAL DATA FOR SELECTED RECEPTORS

ANNUAL SO₂

MICROGRAMS PER CUBIC METER

AVERAGING TIME 24. HOURS

AIR QUALITY STANDARD 265.00

RECEPTOR NUMBER	EXPECTED ARITHMETIC MEAN	EXPECTED GEOMETRIC MEAN	0.8 PERCENT CONCENTRATION	STANDARD GEOMETRIC DEVIATION	AIR QUALITY STANDARD EXCEEDED
226	45.	39.	149.	1.74	0.0
227	67.	56.	237.	1.83	0.0
228	79.	68.	244.	1.70	0.0
229	65.	49.	300.	2.13	35.0
230	47.	33.	248.	2.31	0.0
231	57.	45.	240.	2.01	0.0
232	60.	49.	226.	1.89	0.0
233	35.	26.	168.	2.18	0.0
234	46.	35.	205.	2.08	0.0
235	85.	60.	441.	2.30	176.5
236	33.	28.	101.	1.70	0.0
237	53.	43.	210.	1.94	0.0

ILLINOIS - CHICAGO REGION

SOURCE CONTRIBUTIONS TO FIVE SELECTED RECEPTORS

ANNUAL SO₂

MICROGRAMS PER CUBIC METER

SOURCE	RECEPTOR 227	RECEPTOR 228	RECEPTOR 229	RECEPTOR 232	RECEPTOR 235
159	1.77 % 1.1858	1.93 % 1.5132	5.22 % 3.3986	2.42 % 1.4535	0.35 % 0.2949
175	0.47 % 0.3165	0.50 % 0.3921	1.49 % 0.9710	0.82 % 0.4917	0.11 % 0.08
194	0.97 % 0.6481	0.95 % 0.7491	1.59 % 1.0363	2.30 % 1.3854	0.78 % 0.65
268	0.09 % 0.0602	0.11 % 0.0850	0.11 % 0.0686	0.33 % 0.2005	3.61 % 3.1040
270	0.12 % 0.0823	0.15 % 0.1191	0.16 % 0.1039	0.49 % 0.2921	5.51 % 4.66
271	0.13 % 0.0848	0.16 % 0.1284	0.16 % 0.1022	0.56 % 0.3386	1.69 % 1.4337
280	0.18 % 0.1213	0.23 % 0.1797	0.25 % 0.1600	0.79 % 0.4762	3.72 % 3.14
282	0.02 % 0.0111	0.02 % 0.0158	0.02 % 0.0133	0.06 % 0.0360	1.42 % 1.20
289	0.28 % 0.1855	0.34 % 0.2661	0.32 % 0.2107	1.05 % 0.6307	6.68 % 5.6546
290	0.07 % 0.0476	0.09 % 0.0714	0.09 % 0.0583	0.30 % 0.1823	2.20 % 1.85
291	0.17 % 0.1145	0.22 % 0.1696	0.19 % 0.1265	0.66 % 0.3970	2.29 % 1.9359
293	0.10 % 0.0688	0.12 % 0.0969	0.10 % 0.0673	0.34 % 0.2037	1.57 % 1.32
304	0.09 % 0.0569	0.10 % 0.0804	0.08 % 0.0549	0.30 % 0.1775	1.15 % 0.97
319	0.14 % 0.0931	0.17 % 0.1333	0.15 % 0.0962	0.50 % 0.3011	2.45 % 2.0751
320	0.27 % 0.1803	0.30 % 0.2372	0.28 % 0.1811	0.74 % 0.4421	2.82 % 2.38
330	1.13 % 0.7546	1.39 % 1.0952	1.45 % 0.9417	4.91 % 2.9538	2.77 % 2.3432
339	1.11 % 0.7428	0.34 % 0.2698	0.93 % 0.6064	0.21 % 0.1288	0.04 % 0.03
347	2.54 % 1.6951	0.81 % 0.6325	0.35 % 0.2292	0.14 % 0.0850	0.03 % 0.02
371	1.00 % 0.6709	1.14 % 0.8940	1.05 % 0.6821	0.79 % 0.4726	0.08 % 0.0681
372	1.85 % 1.2336	0.27 % 0.2099	0.16 % 0.1030	0.05 % 0.0313	0.01 % 0.01
377	0.89 % 0.5937	1.17 % 0.9173	0.61 % 0.3952	0.49 % 0.2945	0.05 % 0.0

ILLINOIS - CHICAGO REGION

SOURCE CONTRIBUTIONS TO FIVE SELECTED RECEPTORS

ANNUAL SO₂

MICROGRAMS PER CUBIC METER

SOURCE	RECEPTOR 227	RECEPTOR 228	RECEPTOR 229	RECEPTOR 232	RECEPTOR 235
381	2.76 % 1.8450	1.96 % 1.5395	0.98 % 0.6389	1.17 % 0.7016	0.18 % 0.1536
382	1.82 % 1.2123	0.87 % 0.6833	0.55 % 0.3601	0.68 % 0.4089	0.13 % 0.1531
383	2.44 % 1.6279	2.26 % 1.7737	1.21 % 0.7883	1.91 % 1.1506	0.47 % 0.3974
385	0.30 % 0.1998	0.29 % 0.2311	1.09 % 0.7084	0.13 % 0.0777	0.02 % 0.0171
388	0.30 % 0.2005	0.40 % 0.3149	1.02 % 0.6646	0.15 % 0.0906	0.02 % 0.0174
390	2.48 % 1.6594	2.59 % 2.0363	13.65 % 8.8823	2.34 % 1.4056	0.32 % 0.2703
410	0.13 % 0.0837	0.30 % 0.2385	0.10 % 0.0674	1.62 % 0.9717	0.05 % 0.0392
411	0.41 % 0.2724	1.34 % 1.0512	0.19 % 0.1264	0.07 % 0.0429	0.02 % 0.0128
421	0.06 % 0.0422	0.08 % 0.0599	0.08 % 0.0546	0.24 % 0.1417	2.75 % 2.3268
428	0.77 % 0.5133	0.97 % 0.7641	0.91 % 0.5933	3.34 % 2.0624	8.21 % 6.9515
461	1.24 % 0.8309	1.47 % 1.1532	0.43 % 0.2782	0.19 % 0.1124	0.03 % 0.0242
462	1.36 % 0.9068	0.99 % 0.7760	0.36 % 0.2367	0.13 % 0.0796	0.02 % 0.0176
465	0.66 % 0.4441	2.13 % 1.6741	0.31 % 0.1999	0.19 % 0.1156	0.03 % 0.0225
466	1.43 % 0.9576	4.54 % 3.5634	0.66 % 0.4311	0.37 % 0.2237	0.05 % 0.0402
467	1.24 % 0.8320	1.87 % 1.4715	0.52 % 0.3363	0.19 % 0.1140	0.03 % 0.0238
470	0.36 % 0.2410	2.61 % 2.0481	0.26 % 0.1704	0.18 % 0.1066	0.02 % 0.0175
471	0.69 % 0.4619	3.41 % 2.6754	0.51 % 0.3306	0.28 % 0.1666	0.03 % 0.0269
472	0.93 % 0.6245	2.02 % 1.5865	0.64 % 0.4185	0.24 % 0.1459	0.03 % 0.0258
473	0.58 % 0.3888	1.05 % 0.8219	0.67 % 0.4368	0.19 % 0.1119	0.02 % 0.0192
475	0.28 % 0.1895	1.69 % 1.3255	0.19 % 0.1241	0.25 % 0.1491	0.02 % 0.0192
476	0.29 % 0.1954	1.18 % 0.9255	0.19 % 0.1228	0.17 % 0.1017	0.02 % 0.0152

ILLINOIS - CHICAGO REGION

SOURCE CONTRIBUTIONS TO FIVE SELECTED RECEPTORS

ANNUAL SO₂

MICROGRAMS PER CUBIC METER

SOURCE	RECEPTOR 227	RECEPTOR 228	RECEPTOR 229	RECEPTOR 232	RECEPTOR 235
477	0.70 % 0.4653	1.47 % 1.1552	0.43 % 0.2830	0.30 % 0.1792	0.03 % 0.021
480	0.23 % 0.1542	1.16 % 0.9094	0.16 % 0.1022	0.32 % 0.1895	0.02 0.0192
481	0.34 % 0.2247	1.20 % 0.9449	0.25 % 0.1656	0.32 % 0.1895	0.03 % 0.021
486	0.26 % 0.1731	1.04 % 0.8132	0.19 % 0.1212	0.57 % 0.3398	0.03 0.0281
491	7.27 % 4.8583	0.88 % 0.6928	0.56 % 0.3667	0.32 % 0.1939	0.05 0.041
492	3.91 % 2.6116	0.58 % 0.4584	0.50 % 0.3245	0.20 % 0.1174	0.04 % 0.031
493	1.76 % 1.1795	0.35 % 0.2735	0.51 % 0.3315	0.15 % 0.0905	0.03 0.0251
494	5.24 % 3.5044	2.02 % 1.5860	1.10 % 0.7143	0.55 % 0.3289	0.08 % 0.061
495	2.95 % 1.9737	1.15 % 0.9007	0.89 % 0.5773	0.29 % 0.1761	0.05 0.0434
496	2.00 % 1.3347	0.88 % 0.6936	1.20 % 0.7831	0.33 % 0.1973	0.05 0.041
497	1.03 % 0.6917	0.91 % 0.7176	2.48 % 1.6115	0.35 % 0.2085	0.05 % 0.042
498	1.36 % 0.9058	1.57 % 1.2361	9.43 % 6.1329	0.71 % 0.4298	0.10 0.0820
499	0.34 % 0.2298	0.36 % 0.2618	1.34 % 0.8700	0.35 % 0.2101	0.03 % 0.027
500	0.88 % 0.5909	2.41 % 1.8946	0.72 % 0.4687	5.50 % 3.3059	0.22 0.1841
501	0.55 % 0.3669	0.89 % 0.6976	0.47 % 0.3046	1.55 % 0.9336	0.08 0.065
502	0.57 % 0.3829	0.74 % 0.5810	1.22 % 0.7922	1.36 % 0.8182	0.08 % 0.071
503	0.33 % 0.2182	0.38 % 0.2965	1.16 % 0.7541	0.54 % 0.3262	0.04 0.0371
504	0.23 % 0.1534	0.44 % 0.3430	0.19 % 0.1229	3.96 % 2.3797	0.12 0.105
505	0.60 % 0.4030	1.37 % 1.0779	0.55 % 0.3586	6.73 % 4.0471	0.21 0.1776
506	0.51 % 0.3440	0.69 % 0.5449	0.45 % 0.2904	2.18 % 1.3135	0.10 0.088
529	2.44 % 1.6313	0.78 % 0.6158	0.87 % 0.5639	0.46 % 0.2790	0.08 0.062

ILLINOIS - CHICAGO REGION

SOURCE CONTRIBUTIONS TO FIVE SELECTED RECEPTORS

ANNUAL SO₂

MICROGRAMS PER CUBIC METER

SOURCE	RECEPTOR 227	RECEPTOR 228	RECEPTOR 229	RECEPTOR 232	RECEPTOR 235
532	1.08 % 0.7203	0.57 % 0.4459	1.32 % 0.8568	0.39 % 0.2338	0.07 % 0.0614
533	0.63 % 0.5568	0.44 % 0.3479	1.04 % 0.6793	0.38 % 0.2264	0.07 % 0.0572
537	0.79 % 0.5199	0.65 % 0.5109	1.93 % 1.2549	0.65 % 0.3916	0.08 % 0.0702
539	0.59 % 0.3922	0.57 % 0.4480	1.40 % 0.9111	0.89 % 0.5368	0.16 % 0.1314
544	0.67 % 0.4485	0.84 % 0.6604	0.77 % 0.5002	2.35 % 1.4127	0.53 % 0.4496
556	0.44 % 0.2940	0.42 % 0.2307	0.76 % 0.4918	1.02 % 0.6107	0.52 % 0.4393
573	0.02 % 0.0145	0.03 % 0.0211	0.03 % 0.0179	0.09 % 0.0513	1.66 % 1.4240
574	0.02 % 0.0159	0.03 % 0.0235	0.03 % 0.0208	0.10 % 0.0596	1.17 % 0.9868
591	0.04 % 0.0291	0.05 % 0.0412	0.06 % 0.0377	0.16 % 0.0966	2.50 % 2.1138
602	0.06 % 0.0425	0.07 % 0.0570	0.08 % 0.0511	0.19 % 0.1167	1.59 % 1.3455
628	0.01 % 0.0066	0.01 % 0.0095	0.01 % 0.0077	0.04 % 0.0220	1.95 % 1.6502
BACK- GROUND	0.0 % 0.	0.0 % 0.	0.0 % 0.	0.0 % 0.	0.0 % 0.
TOTAL	100.0 % 66.8349	100.0 % 78.5415	100.0 % 65.0702	100.0 % 60.1159	100.0 % 84.6421

APPENDIX C

Isopleth Maps Showing Annual
Geometric Means ($\mu\text{g}/\text{m}^3$) for the
Particulate Control Strategies
Listed in Table 5.2

Illinois Standard = 75

Expected Particulate Annual Geometric Means
(Uncontrolled Emission Inventory)
and Control Receptors

COOK COUNTY

DuPAGE COUNTY

COOK COUNTY

WILL COUNTY

LAKE COUNTY

125

100

125

100

.5

.2

.10

.11

.6

.12

.9

.1

.4

C-2

COOK COUNTY

DUPAGE COUNTY

75

COOK COUNTY

WILL COUNTY

LAKE COUNTY

Particulate Ill Chicago Ind

C-4

Particulate 103 107 113

COOK COUNTY

DUPAGE COUNTY

COOK COUNTY

WILL COUNTY

LAKE COUNTY

Particulate 118 115 113

75

C-6

Particulate 117 107 111

C-8

Particulate 14 15 13

C-10

Particulate 3 15 13

C-12

COOK COUNTY

DUPAGE COUNTY

75

COOK COUNTY

WILL COUNTY

LAKE COUNTY

Particulate 18 7 13

Particulate 18 15 13

C-14

COOK COUNTY

DUPAGE COUNTY

75

100

COOK COUNTY

WILL COUNTY

LAKE COUNTY

Particulate 1 7 11

L 5 11 E

C-16

COOK COUNTY

DuPAGE COUNTY

100

75

COOK COUNTY

WILL COUNTY

LAKE COUNTY

Particulate 17 15 11

APPENDIX D

Isopleth Maps Showing Annual
Geometric Means ($\mu\text{g}/\text{m}^3$) for the
Sulfur Dioxide Control Strategies
Listed in Table 5.4

Illinois Standard = 40

Expected Sulfur Dioxide Annual Geometric Means
(Uncontrolled Emission Inventory)
and Control Receptors

SO₂ Illinois and Indiana proposed regs.
City of Chicago ordinance.

COOK COUNTY

DUPAGE COUNTY

COOK COUNTY

WILL COUNTY

LAKE COUNTY

40

SO₂ 112 115

SO₂

112 115

40

60

D-4

COOK COUNTY

DUPAGE COUNTY

COOK COUNTY

WILL COUNTY

LAKE COUNTY

SO₂ 112 109

COOK COUNTY

DuPAGE COUNTY

COOK COUNTY

WILL COUNTY

LAKE COUNTY

SO₂ 111 115

SO₂ 111 115

D-6

SO₂ 111 109

COOK COUNTY

DUPAGE COUNTY

COOK COUNTY

WILL COUNTY

LAKE COUNTY

SO₂ 104 115

Sb2 104 115

0

40

60

40

SO₂ 104 109

COOK COUNTY

DUPAGE COUNTY

COOK COUNTY

WILL COUNTY

LAKE COUNTY

SO₂ 101 115

40

40

60

D-10

SO₂ 101 109

SO₂ 118 115

COOK COUNTY

DUPAGE COUNTY

COOK COUNTY

WILL COUNTY

LAKE COUNTY

SO₂ 13 9

SO₂ 13 9

WILL COUNTY

LAKE COUNTY

SO₂ 12 15

SO₂ 12 15

40

40

40

60

40

WILL COUNTY

SO₂ 11 15

LAKE COUNTY

SP2

11 15

SO₂ 11 9

COOK COUNTY

DUPAGE COUNTY

COOK COUNTY

WILL COUNTY

LAKE COUNTY

40

60

40

40

60

40

SO₂ 1 15

SO₂

1 15

40

SO₂ 1 9

SO₂

1 9

542

SO₂ 1 6

Illinois reg.

D-22

SO₂ 4 15

SO₂ 4 9

SO₂ 8 15

SO₂ 8 9

COOK COUNTY

DUPAGE COUNTY

COOK COUNTY

WILL COUNTY

LAKE COUNTY

SO₂ 18 15

SO₂ 18.9

SO₂ 17 15

17 15

REFERENCES

Farmer, J. R., et al, 1970: "Proceeding from Air Quality Standards to Emission Standards," Paper No. 70-85, A.P.C.A. Conf., St. Louis, Mo., June 1970.

Fisher, R. A., 1954: "Statistical Methods for Research Workers." Hafner Publishing Company, Inc., Twelfth Edition, New York, New York.

Gifford, F. A., Jr., 1961: "Use of Routine Meteorological Observations for Estimating Atmospheric Dispersion. Nuclear Safety."

Larsen, Ralph I., January, 1969: "A New Mathematical Model of Air Pollution Concentration Averaging Time and Frequency." APCA Journal, Vol. 19, No. 1.

Martin, Delance O., and Tikvart, Joseph A., June, 1968: "A General Atmospheric Diffusion Model for Estimating the Effects on Air Quality of One or More Sources," APCA Paper.

Pasquill, F., 1961: "The Estimation of the Dispersion of Windborne Material." Meteorol. Magazine, 90, 1963.

Stumph, T. L. and Duprey, R. L., 1969: "Trends in Air Pollution Control Regulations," APCA Paper 69-175, presented to the Annual Meeting of the Air Pollution Control Association, New York, New York (June 1969).

Turner, D. B., February, 1964: "A Diffusion Model of an Urban Area." Journal of Applied Meteorology, 3.

Control Techniques For Sulfur Oxide Air Pollutants, U.S. Department of Health, Education, and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, National Air Pollution Control Administration, Washington, D. C., January 1969.

Petkus, E. J., The Availability of Low Sulfur Coal in Chicago, Department of Environmental Control, Chicago, Illinois, March 1970.

Petkus, E. J., Analysis of the Fuel Shortage Problem in Chicago Area for 1970-71 Winter, Department of Environmental Control, Chicago, Illinois, Aug. 17, 1970.

Risser, H. E., Testimony Before the Illinois Commerce Commission. General factors of availability and cost of fuels for electric utility plants, May 1, 1970.

Simon, J. A., Information Testimony for Illinois Commerce Commission Docket #55321. Comments on Fuel Resources and Pollution in the Power Generation Industry, Feb. 24, 1970.

REFERENCES (Contd.)

Bosanquet, C. H., and Pearson, J. L., 1936: "The Spread of Smoke and Gases from Chimneys." Trans. Faraday Soc., 32, pages 1249-1263.

Clarke, J. F., 1969: "Nocturnal Urban Boundary Layer Over Cincinnati, Ohio." Monthly Weather Review (in press).

Holzworth, G. C., May, 1964: "Estimates of Mean Maximum Mixing Depths in the Contiguous United States." Monthly Weather Review, Vol. 92, No. 5, pages 235-242.

Sutton, O. G., 1932: "A Theory of Eddy Diffusion in the Atmosphere." Proc. Roy. Soc., A, 135, pages 143-165.