THE AIR QUALITY DISPLAY MODEL ANALYSIS FOR SUSPENDED PARTICULATES IN MARSHALLTOWN, IOWA

DEPARTMENT OF ENVIRONMENTAL QUALITY
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Abstract

The Iowa Department of Environmental Quality (DEQ) is currently examining possible revisions of the State Implementation Plan. These air pollution control srategy revisions are being evaluated so that the National Ambient Air Quality Standards can eventually be attained and maintained in all parts of Iowa as required by the Clean Air Act Amendments of 1977. To accomplish this, it is necessary to analyze current air quality attainment problems.

To examine these current air quality attainment problems, a dispersion model is used. The dispersion model is a computer program that predicts what the ambient air quality will be at a certain point within an air basin. The Air Quality Display Model (AQDM) is the major tool DEQ used to model each air basin. AQDM is a computer model that combines point source emissions (industrial plants), area source emissions (residential heating, fugitive dust, solid waste disposal, transportation, etc.) and meteorological factors (wind speed, wind direction, average temperature, pressure, and mixing height) over a specified area to predict the annual distribution of pollutants for that area. From the results obtained by using AQDM, a reliable estimation of source contribution is found.

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Introduction

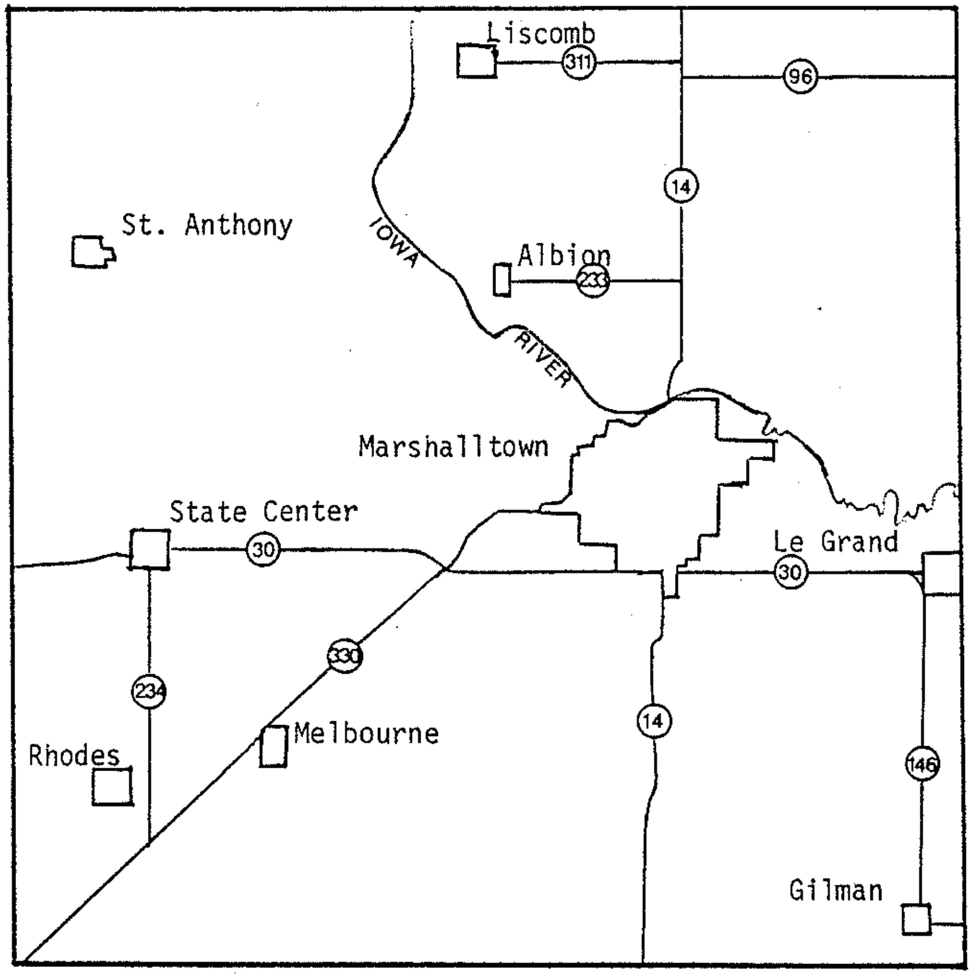
Total suspended particulate (TSP) is one of the six pollutants for which the federal EPA has declared national air quality standards for the protection of human health and welfare. A set of strategies to control TSP emissions, and thereby reduce ambient concentrations of this pollutant to acceptable levels, was developed by the Iowa Air Pollution Control Commission in 1971 and 1972. These strategies became part of a federally approved State Implementation Plan on May 31, 1972 (40 CFR, Part 52). Since that time most air pollution sources have reached compliance with State particulate emission standards, yet air monitoring has shown portions of Iowa are still plagued with unacceptably high TSP concentrations. The Clean Air Act Amendments of 1977 required each state to identify those areas with unacceptably high TSP concentrations and devise a control strategy to reduce these high concentrations.

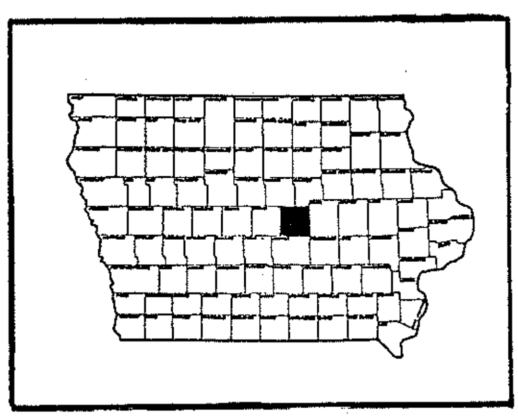
The purpose of this analysis is to explore the causes of these high TSP concentrations to aid in the future development of necessary control strategies which will lead to reducing TSP to an acceptable level.

County Statistics

Marshall County is located in the gently rolling terrain of Central Iowa. The City of Marshalltown is the major urban center and borders the Iowa River in the east-central section of the county. (See Figure 1) The 1970 population for the Marshalltown metropolitan area was 26,219; the 1970 population for Marshall County was 41,086. Major industrial processes in Marshall County consist of cast metal production, grain transferring, mineral product manufacturing, and electricity generation. Major sources of fugitive dust and fugitive emissions include grain transferring, construction, agricultural tilling, and roads (both paved and unpaved).

Figure 1
Marshall County in Iowa





Marshall County is situated in a temperate climate in the middle of a large land mass. The area is largely influenced by pressure systems moving in a general west-east direction. The winds are dominant from the northwest and the south to southeast. The mean annual temperature is 49 degrees Fahrenheit, the mean annual precipitaton is 32 inches. Neutral atmospheric stability is dominant for this area, with slightly unstable and stable conditions occurring less frequently.

Background

Because of large-scale natural suspended particulate emissions (such as volcanoes and dust storms) and large-scale man-made suspended particulate sources (such as agricultural activities) which cannot be accurately modeled, a natural background estimate must be developed for Iowa to include in any modeling.

To develop a numeric value for background, extensive monitoring of an isolated rural area must be conducted. The background of suspended particulates in Iowa was estimated from monitoring conducted from 1959 to 1965 at Backbone State Park in northeast Iowa. This site appears to be the most isolated area monitored in the State and is located away from any localized agricultural and urban sources. However, because of the large amount of agricultural activity in the State, an additional contribution from soil erosion, tilling, and travel on unpaved surfaces is inevitable and thus a true background measurement not influenced by any man-made sources is unlikely. Therefore the background recorded at Backbone State Park is expected to include not only a natural worldwide background but a local and statewide background. To estimate the contribution of all sources to the background site, a study of rural sources was conducted.

The background figure monitored at Backbone State Park averaged 44 micrograms per cubic meter annual arithmetic mean. An estimated breakdown of sources accounting for this monitored value is shown in Table 1 below.

TABLE 1

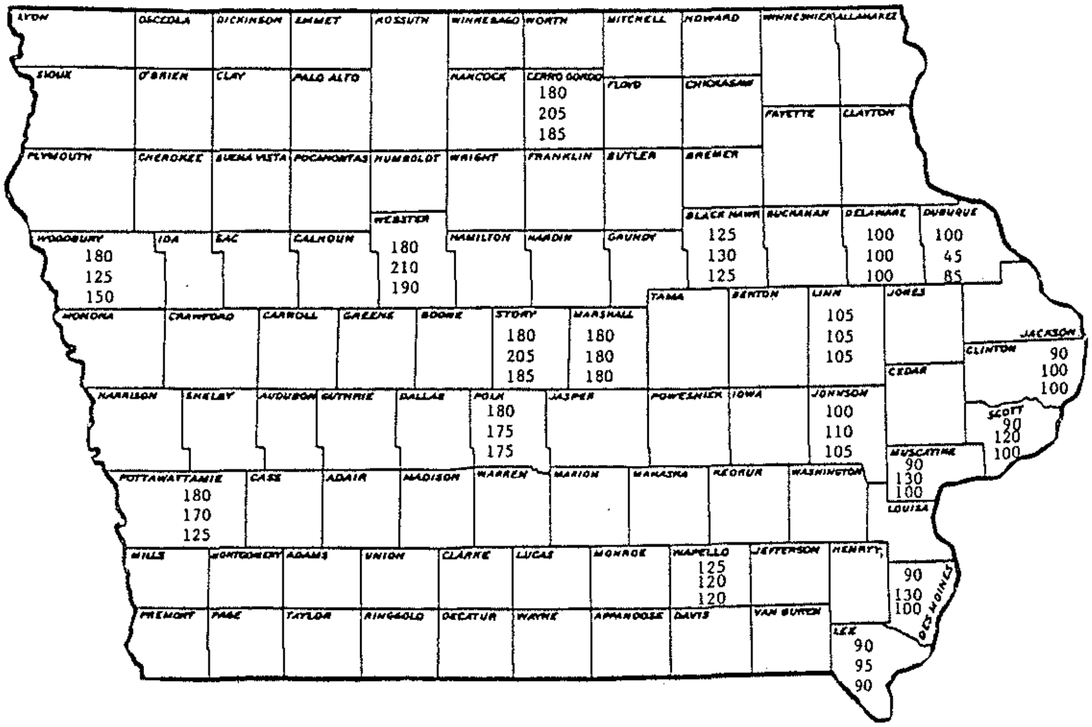
Source Contributions to the Recorded
Background level at Backbone State Park
(Values shown are in micrograms per cubic meter [ug/m^3])

Worldwide Concentration	15 ug/m^3
Continental Concentration	10 ug/m^3
Unpaved Roads	6 ug/m^3
Agriculture (soil erosion)	13 ug/m^3
Total Background	44 ug/m^3

The worldwide and continental values were obtained from studies conducted by GCA Corporation for DEQ[1]. This natural background that is not influenced by man is approximately 25 ug/m^3. The unpaved road estimate of 6 ug/m^3 was established by computer modeling of all rural unpaved roads in a five county area. The remaining 13 ug/m^3 was assumed to be from agricultural processes such as tilling and soil erosion.

Since the contribution from agricultural processes could easily be larger or smaller in other areas of the state depending on the farming practices, an investigation of these farming practices throughout the state was conducted. By comparing climatic factors, soil types, crops planted, and tilling frequencies in other areas of the state with the area around Backbone State Park, an index of soil erodibility was developed as shown in Figure 2. Using this index to increase or decrease the contribution of agricultural sources, an estimation of background throughout the State has been developed as shown in Figure 3.

Figure 2
Agricultural Index For Selected
Counties in Iowa



100 The first number represents the climatic factor for the county using the Federal Soil Conservation's climatic factors for Iowa. Deleware County is the reference county and has been given a value of 100. Numbers greater than 100 represent drier conditions while numbers less than 100 represent wetter conditions.

100 The second number represents the proportion of tilled land in soybeans or row crops. Deleware County is the reference county and has been given a value of 100. A county registering 200 would have twice the amount of land in soybeans or row crops.

100 The third number represents the agricultural index for the county. Deleware County is the reference county and has been given a value of 100. This index was based on the climatic factor, proportion of tilled land, and county size. Numbers greater than 100 represent areas of more severe wind erosion than Deleware County while numbers less than 100 represent areas of less severe soil erosion.

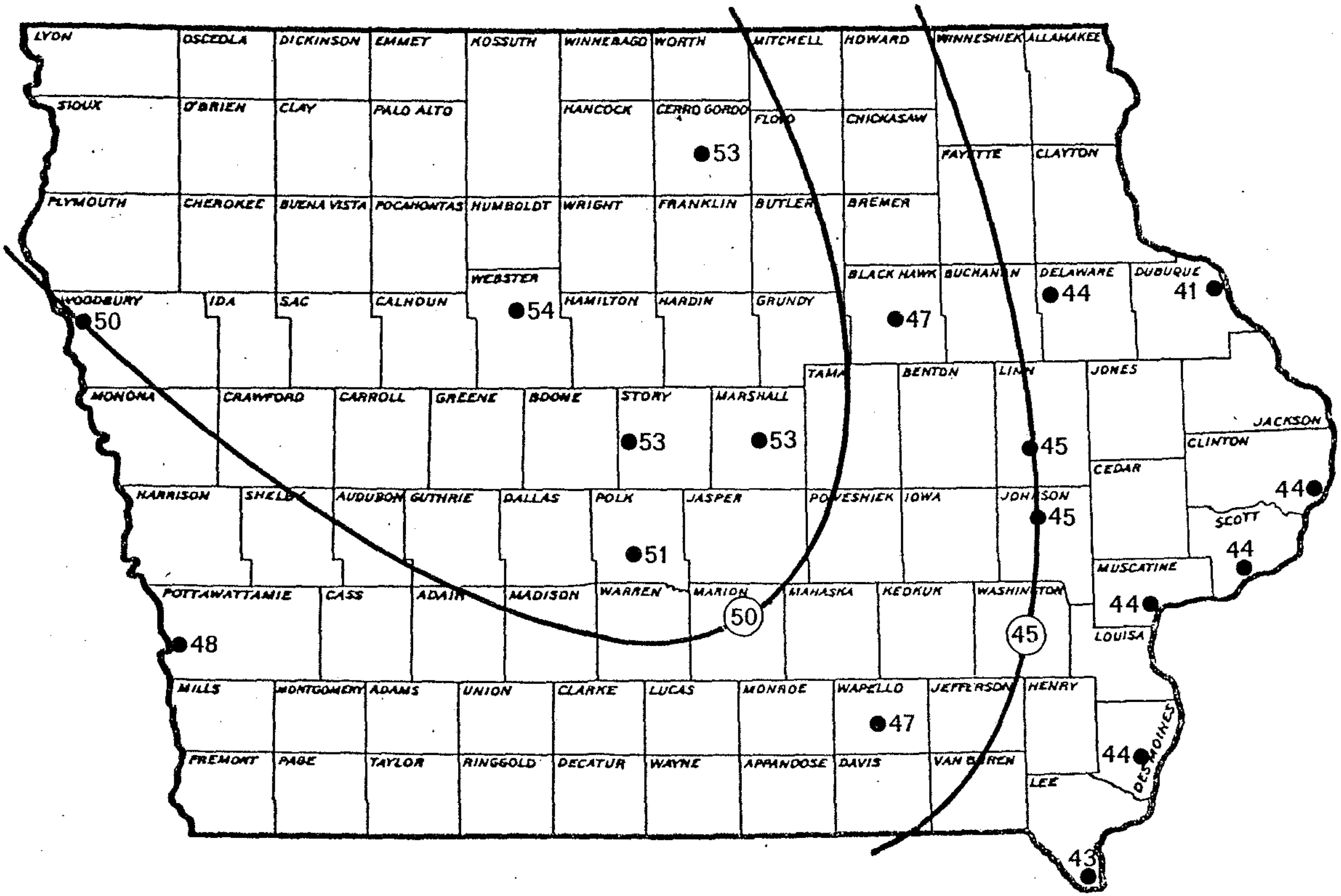


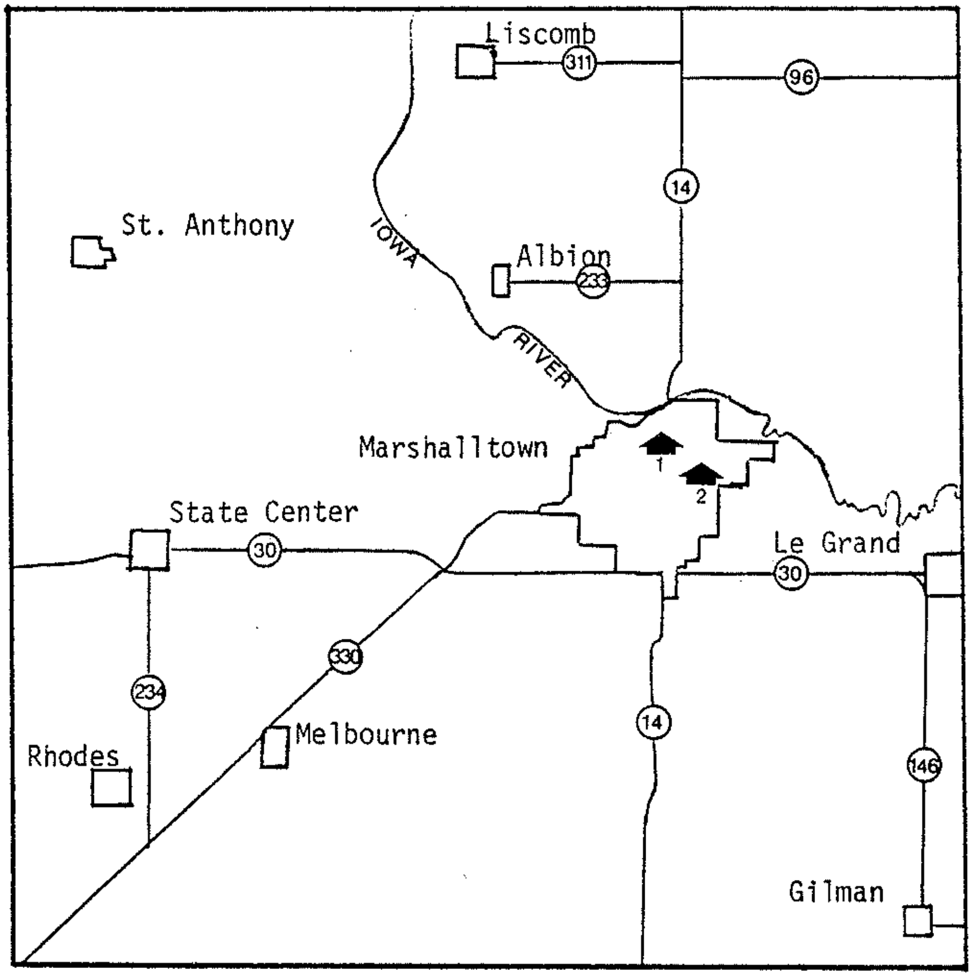
Figure 3
Estimations of Rural Background levels in Iowa
(Values shown are arithmetic means in micrograms per cubic meter)

Air Monitoring

The most accurate measurement of suspended particulate levels in an area is obtained by monitoring the air. Air quality data for suspended particulate are obtained using the high volume sampler. The sampler draws a known quantity of ambient air through a preweighed glass fiber filter for a twenty-four-hour period once every six days. After each twenty-four-hour period the sample filter is sent to the laboratory where it is weighed again. The weight difference measured in micrograms is the amount of particulate. Combined with the volume of air that passed through the filter during the twenty-four-hour period, the sampling results are calculated and recorded as the average micrograms of particulate matter per cubic meter of air for a twenty-four-hour period. Two State owned high volume samplers are currently located in Marshalltown. These monitors are located at (1) City Hall, State and Center Streets; (2) Marshalltown Manufacturing, 710 Twelfth Street. (See Figure 4) Table 2 shows the monitored values at these sites. An asterik after the year indicates insufficient data for that year to calculate a valid annual mean.

The air monitoring data are an essential tool in calibrating the computer model. The annual means that are predicted by the model are correlated with the monitoring data to estimate the accuracy of the projections. Large variances between the monitored values and the projections indicates poor correlation and revisions to the model inputs must be made. Small variances indicate good correlation and correct model inputs.

Figure 4
Location of Suspended Particulate Air
Monitoring Equipment in Marshall County



Monitor locations

1. City Hall
2. Marshalltown Mfg.

TABLE 2

Air monitoring data for Marshalltown

Location	Year	Number of Samples	Maximum 24-Hour Value	2nd Max. 24-Hour Value	Arithmetic Mean	Geometric Mean	Standard Geometric Deviation
1. City Hall	1976*	16	137.0	118.0	67	57	2.03
	1977	50	204.2	167.3	73	65	1.64
2. Marshall-town Mfg.	1976*	13	304.0	153.0	107	94	1.65
	1977	61	132.0	130.1	63	58	1.51

* These years do not have a sufficient number of samples to calculate a valid annual mean.

The Model (Annual Average Estimation)

A dispersion model is a compter program that predicts what the ambient air quality will be at a certain point within an air basin. The Air Quality Display Model (AQDM)[2] is the model DEQ used in each air basin. AQDM is a computer model that combines point source emissions (industrial plants), area source emissions (residential heating, fugitive dust, solid waste disposal, transportation, etc.) and meteorological factors (wind speed, wind direction, average temperature, pressure, and mixing height) over a specified area to predict the annual distribution of pollutants for that area. The annual particulate concentrations predicted by the model for each year are plotted as isopleths over the air basin. Five designated receptors are also broken down into specific source contribution percentages.

The computer algorithm and the program inputs reflect several assumptions. Assumptions used in the computer algorithm are:

(a) Total reflection of the pollutant plume takes place at the earth's surface.

(b) Conditions describing the plume are averaged over a time period of several minutes.

(c) All effluent gases and particulates have diameters less than 20 microns and have neutral buoyancy in the atmosphere. Zero fallout is assumed.

(d) The plume exhibits a Gaussian concentraton distribution and the spread in both directions is 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.

Assumptions used in the program input are:

(a) Point source data from plant emission inventory forms, from stack tests, and from permit information are accurate and complete.

(b) Sources not reporting stack parameters were given parameters of similar sources (this was true in interstate air basins where other states occasionally were not able to provide stack parameters).

(c) Area source data from the National Emissions Data System (NEDS) are accurate and complete.

(d) Population distribution and area source emissions are directly related.

(e) Fugitive emissions from paved and unpaved roads are accurately calculated.

<u>Source of Suspended Particulates (Point)</u>

All Marshalltown point sources were acquired from DEQ's current emission inventory. Stack emissions, diameters, emission velocities and temperatures were taken from values supplied by the plant operators on emission inventory forms, permit applications, or stack tests performed at the plant. Emissions for the modeled year were taken from the 1975 emission inventory and updated by permit applications, compliance schedules, or stack tests. All plant emission controls were assumed to be working the entire year unless breakdown or maintenance reports were submitted to the Department. The emissions during periods of emission control device breakdown or maintenance were added to the plant totals. All industrial point source estimates calculated were verified by the appropriate plant officials. Fugitive dust point sources were given plume heights of 6.0 meters. All source emissions were calculated in tons per year and divided by 365 days to obtain the necessary model input of tons per day. No consideration was given to seasonal operation or weekend shutdowns.

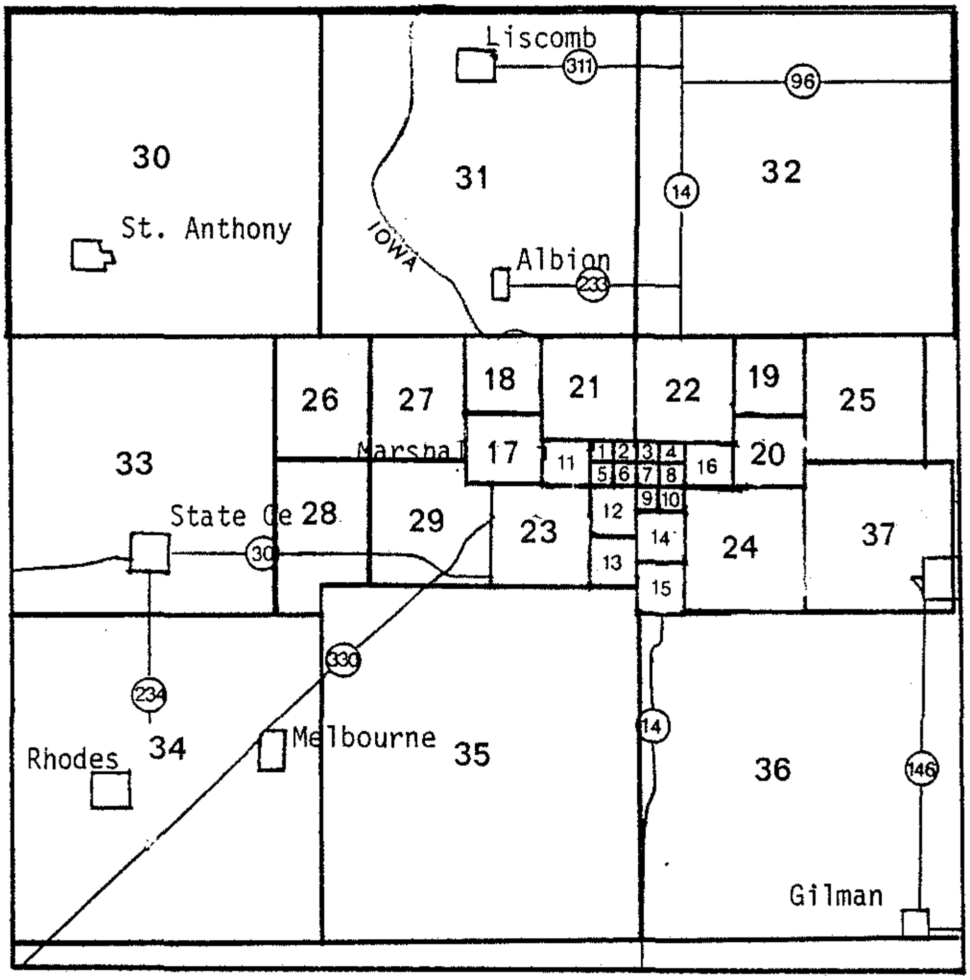
Sources of Suspended Particulates (Area)

Residential Emissions

Total residential emissions for fuel use in Marshall County were taken from the National Emissions Data System (NEDS) estimates of area source emissions supplied by EPA. Solid waste emissions were calculated using an estimated tonage of solid waste and an appropriate emission factor. The emissions were distributed by housing population calculated from the census population for 1970 and updated from projections from the Iowa Office of Planning and Programming.[3] The 1977 Marshalltown population growth was estimated at 1.090 times the 1970 census figure.

The Marshalltown County census population was broken down into designated area sources in the model region as shown in Figure 5. Area housing populations were

Figure 5
Area Source Grid Pattern for Marshall County



divided by the total county housing population and multiplied by the county emission totals to obtain area emissions for residential fuel use and solid waste.

All housing emissions were assumed to be uniform for the county. Total particulate emissions for the modeled year obtained from NEDS were:

	1977
Residential Fuel	31 tons per year
Residential Solid Waste	74 tons per year

Commercial-Institutional Emissions

Total commercial-institutional emissions for fuel use and solid waste disposal in Marhsall County were taken from the NEDS data supplied by EPA. Ninety percent of the county emissions was assumed to be in the major urban center, while ten percent was assumed to be in the smaller cities.

All commercial-institutional building emissions were assumed to be uniform for the county. Total particulate emissions for the modeled year were:

	1977
Commercial-Institutional Fuel	41 tons per year
Commercial-Institutional Solid Waste	22 tons per year

Transportation-Motor Vehicle

Total emissions from transportation sources, excluding fugitive emissions, were taken from the NEDS data supplied by EPA. Emissions from major highway line sources and rural paved and unpaved roads were individually calculated.

Major access street and highway line source emissions were calculated by multiplying the emission factor for vehicles (0.66 grams per vehicle mile)[4] by the product of the length of the road segment and the traffic flow count. Each line source emission was assigned to the appropriate designated area and was assumed to disperse equally over the area. All car and truck emissions were assumed to be approximately the same. After all major access highway emissions were calculated, the total line source emissions assigned to each area was subtracted from the NEDS county total and distributed by the population proportion in each area.

Fugitive dust from vehicle travel on paved and unpaved roads was calculated from emission factors found in two recent reports.[5,6] Fugitive dust from unpaved roads was calculated by multiplying the emission factor (1179 grams per vehicle mile) by the product of the length of the road segment and the traffic flow count. Thirty percent of these emissions was assumed to actually become suspended. Paved road emissions were also calculated by multiplying the emission factor (11 grams per vehicle mile) by the product of the length of the road segment and the traffic flow count. These emission factors were derived from an emission formula that combines conditions of the road, vehicle speeds, and climatological factors to obtain grams of particulate per vehicle mile. Emissions from each road segment are assumed to disperse equally over the designated areas.

Total estimated particulate emissions for the modeled year were:

	1977
Vehicles	193 tons per year
Fugitive (paved roads)	4171 tons per year
Fugitive (unpaved roads)	10477 tons per year

Transportation - Railroads

Total railroad fuel use emissions for railroads in Marshall County were taken from the NEDS data supplied by EPA. Approximate track mileage was estimated for each designated area. Emissions were distributed by the proportion of track miles in each area.

Transportation - Off Highway

Off highway transportation was considered to be any fuel burning machine not operated on a road (i.e., farm tractor, lawnmowers, motorized boats, etc.). Because of the difficulty in estimating the concentration of off-highway transportation, it was assumed that the NEDS emissions were distributed equally over the entire county.

Transportation - Aircraft

The Marshalltown Airport emissions were distributd as a one square kilometer area source. Emissions were based on projections from the State airport system plan.[6]

A listing of area sources and total emissions used in the model is given in Appendix A.

Model Meteorology Parameters

To accurately model the suspended particulate emission sources, detailed meterological parameters are necessary.

Meteorological wind data consists of five stability classes and sixteen wind directions. These data were not available for Marshalltown, therefore wind data from Des Moines, southwest of Marshalltown, were chosen. The wind data from Des Moines were chosen over other cities because of the close proximity of the cities and the similarity of topography.

Other necessary meteorological parameters that were obtained for Marshalltown are shown below:

Average daily mixing depth:	1200 meters
Average ambient temperature	282 degrees Kelvin (11 degrees Celsius)
Average ambient pressure	985 millibars

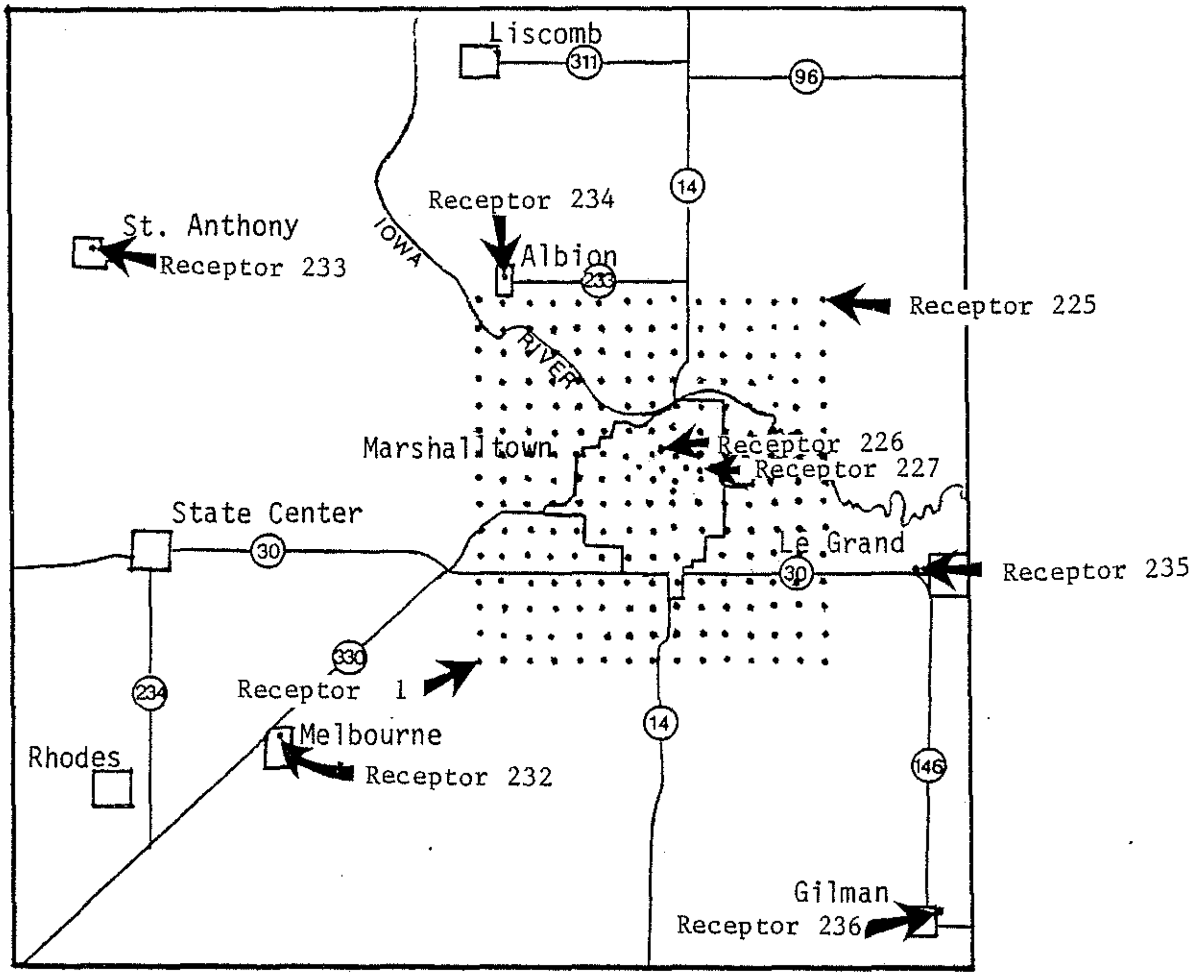
Results

A grid area of 15 kilometers by 15 kilometers was set up around Marshalltown with receptors placed at one kilometer intervals as shown in Figure 6. Twelve additional receptors located throughout the county were also included in the total receptor count.

Expected concentrations at each receptor are given in Appendix B. Graphical displays of thse results are illustrated in Figure 7 for Marshall County and Figure 8 for the City of Marshalltown. Each line represents an isopleth of suspended particulate concentration as an annual arithmetic mean. The highest concentration expected was 224 micrograms per cubic meter at receptor 232.

To estimate the impact of each source on a receptor, a special audit was requested for receptors 129, 143, 226, 227, and 232. Results for each source are given in Appendix B while a summary is shown in Table 3.

Figure 6
Receptor Locations for Marshalltown AQDM Model



NOTE: Except for Receptors 226-233, grid numbering runs bottom to top and left to right.

Figure 7
Marshall County
1977 Suspended Particulate Isopleth Map
(values shown are arithmetic means in micrograms per cubic meter)

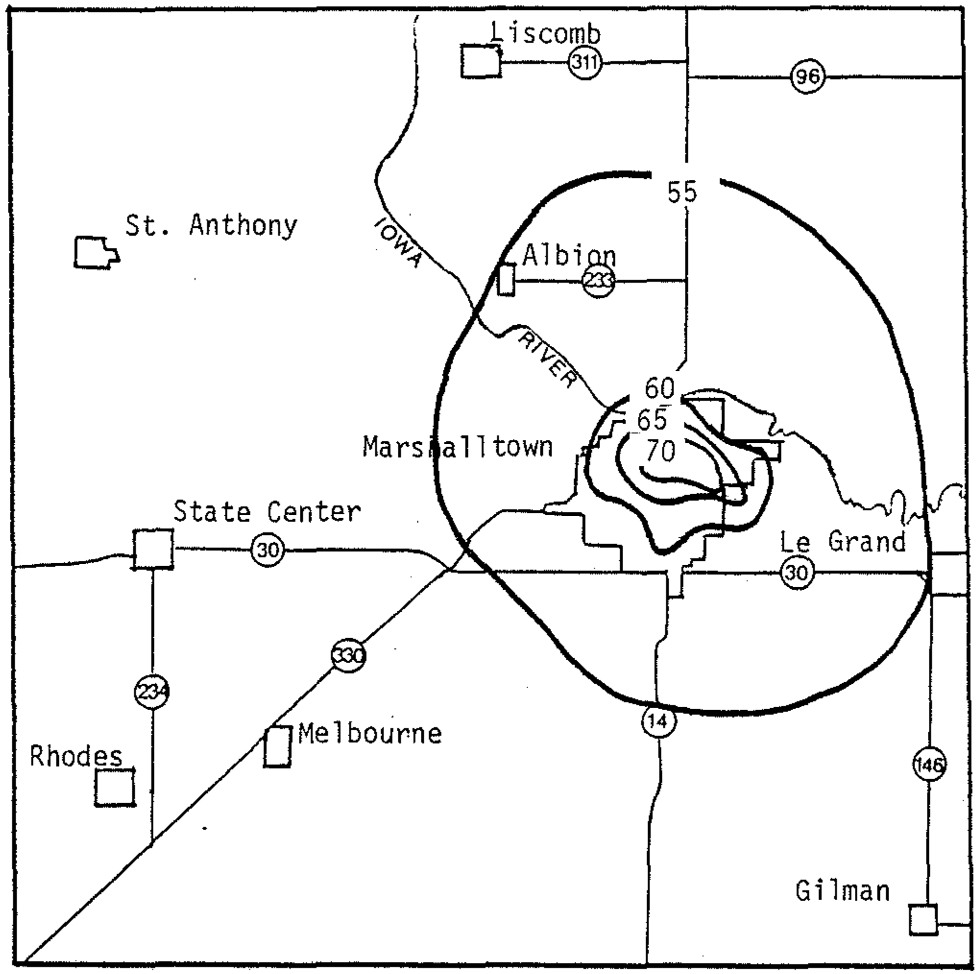


Figure 8
Suspended Particulate Isopleth Map for Marshalltown
(Values shown are arithmetic means in micrograms per cubic meter)

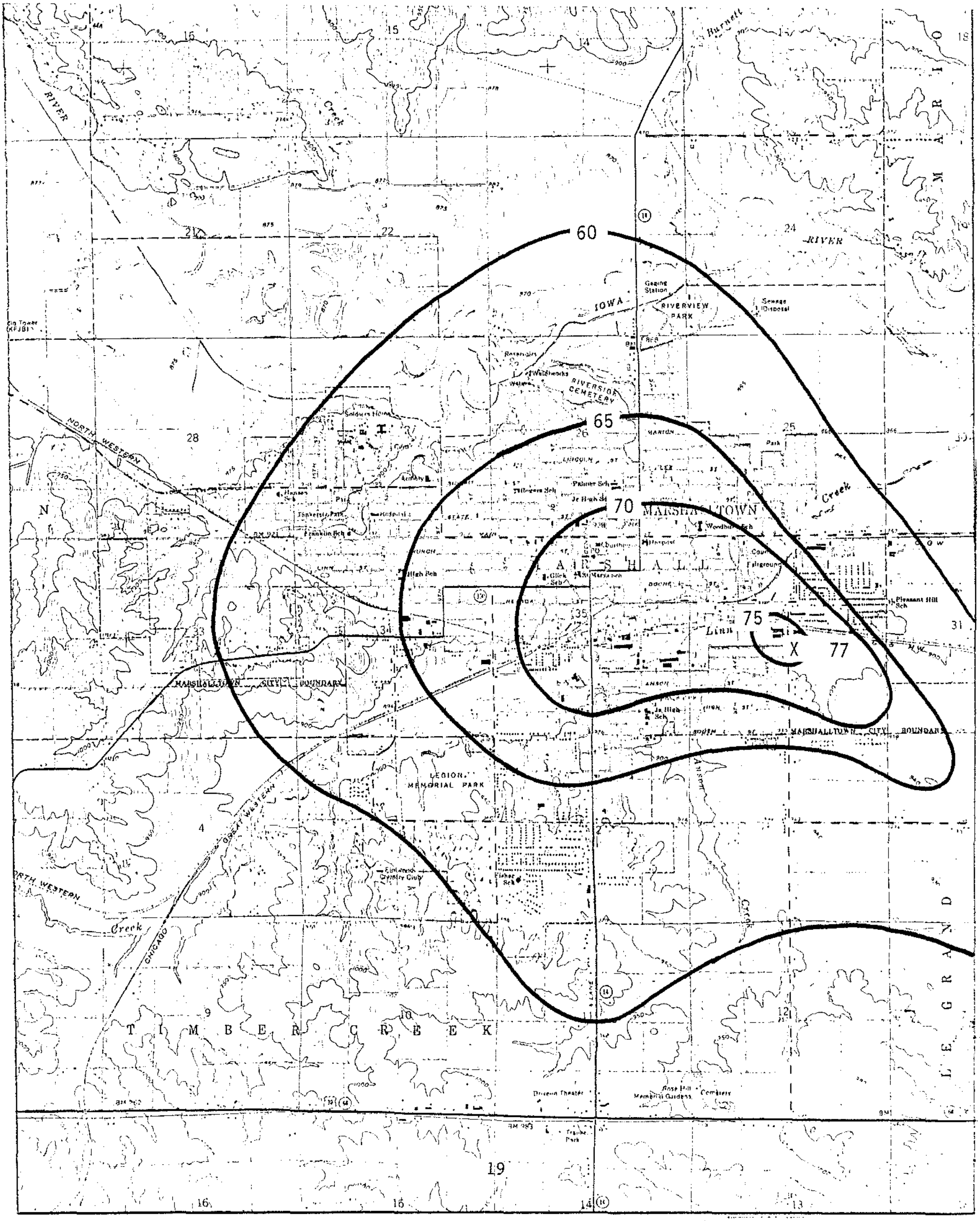


TABLE 3
Source Contributions to Five
Selected Receptors
(values shown are in micrograms per cubic meter)

Source	Receptor 114 City Hall	Receptor 227 Marshalltown Manufacturing	Receptor 232 Melbourne	Receptor 129 Central Marshalltown	Receptor 143 Central Marshalltown
Point Sources					
Iowa Electric Light & Power	0.1	0.0	0.0	0.1	0.0
Gra-Iron Foundry	1.3	11.4	0.0	1.4	7.0
Bob Feed and Supply	0.2	0.9	0.0	0.4	1.1
Bigelow-Liptak	0.0	0.0	0.0	0.0	0.0
Arbie Mineral Feed	0.2	0.1	0.0	0.2	0.1
Kiowa	0.1	1.2	0.0	0.2	0.8
Marshalltown Trowell	0.2	0.6	0.0	1.8	0.4
Area Sources	14.9	9.8	0.7	15.0	10.4
Background	53.0	53.0	53.0	53.0	53.0
Total Concentration	70.0	77.5	53.8	72.1	72.8

To estimate the accuracy of the modeling results, a comparison of expected concentrations and monitoring data is shown in Table 4. This comparison appears to be relatively close at the City Hall monitoring site; however, the discrepancy at the Marshalltown Manufacturing site appears to be the cause of improper area source input data. This site may be calculated too high because of an overestimation of fugitive emissions from Gra-Iron Foundry and fugitive dust from unpaved roads near the monitor.

Although the calculated concentrations are not exactly the same as the actual monitored values, the projected concentrations represent averages that do not reflect changing weather conditions, as occurred in 1976 and 1977, which may vary the actual monitored values. Therefore, these projections should be used more as a guideline on locating high concentration areas than an exact calculation of suspended particulate levels at each receptor.

TABLE 4

Comparison of Air Monitoring Data

with Projected Concentrations

Monitor Location	1977 Arithmetic Mean	Projected Concentration
1. City Hall	73	70
2. Marshalltown Manufacturing	63	77

Summary

Using the AQDM results, a portion of Marshalltown is projeced to exceed the annual secondary ambient air quality standard unless additional emission reduction is implemented.

An area of east-central Marshalltown is projected to have annual arithmetic means in excess of 70 micrograms per cubic meter. An estimated breakdown of the annual suspended particulate concentrations using this model for Marshalltown and a Marshall County rural city, Melbourne, located in south-western Marshall County is shown in Table 5.

The largest sources of particulates shown in the table, aside from background, are from industrial sources and from transportation sources causing fugitive dust. The industrial sources located in east-central Marshalltown account for about fifteen percent of the total projected concentration in Marshalltown. However, a number of these sources contributing the large amount of particulate are fugitive sources that do not currently require stringent control. Also an additional fluctuation in annual averages has been calculated from excessive breakdown or maintenance emissions from installed air pollution control equipment at some of these industries.

The second largest source of particulates shown in Table 5 is transportation oriented sources causing fugitive dust. These fugitive dust emissions are estimated to contribute over ten percent of the total calculated particulate concentration while the emissions from the transportation source itself (i.e., from engine exhaust and tire wear) accounts for less than one percent. Particulates from unpaved roads in or adjacent to the City of Marshalltown are projected to add an additional four micrograms to the annual concentration in eastern Marshalltown.

An additional contribution of one to three micrograms per cubic meter is calculated from the levee construction on Linn Creek and smaller construction activities throughout the center city.

TABLE 5

Breakdown of Annual Suspended Particulate Concentration for Three Selected Sites in Marshall County

Sources of Particulate	Expected Concentrations (ug/m^3)	
	Marshalltown	Melbourne
Point Sources (Industrial Process)	9.4	0.06
Area Sources		
Fuel use (Residential and Commercial)	0.42	0.02
Solid Waste Disposal (Open Burning)	0.52	0.04
Transportation		
Exhaust, Tire Wear	0.68	0.08
Fugitive Dust from Paved Roads	3.93	0.58
Fugitive Dust from Unpaved Roads	4.21	0.00*
Miscellaneous (structural fire, construction)	0.58	0.02
Background	53.0	53.0
TOTAL	72.8	53.8

* This amount is included in the background concentration.

References

1. GCA/Technology Division, "Assessment of Particulate Attainment and Maintenance Problem", Volume 1 and 4, DEQ Contract No. 76-2000-06, September, 1976.

2. Air Quality Display Model prepared for Department of Health Education and Welfare Public Health Service by TRW Systems Group, November 1969, Contract No. PH-22-68-60.

3. "Official Iowa Population Projections, 1975-2020", Iowa Office of Planning and Programming, Series I-76, No. 1, July, 1976.

4. AP-42, "Compilation of Air Pollutant Emission Factors, Second Edition", U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, February 1976.

5. Amick, R. S., Axetell, K., and Wells, D. M., "Fugitive Dust Emissions Inventory Techniques", Presented at the 67th Annual APCA meeting, #74-58, Page 7.

6. Cowherd, C. Jr., and Mann, C. O., "Quantification of Dust Entrainment from Paved Roads", Presented at the 69th Annual APCA meeting, #76-5.4, Page 13.

7. Iowa Airport System Plan, 1972, Department of Transportaton, Table 41.

Appendix A

Marshalltown Sources and Corresponding Source Numbers

Source Number	Source
1-3	Iowa Electric Light & Power Company
4-7	Gra-Iron Foundry
8-10	Bobs Feed and Supply
11	Bigelow-Liptak
12	Arbie Mineral Feed
13	Kiowa
14	Marshalltown Trowell
15	Marshalltown Airport
16-52	Area Sources

MARSHALLTOWN, IOWA 1977 PARTICULATE MODELING MARCH 1978

SOURCE DATA

SOURCE NUMBER	SOURCE LOCATION (KILOMETERS) HORIZONTAL	SOURCE LOCATION (KILOMETERS) VERTICAL	SOURCE AREA SQUARE KILOMETERS	ANNUAL SOURCE EMISSION RATE (TONS/DAY) SO2	ANNUAL SOURCE EMISSION RATE (TONS/DAY) PART	STACK DATA HT (M)	STACK DATA DIAM (M)	STACK DATA VEL (M/SEC)	STACK DATA TEMP (DEG.K)
1	511.6	4654.8	0.0	0.0	0.404	75.3	2.4	12.7	437.
2	511.6	4654.8	0.0	0.0	0.300	75.3	2.4	12.7	437.
3	511.6	4654.8	0.0	0.0	0.834	75.3	2.9	22.4	443.
4	508.7	4654.2	0.0	0.0	0.231	18.8	2.0	10.0	1366.
5	508.7	4654.2	0.0	0.0	0.027	12.1	0.4	1.0	294.
6	508.7	4654.2	0.0	0.0	0.014	9.1	0.4	1.0	294.
7	508.7	4654.2	0.0	0.0	0.072	9.1	0.0	0.0	300.
8	509.7	4652.7	0.0	0.0	0.078	6.0	0.0	0.0	294.
9	509.7	4652.7	0.0	0.0	0.040	6.0	0.0	0.0	294.
10	509.7	4652.7	0.0	0.0	0.030	10.0	5.0	1.0	300.
11	509.7	4654.9	0.0	0.0	0.006	15.3	1.2	11.0	440.
12	507.4	4654.4	0.0	0.0	0.016	6.0	0.0	0.0	294.
13	508.8	4654.3	0.0	0.0	0.019	10.0	1.0	5.0	300.
14	508.3	4654.7	0.0	0.0	0.033	7.3	0.6	6.1	294.
15	505.3	4661.8	1.00	0.0	0.022	3.0	0.0	0.0	0.
16	505.0	4655.0	1.00	0.0	0.064	3.0	0.0	0.0	0.
17	506.0	4655.0	1.00	0.0	0.110	3.0	0.0	0.0	0.
18	507.0	4655.0	1.00	0.0	0.158	3.0	0.0	0.0	0.
19	508.0	4655.0	1.00	0.0	0.216	3.0	0.0	0.0	0.
20	505.0	4654.0	1.00	0.0	0.054	3.0	0.0	0.0	0.
21	506.0	4654.0	1.00	0.0	0.143	3.0	0.0	0.0	0.
22	507.0	4654.0	1.00	0.0	0.310	3.0	0.0	0.0	0.
23	508.0	4654.0	1.00	0.0	0.171	3.0	0.0	0.0	0.
24	507.0	4653.0	1.00	0.0	0.122	3.0	0.0	0.0	0.
25	508.0	4653.0	1.00	0.0	0.056	3.0	0.0	0.0	0.
26	503.0	4654.0	4.00	0.0	0.158	3.0	0.0	0.0	0.
27	505.0	4652.0	4.00	0.0	0.149	3.0	0.0	0.0	0.
28	505.0	4650.0	4.00	0.0	0.214	3.0	0.0	0.0	0.
29	507.0	4651.0	4.00	0.0	0.202	3.0	0.0	0.0	0.
30	507.0	4649.0	4.00	0.0	0.137	3.0	0.0	0.0	0.
31	509.0	4654.0	4.00	0.0	0.434	3.0	0.0	0.0	0.
32	500.0	4654.0	9.00	0.0	0.145	3.0	0.0	0.0	0.
33	500.0	4657.0	9.00	0.0	0.136	3.0	0.0	0.0	0.
34	511.0	4657.0	9.00	0.0	0.130	3.0	0.0	0.0	0.
35	511.0	4654.0	9.00	0.0	0.240	3.0	0.0	0.0	0.
36	503.0	4656.0	16.00	0.0	0.301	3.0	0.0	0.0	0.
37	507.0	4656.0	16.00	0.0	0.141	3.0	0.0	0.0	0.
38	501.0	4650.0	16.00	0.0	0.220	3.0	0.0	0.0	0.
39	502.0	4649.0	25.00	0.0	0.223	3.0	0.0	0.0	0.
40	514.0	4655.0	25.00	0.0	0.058	3.0	0.0	0.0	0.
41	492.0	4655.0	20.00	0.0	0.019	3.0	0.0	0.0	0.
42	496.0	4655.0	20.00	0.0	0.019	3.0	0.0	0.0	0.
43	492.0	4650.0	20.00	0.0	0.125	3.0	0.0	0.0	0.
44	496.0	4650.0	25.00	0.0	0.185	3.0	0.0	0.0	0.
45	481.0	4660.0	169.00	0.0	0.119	3.0	0.0	0.0	0.
46	494.0	4660.0	169.00	0.0	0.167	3.0	0.0	0.0	0.
47	507.0	4660.0	169.00	0.0	0.395	3.0	0.0	0.0	0.
48	481.0	4649.0	121.00	0.0	0.154	3.0	0.0	0.0	0.
49	481.0	4636.0	169.00	0.0	0.192	3.0	0.0	0.0	0.
50	494.0	4636.0	169.00	0.0	0.126	3.0	0.0	0.0	0.
51	507.0	4636.0	169.00	0.0	0.145	3.0	0.0	0.0	0.
52	514.0	4649.0	36.00	0.0	0.169	3.0	0.0	0.0	0.

Appendix B

RECEPTOR CONCENTRATION DATA

RECEPTOR NUMBER	RECEPTOR LOCATION (KILOMETERS) HORIZ	VERT	EXPECTED ARITHMETIC MEAN (MICROGRAMS/CU. METER) SO2	PARTICULATES
1	500.0	4647.0	0.	54.
2	500.0	4648.0	0.	55.
3	500.0	4649.0	0.	55.
4	500.0	4650.0	0.	55.
5	500.0	4651.0	0.	55.
6	500.0	4652.0	0.	56.
7	500.0	4653.0	0.	56.
8	500.0	4654.0	0.	56.
9	500.0	4655.0	0.	56.
10	500.0	4656.0	0.	56.
11	500.0	4657.0	0.	56.
12	500.0	4658.0	0.	56.
13	500.0	4659.0	0.	56.
14	500.0	4660.0	0.	56.
15	500.0	4661.0	0.	55.
16	501.0	4647.0	0.	55.
17	501.0	4648.0	0.	55.
18	501.0	4649.0	0.	55.
19	501.0	4650.0	0.	56.
20	501.0	4651.0	0.	56.
21	501.0	4652.0	0.	56.
22	501.0	4653.0	0.	56.
23	501.0	4654.0	0.	57.
24	501.0	4655.0	0.	57.
25	501.0	4656.0	0.	57.
26	501.0	4657.0	0.	56.
27	501.0	4658.0	0.	56.
28	501.0	4659.0	0.	56.
29	501.0	4660.0	0.	56.
30	501.0	4661.0	0.	56.
31	502.0	4647.0	0.	55.
32	502.0	4648.0	0.	55.
33	502.0	4649.0	0.	55.
34	502.0	4650.0	0.	56.
35	502.0	4651.0	0.	56.
36	502.0	4652.0	0.	56.
37	502.0	4653.0	0.	57.
38	502.0	4654.0	0.	57.
39	502.0	4655.0	0.	57.
40	502.0	4656.0	0.	57.
41	502.0	4657.0	0.	57.
42	502.0	4658.0	0.	56.
43	502.0	4659.0	0.	56.
44	502.0	4660.0	0.	56.
45	502.0	4661.0	0.	56.
46	503.0	4647.0	0.	55.
47	503.0	4648.0	0.	55.
48	503.0	4649.0	0.	55.
49	503.0	4650.0	0.	56.
50	503.0	4651.0	0.	56.
51	503.0	4652.0	0.	57.
52	503.0	4653.0	0.	58.
53	503.0	4654.0	0.	59.
54	503.0	4655.0	0.	58.
55	503.0	4656.0	0.	58.
56	503.0	4657.0	0.	57.
57	503.0	4658.0	0.	57.
58	503.0	4659.0	0.	57.
59	503.0	4660.0	0.	56.
60	503.0	4661.0	0.	56.
61	504.0	4647.0	0.	55.
62	504.0	4648.0	0.	55.
63	504.0	4649.0	0.	56.
64	504.0	4650.0	0.	57.
65	504.0	4651.0	0.	57.
66	504.0	4652.0	0.	58.
67	504.0	4653.0	0.	58.
68	504.0	4654.0	0.	59.
69	504.0	4655.0	0.	59.
70	504.0	4656.0	0.	59.
71	504.0	4657.0	0.	58.
72	504.0	4658.0	0.	57.
73	504.0	4659.0	0.	57.
74	504.0	4660.0	0.	57.
75	504.0	4661.0	0.	56.
76	505.0	4647.0	0.	55.
77	505.0	4648.0	0.	56.
78	505.0	4649.0	0.	57.
79	505.0	4650.0	0.	58.
80	505.0	4651.0	0.	58.

RECEPTOR CONCENTRATION DATA

RECEPTOR NUMBER	RECEPTOR LOCATION (KILOMETERS) HORIZ	VERT	EXPECTED ARITHMETIC MEAN (MICROGRAMS/CU. METER) SO2	PARTICULATES
81	505.0	4652.0	0.	59.
82	505.0	4653.0	0.	60.
83	505.0	4654.0	0.	62.
84	505.0	4655.0	0.	62.
85	505.0	4656.0	0.	60.
86	505.0	4657.0	0.	59.
87	505.0	4658.0	0.	58.
88	505.0	4659.0	0.	57.
89	505.0	4660.0	0.	57.
90	505.0	4661.0	0.	57.
91	506.0	4647.0	0.	56.
92	506.0	4648.0	0.	56.
93	506.0	4649.0	0.	57.
94	506.0	4650.0	0.	58.
95	506.0	4651.0	0.	58.
96	506.0	4652.0	0.	59.
97	506.0	4653.0	0.	61.
98	506.0	4654.0	0.	66.
99	506.0	4655.0	0.	66.
100	506.0	4656.0	0.	62.
101	506.0	4657.0	0.	60.
102	506.0	4658.0	0.	58.
103	506.0	4659.0	0.	58.
104	506.0	4660.0	0.	57.
105	506.0	4661.0	0.	57.
106	507.0	4647.0	0.	56.
107	507.0	4648.0	0.	57.
108	507.0	4649.0	0.	58.
109	507.0	4650.0	0.	59.
110	507.0	4651.0	0.	60.
111	507.0	4652.0	0.	60.
112	507.0	4653.0	0.	65.
113	507.0	4654.0	0.	72.
114	507.0	4655.0	0.	70.
115	507.0	4656.0	0.	63.
116	507.0	4657.0	0.	60.
117	507.0	4658.0	0.	59.
118	507.0	4659.0	0.	58.
119	507.0	4660.0	0.	57.
120	507.0	4661.0	0.	57.
121	508.0	4647.0	0.	56.
122	508.0	4648.0	0.	57.
123	508.0	4649.0	0.	58.
124	508.0	4650.0	0.	58.
125	508.0	4651.0	0.	59.
126	508.0	4652.0	0.	60.
127	508.0	4653.0	0.	64.
128	508.0	4654.0	0.	72.
129	508.0	4655.0	0.	72.
130	508.0	4656.0	0.	63.
131	508.0	4657.0	0.	60.
132	508.0	4658.0	0.	59.
133	508.0	4659.0	0.	58.
134	508.0	4660.0	0.	57.
135	508.0	4661.0	0.	57.
136	509.0	4647.0	0.	56.
137	509.0	4648.0	0.	57.
138	509.0	4649.0	0.	57.
139	509.0	4650.0	0.	58.
140	509.0	4651.0	0.	59.
141	509.0	4652.0	0.	60.
142	509.0	4653.0	0.	64.
143	509.0	4654.0	0.	73.
144	509.0	4655.0	0.	64.
145	509.0	4656.0	0.	60.
146	509.0	4657.0	0.	59.
147	509.0	4658.0	0.	58.
148	509.0	4659.0	0.	57.
149	509.0	4660.0	0.	57.
150	509.0	4661.0	0.	56.
151	510.0	4647.0	0.	56.
152	510.0	4648.0	0.	56.
153	510.0	4649.0	0.	57.
154	510.0	4650.0	0.	57.
155	510.0	4651.0	0.	58.
156	510.0	4652.0	0.	61.
157	510.0	4653.0	0.	65.
158	510.0	4654.0	0.	63.
159	510.0	4655.0	0.	59.
160	510.0	4656.0	0.	58.

RECEPTOR CONCENTRATION DATA				
RECEPTOR NUMBER	RECEPTOR LOCATION (KILOMETERS)		EXPECTED ARITHMETIC MEAN (MICROGRAMS/CU. METER)	
	HORIZ	VERT	SO2	PARTICULATES
161	510.0	4657.0	0.	58.
162	510.0	4658.0	0.	57.
163	510.0	4659.0	0.	57.
164	510.0	4660.0	0.	56.
165	510.0	4661.0	0.	56.
166	511.0	4647.0	0.	56.
167	511.0	4648.0	0.	56.
168	511.0	4649.0	0.	57.
169	511.0	4650.0	0.	57.
170	511.0	4651.0	0.	58.
171	511.0	4652.0	0.	58.
172	511.0	4653.0	0.	59.
173	511.0	4654.0	0.	59.
174	511.0	4655.0	0.	58.
175	511.0	4656.0	0.	57.
176	511.0	4657.0	0.	57.
177	511.0	4658.0	0.	57.
178	511.0	4659.0	0.	56.
179	511.0	4660.0	0.	56.
180	511.0	4661.0	0.	56.
181	512.0	4647.0	0.	56.
182	512.0	4648.0	0.	56.
183	512.0	4649.0	0.	56.
184	512.0	4650.0	0.	57.
185	512.0	4651.0	0.	57.
186	512.0	4652.0	0.	57.
187	512.0	4653.0	0.	58.
188	512.0	4654.0	0.	58.
189	512.0	4655.0	0.	57.
190	512.0	4656.0	0.	56.
191	512.0	4657.0	0.	56.
192	512.0	4658.0	0.	56.
193	512.0	4659.0	0.	56.
194	512.0	4660.0	0.	56.
195	512.0	4661.0	0.	55.
196	513.0	4647.0	0.	56.
197	513.0	4648.0	0.	56.
198	513.0	4649.0	0.	56.
199	513.0	4650.0	0.	56.
200	513.0	4651.0	0.	56.
201	513.0	4652.0	0.	56.
202	513.0	4653.0	0.	57.
203	513.0	4654.0	0.	56.
204	513.0	4655.0	0.	56.
205	513.0	4656.0	0.	56.
206	513.0	4657.0	0.	56.
207	513.0	4658.0	0.	55.
208	513.0	4659.0	0.	55.
209	513.0	4660.0	0.	55.
210	513.0	4661.0	0.	55.
211	514.0	4647.0	0.	55.
212	514.0	4648.0	0.	56.
213	514.0	4649.0	0.	56.
214	514.0	4650.0	0.	56.
215	514.0	4651.0	0.	56.
216	514.0	4652.0	0.	56.
217	514.0	4653.0	0.	56.
218	514.0	4654.0	0.	56.
219	514.0	4655.0	0.	56.
220	514.0	4656.0	0.	55.
221	514.0	4657.0	0.	55.
222	514.0	4658.0	0.	55.
223	514.0	4659.0	0.	55.
224	514.0	4660.0	0.	55.
225	514.0	4661.0	0.	55.
226	507.2	4655.9	0.	63.
227	508.9	4654.1	0.	77.
228	509.5	4654.5	0.	63.
229	508.0	4654.5	0.	71.
230	507.5	4654.5	0.	70.
231	508.0	4653.5	0.	66.
232	492.0	4644.0	0.	54.
233	484.0	4662.0	0.	54.
234	501.5	4662.0	0.	56.
235	518.0	4650.0	0.	55.
236	517.5	4636.5	0.	54.
237	506.5	4654.5	0.	65.

Marshalltown Sources and Corresponding Source Numbers

Source Number	Source
1-3	Iowa Electric Light & Power Company
4-7	Gra-Iron Foundry
8-10	Bobs Feed and Supply
11	Bigelow-Liptak
12	Arbie Mineral Feed
13	Kiowa
14	Marshalltown Trowell
15	Marshalltown Airport
16-52	Area Sources

MARSHALLTOWN, IOWA 1977 PARTICULATE MODELING MARCH 1978

SOURCE CONTRIBUTIONS TO FIVE SELECTED RECEPTORS

ANNUAL PARTICULATES

MICROGRAMS PER CUBIC METER

SOURCE	RECEPTOR 226	RECEPTOR 227	RECEPTOR 232	RECEPTOR 129	RECEPTOR 143
1	0.05 %	0.03 %	0.01 %	0.05 %	0.03 %
	0.0304	0.0214	0.0076	0.0348	0.0189
2	0.04 %	0.02 %	0.01 %	0.04 %	0.02 %
	0.0226	0.0159	0.0056	0.0258	0.0141
3	0.03 %	0.02 %	0.02 %	0.03 %	0.01 %
	0.0120	0.0124	0.0092	0.0217	0.0105
4	0.07 %	0.00 %	0.01 %	0.03 %	0.00 %
	0.0442	0.0000	0.0057	0.0226	0.0006
5	0.15 %	2.62 %	0.00 %	0.46 %	2.05 %
	0.0963	2.0292	0.0022	0.3323	1.4907
6	0.08 %	1.87 %	0.00 %	0.25 %	1.23 %
	0.0504	1.4450	0.0011	0.1771	0.8959
7	0.41 %	10.26 %	0.01 %	1.27 %	6.51 %
	0.2595	7.9428	0.0059	0.9150	4.7440
8	0.18 %	0.69 %	0.01 %	0.28 %	0.85 %
	0.1149	0.5353	0.0074	0.2005	0.6201
9	0.09 %	0.35 %	0.01 %	0.14 %	0.44 %
	0.0582	0.2745	0.0038	0.1028	0.3180
10	0.07 %	0.19 %	0.01 %	0.09 %	0.22 %
	0.0421	0.1445	0.0029	0.0672	0.1632
11	0.01 %	0.01 %	0.00 %	0.02 %	0.01 %
	0.0047	0.0070	0.0003	0.0108	0.0079
12	0.25 %	0.13 %	0.00 %	0.27 %	0.11 %
	0.1571	0.0968	0.0013	0.1933	0.0805
13	0.10 %	1.51 %	0.00 %	0.26 %	1.17 %
	0.0653	1.1674	0.0015	0.1883	0.8496
14	0.31 %	0.74 %	0.00 %	2.46 %	0.61 %
	0.1954	0.5760	0.0025	1.7703	0.4453
15	0.02 %	0.01 %	0.00 %	0.02 %	0.02 %
	0.0155	0.0115	0.0012	0.0129	0.0115
16	0.16 %	0.10 %	0.01 %	0.15 %	0.10 %
	0.0998	0.0739	0.0044	0.1111	0.0722
17	0.65 %	0.25 %	0.01 %	0.37 %	0.25 %
	0.4092	0.1917	0.0078	0.2693	0.1848
18	2.00 %	0.52 %	0.02 %	1.35 %	0.52 %
	1.2602	0.4004	0.0113	0.9717	0.3807
19	2.34 %	1.66 %	0.03 %	9.12 %	1.58 %
	1.4804	1.2836	0.0156	6.5767	1.1524
20	0.11 %	0.09 %	0.01 %	0.09 %	0.10 %
	0.0684	0.0698	0.0043	0.0654	0.0706
21	0.51 %	0.32 %	0.02 %	0.33 %	0.34 %
	0.3228	0.2461	0.0116	0.2388	0.2482
22	1.83 %	0.98 %	0.05 %	1.93 %	1.04 %
	1.1554	0.7559	0.0252	1.3945	0.7561
23	1.00 %	1.39 %	0.03 %	2.09 %	1.44 %
	0.6343	1.0751	0.0138	1.5079	1.0516
24	0.52 %	0.27 %	0.02 %	0.42 %	0.28 %
	0.3299	0.2092	0.0111	0.3013	0.2037
25	0.23 %	0.33 %	0.01 %	0.31 %	0.35 %
	0.1453	0.2525	0.0050	0.2205	0.2519
26	0.17 %	0.15 %	0.03 %	0.16 %	0.16 %
	0.1068	0.1185	0.0145	0.1149	0.1191
27	0.22 %	0.14 %	0.03 %	0.16 %	0.14 %
	0.1419	0.1050	0.0149	0.1148	0.1039
28	0.28 %	0.16 %	0.06 %	0.22 %	0.19 %
	0.1762	0.1271	0.0329	0.1569	0.1279
29	0.41 %	0.28 %	0.05 %	0.35 %	0.29 %
	0.2574	0.2151	0.0251	0.2549	0.2100
30	0.21 %	0.17 %	0.04 %	0.18 %	0.18 %
	0.1319	0.1312	0.0217	0.1322	0.1306
31	1.22 %	4.69 %	0.06 %	1.58 %	5.19 %
	0.7716	3.6331	0.0333	1.1356	3.7825
32	0.10 %	0.09 %	0.03 %	0.09 %	0.09 %
	0.0641	0.0686	0.0165	0.0671	0.0689
33	0.12 %	0.08 %	0.02 %	0.09 %	0.08 %
	0.0731	0.0602	0.0119	0.0681	0.0595
34	0.12 %	0.11 %	0.01 %	0.11 %	0.12 %
	0.0772	0.0839	0.0073	0.0816	0.0942
35	0.29 %	0.26 %	0.03 %	0.31 %	0.34 %
	0.1861	0.2049	0.0183	0.2202	0.2499
36	0.29 %	0.20 %	0.05 %	0.24 %	0.21 %
	0.1330	0.1562	0.0269	0.1755	0.1548
37	0.55 %	0.17 %	0.02 %	0.36 %	0.15 %
	0.3455	0.1291	0.0098	0.2627	0.1106
38	0.11 %	0.09 %	0.07 %	0.10 %	0.09 %
	0.0700	0.0691	0.0396	0.0694	0.0679
39	0.20 %	0.19 %	0.06 %	0.19 %	0.21 %
	0.1242	0.1483	0.0298	0.1398	0.1496
40	0.03 %	0.03 %	0.01 %	0.03 %	0.03 %
	0.0128	0.0225	0.0044	0.0215	0.0225
41	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %
	0.0048	0.0046	0.0056	0.0050	0.0045
42	0.01 %	0.01 %	0.01 %	0.01 %	0.01 %
	0.0060	0.0056	0.0035	0.0062	0.0056

MARSHALLTOWN, IOWA 1977 PARTICULATE MODELING MARCH 1978

SOURCE CONTRIBUTIONS TO FIVE SELECTED RECEPTORS

ANNUAL PARTICULATES

MICROGRAMS PER CUBIC METER

SOURCE	RECEPTOR 226	RECEPTOR 227	RECEPTOR 232	RECEPTOR 129	RECEPTOR 143
43	0.04 %	0.03 %	0.11 %	0.03 %	0.03 %
	0.0229	0.0217	0.0565	0.0225	0.0216
44	0.06 %	0.05 %	0.09 %	0.06 %	0.06 %
	0.0398	0.0416	0.0470	0.0407	0.0417
45	0.02 %	0.02 %	0.03 %	0.02 %	0.02 %
	0.0135	0.0130	0.0152	0.0133	0.0130
46	0.04 %	0.03 %	0.04 %	0.04 %	0.03 %
	0.0257	0.0250	0.0192	0.0255	0.0250
47	0.18 %	0.15 %	0.05 %	0.16 %	0.16 %
	0.1168	0.1136	0.0244	0.1169	0.1147
48	0.03 %	0.02 %	0.05 %	0.02 %	0.02 %
	0.0164	0.0169	0.0289	0.0167	0.0169
49	0.02 %	0.02 %	0.06 %	0.02 %	0.02 %
	0.0153	0.0144	0.0297	0.0144	0.0144
50	0.02 %	0.02 %	0.05 %	0.02 %	0.02 %
	0.0142	0.0135	0.0243	0.0137	0.0135
51	0.04 %	0.03 %	0.03 %	0.04 %	0.04 %
	0.0266	0.0260	0.0178	0.0264	0.0260
52	0.09 %	0.09 %	0.03 %	0.09 %	0.10 %
	0.0594	0.0724	0.0173	0.0655	0.0732
BACK-	83.90 %	68.43 %	98.58 %	73.52 %	72.76 %
GROUND	53.	53.	53.	53.	53.
TOTAL	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
	63.1686	77.4770	53.7648	72.1133	72.8559