EVALUATION OF HEALTH EFFECTS OF AIR POLLUTION IN THE CHESTNUT RIDGE AREA--PRELIMINARY ANALYSIS

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Progress Report
for Period September 15, 1979 to March 15, 1980

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ABSTRACT

This project involves several tasks designed to take advantage of (1) a very extensive air pollution monitoring system that is operating in the Chestnut Ridge region of Western Pennsylvania and (2) the very well developed analytic dispersion models that have been previously fine-tuned to this particular area. The major task in this project is to establish, through several distinct epidemiologic approaches, health data to be used to test hypotheses about relations of air pollution exposures to morbidity and mortality rates in this region. Because the air quality monitoring network involves no expense to this contract, this project affords a very cost-effective opportunity for state-of-the-art techniques to be used in both costly areas of air pollution and health effects data collection. The closely spaced network of monitors, plus the dispersion modeling capabilities, allow for the investigation of health impacts of various pollutant gradients in neighboring geographic areas, thus minimizing the confounding effects of social, ethnic, and economic factors. The pollutants that are monitored in this network include total gaseous sulfur, sulfates, total suspended particulates, NOx, NO, ozone/oxidants, and coefficient of haze. In addition to enabling the simulation of exposure profiles between monitors, the air quality modeling, along with extensive source and background inventories, will allow for upgrading the quality of the monitored data as well as simulating the exposure levels for about 25 additional air pollutants. Another important goal of this project is to collect and test the many available models for associating health effects with air pollution, to determine their predictive validity and their usefulness in the choice and siting of future energy facilities.

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1. Summary

The ultimate usefulness of this research project will be to provide methodologies and information that could be used to compare various energy options from a human health impact viewpoint. The specific products of this research will include:

(1) information about the health impacts of various combinations and durations of air pollutants of concentrations experienced in communities,

(2) methodologies for modeling and characterization of human dosages of air pollutant emissions from various point and background sources,

(3) ideal formats for human dosage characterization as well as formats for meteorologic and demographic data collections that could be supportive of predictive dosage modeling, and

(4) informations on the uncertainties and validities of various air pollutant/human health correlative models.

It is proposed that these broad goals be approached using several data collection and analytic activities that are described in greater detail in the remainder of this document. Generally these activities include:

(1) collection of health, socio-ethnic, and other confounding information from the children and adults in the Chestnut Ridge area of mid-western Pennsylvania, see Figure 1-1,

(2) collection of air pollution, meteorologic, and emissions data from the same region, including the emissions from the coal-fired power plants and the coal gasification plant that are in this area,

(3) analysis and correlation of the otherwise unexplained health impact data with the air pollution exposure profiles, and

(4) simulation of the emissions and health impacts of various potential future combinations of fuels, control equipments, and advanced coal combustion equipment.

The following section presents a short review of research completed to date on this contract. Considerably more detail is available from the previously completed reports C00-4968-01 September 1979

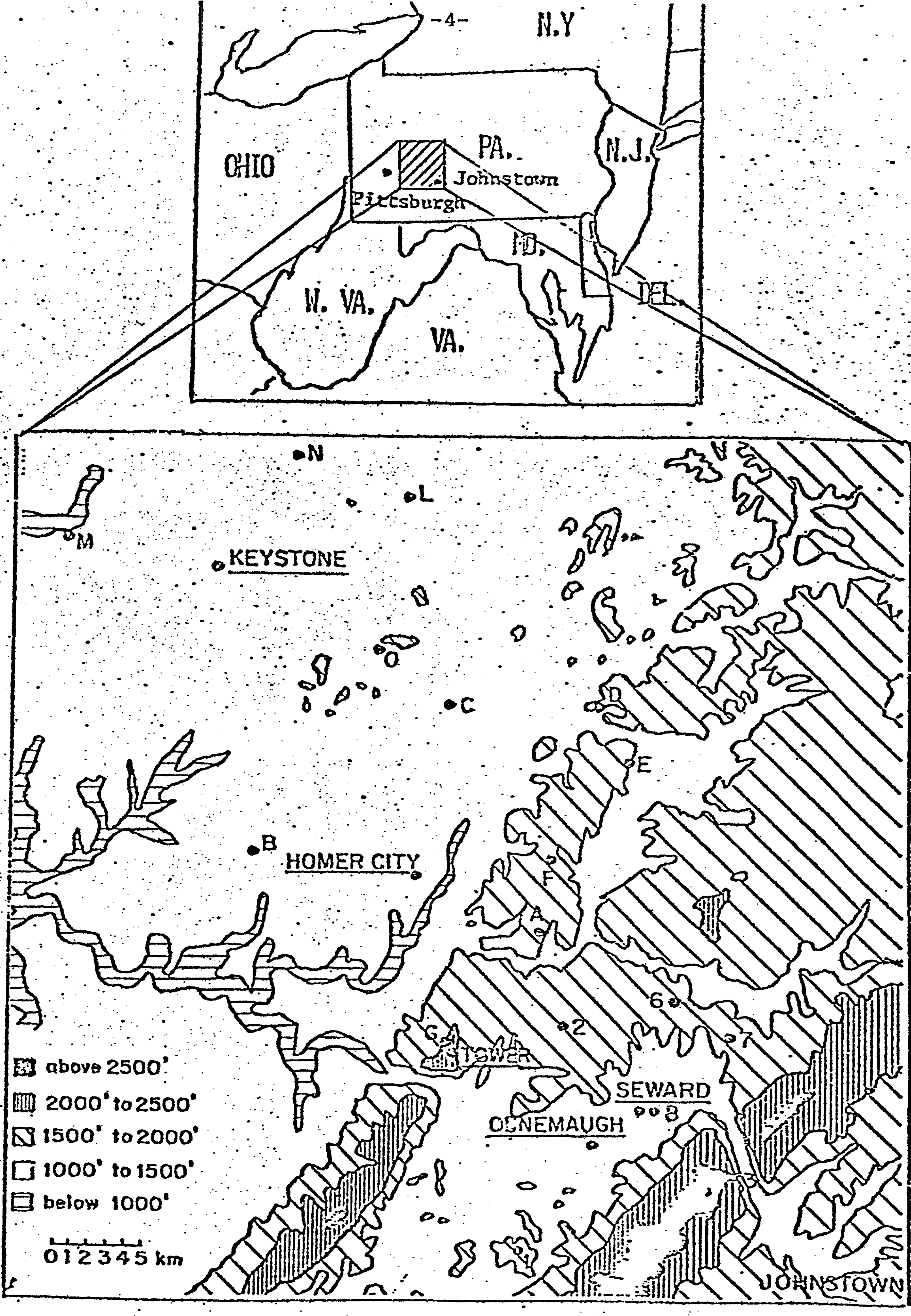

Figure 1-1.

Chestnut Ridge Area

(Gruhl,Speizer,Maher,Samet,Schenker,1979) and C00-4968-2 January 1980 (Maher,1980). Section 3. displays the schedule for the completion of this third year proposed research. Section 4. presents the rationale for these new tasks.

2. Current Status of Chestnut Ridge Research

The Chestnut Ridge section of mid-western Pennsylvania has been the subject area of several air pollution and health impact studies. One of the most extensive was the study of the dispersive potential of the sources within this area, and the real-time control of the pollutant emissions of those sources based upon forecasts of the dispersive potential of the atmosphere. Results of these applied analysis activities are presented in (Ruane, et al, 1977), which is the report of that AEC-funded project. Other particularly important studies in the Chestnut Ridge area include the LAPPES air pollution dispersion studies and the Seward/Florence health effects studies. The principal reason for the attention to this area is the set of very large mine-mouth coal-fired power plants and their requisite air pollutant monitoring equipments. Figure 1-1 shows the general location of four of these large facilities. A gasification plant has been constructed, and this location can be seen in Figure 2-1, in relation to the other sources, monitors, and centers of the study areas. Figure 2-2 presents a more graphic display of the layout of the study areas and monitors. One of the principal cooperative efforts between the air pollutant analysts and the epidemiologists on this project has been the selection of the numbers, sizes, and boundaries of the study areas. The major contributing factors to these decisions have included:

(1) collapsibility into townships, if desired,
(2) aggregatibility into approximate regions closest to each of the 17 pollutant monitors,
(3) school district boundaries,
(4) gradients of air pollution,
(5) population densities,
(6) easy description of the boundaries, such as along major highways,
(7) resolution of the interpolation procedures for pollutant modeling, and
(8) mobility of the population.

The following section presents a very short summary of the health studies that have been conducted as a result of previous contract work. There is a hopefully understandable reluctance to present the interim results of partially completed conclusions.

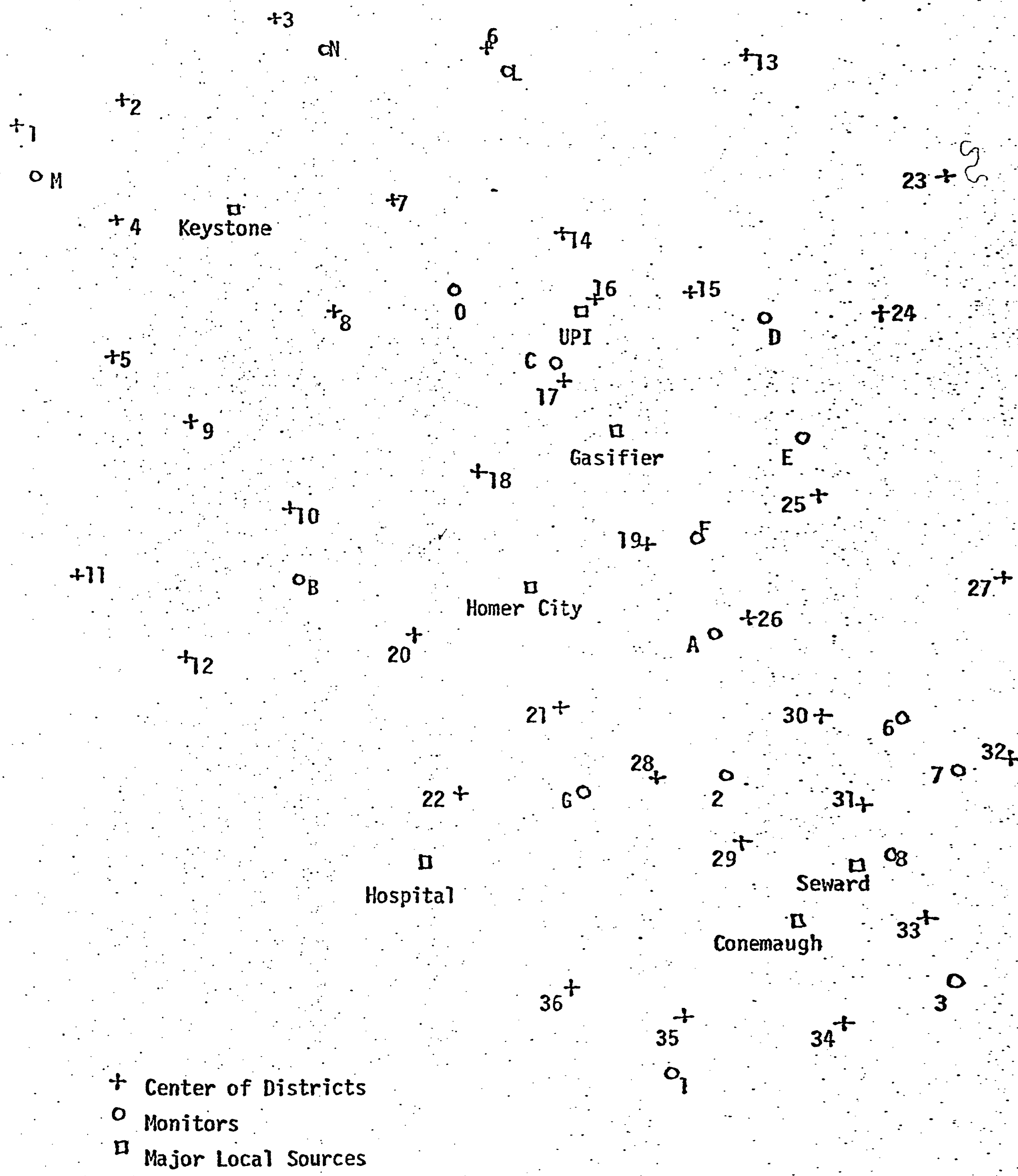

Figure 2-1 Relative locations of the center of the 36 districts and the locations of the 17 monitors and the 7 major local pollution sources.

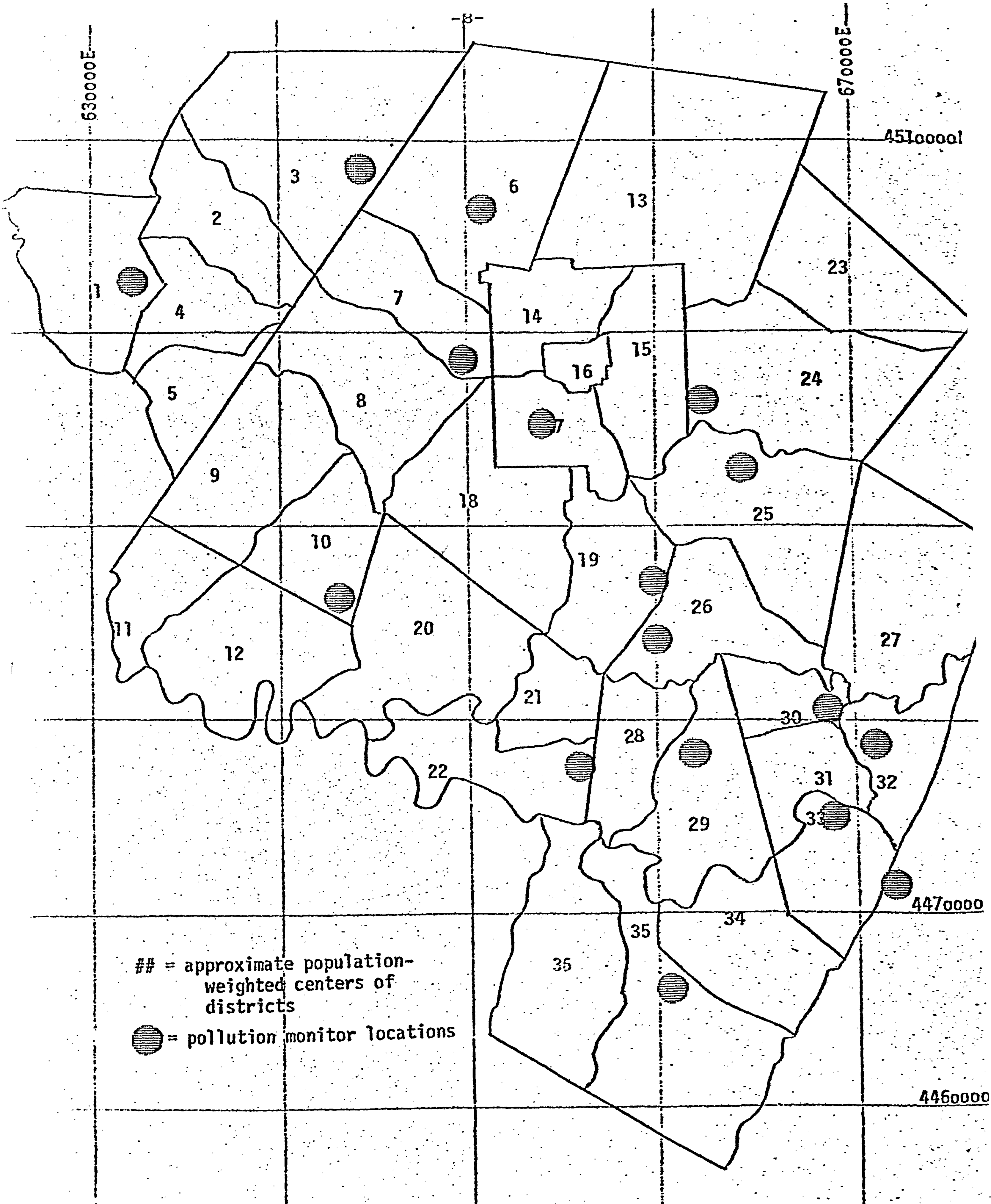

Figure 2-2 Shapes and locations of the 36 districts, along with population-weighted centers of districts and locations of monitoring equipment

2.1 Current Status of Existing Health-related Projects

To date 4 separate surveys have been carried out in the Harvard subcontract of this DOE contract. These have included:

1. The adult women survey -- Sept. 1978 - Jan. 1979
2. The children school survey -- Feb. 1979 - May 1979
3. The Acute effects prospective survey in selected women -- Sept. 1979 - Dec. 1979

and 4. The Acute pollution episode children study -- Nov. - Dec. 1979.

The current status of each data set will be briefly described.

2.1.1 The Adult women survey

Telephone interviews were carried out using a standardized respiratory disease questionnaire and trained interviewers in 5,686 women aged 20 - 74, representing 85% of the potentially available portion of a stratified randomized sample of women from the Chestnut Ridge Region. Each woman was assigned one of 36 specifically designated geographic zones as place of residence. These 36 sites have been modeled by the M.I.T. group on a population weighted basis for each pollutant and are being used to assign pollution exposure scores to individuals within each area. The basic demographic characteristics and cigarette smoking effects in the population have been described. Correlation with pollution data obtained over the same period for which questionnaire data were obtained is currently underway.

2.1.2 The children school survey

The 1 - 6th grade children from a stratified sample representing approximately half of the schools in the Chestnut Ridge region had standardized respiratory disease questionnaires completed by their parents, and had height, weight, and spirometry measured in school. The 3,954 children with completed questionnaires and pulmonary function tests were over 95% of the population sampled.

The questionnaire data have been entered into the computer and are currently being assessed. The spirometry data have been held up, because we have only now acquired sufficient funds to obtain proper digitizing equipment which will allow us to enter sufficient data into the computer to assess flow at low lung volumes, which we believe may be a more sensitive index of small airways responsiveness than the standard tests of forced expiratory volume.

We would anticipate having both these surveys fully analyzed by the end of the current contract period (June 14, 1980).

2.1.3 The acute effects prospective survey in selected women

A sample of 224 women was selected from the initial adult women's cross-sectional survey for intensive follow-up over this last fall and winter season. The women were selected on the basis of residence location and diagnosis. Controls were matched for residence, age and smoking habits. Of the initial sample, 45 (20%) refused to participate in the prospective survey and 24 (10.7%) indicated a willingness to participate but were unable to commit the necessary time for study participation. 35 (15.6%) could not be contacted or had moved from the area. 1 subject was deceased. The remaining sample of 119 was distributed as follows:

Diagnosis	Cases	Matched Controls
Chronic wheeze, not asthma	10	4
Asthma	14	9
Chronic phlegm	15	12
Chronic bronchitis	28	17

The women had spirometry measured every 2 weeks and alternately approximately one-half of the women measured their peak expiratory flow in their own house twice a day for two-week periods for up to 6 cycles. In addition at the end of the period, they again completed the standardized questionnaire. These data currently are in their raw form, awaiting conversion to a data tape for analysis.

2.1.4 The acute children study

During the last fall season, we identified in the "high pollution area" of the region a group of children from the original cross-sectional survey in whom we obtained a new set of base line pulmonary function. We then monitored the air in the region and upon notification of an "alert condition" * we restudied the children. These studies were repeated for the subsequent 3 weeks.

The data from these last two studies is currently being processed.

* Because real time data was not readily available we used real time data from Steubenville, Ohio, which is approximately 70 miles west of the study area and where an exactly comparable acute children study was carried out simultaneously.

2.2 Air Pollutant Data Collection

The monitoring and collection of air pollution data in the Chestnut Ridge area are activities carried out outside the tasks of this project. The owners of the power plants in this region, see describing data in Table 2-1, have set up and maintained the pollutant monitoring grid as part of their initial licensing obligations. They have added additional monitoring capabilities, see Table 2-2, that are however beyond the state siting requirements. The electric utilities participate in the Pennsylvania Electric Association's (PEA) data base program, aimed at collecting all the meteorologic and pollutant information in Pennsylvania in a common accessible data base. Figure 2-3 shows a sample format sheet from DeNardo & McFarland, the contractors for maintaining the PEA data base, which shows some of the monitors and pollutants that have been collected from the Chestnut Ridge monitoring network. Extensive additional information about this monitoring system can be found in the previously cited project documents.

The pollutant concentrations in many cases are collected in hourly averages over the course of each year. This chronological data can be extremely cumbersome and unenlightening to casual or even intensive examinations. For this reason time-collapsed formulations such as the arrowhead curve exposure profiles have been developed and fine-tuned as part of the previous work on this contract (Maher,1980). Figure 2-4 shows the typical form of the exposure profile, with the various concentration quantiles collected and connected for easy display and interpretability. Figure 2-5 displays a common variation of the arrowhead exposure profile, here showing lower overall concentrations and significant long cleansing periods in the lower right-hand portion of the plot. Figure 2-6 contains some profiles for other pollutants collected in the Chestnut Ridge area.

Some of the pollutant information in support of the individual health studies has been collected outside the PEA data base due

Table 2-1 Power Plant Parameters

Units	Capacity (MW)	Stack Height (ft)
Keystone 1 & 2	1640	797
Homer City 1 & 2	1200	796
Conemaugh 1 & 2	1700	1000
Seward 2, 4 & 5	218	600*

*Prior to 1976, stack height was 230 ft.

Table 2-2 Pollution Monitoring Capabilities

Pollutant	Monitors
SOx	All
TSP	All
COH	All
Sulphates	All
NO, NOx	3,7,8,G,F,O
Ozone	3,7,B,E,F,O

Figure 2-3

DeNardo & McFarland Weather Services, Inc.

Continuation of Sites

Sites (Agency/Name or SAROAD Code)	Parameters	Time Periods	(FOR PEA USE) EIY's
	All	All	
NB Lewisville			
NC Rustic Lodge			
ND Penn Run			
NE Brush Valley			
NF Liggette			
NG Penn View, Base			
NL Creekside			
NO Parkwood			
NI W. Fairfield			

Total E.I.Y. 158.1

PARAMETER LISTING

SAROAD Code Parameter	Method	Units	Decimal	Parameter	Units
11201	81	09	2	Soiling Index (COHs)	COH/1000 ft. of Air
42401	16	01	0	Sulfur Dioxide	$\mu g/m^3$
11101	91	01	0	Total Suspended Particulate	$\mu g/m^3$
44201	11	01	0	Ozone	$\mu g/m^3$
61101	50	11	1	Wind Speed	Meters/Second
61102	50	14	0	Wind Direction	Azimuth Degrees
62101	40	37	1	Ambient Temperature	Degrees Kelvin
62103	40	37	1	Dew Point Temperature	Degrees Kelvin
63301	11	18	2	Solar Radiation	Langleys
65102	11	38	2	Rainfall	CM. Water

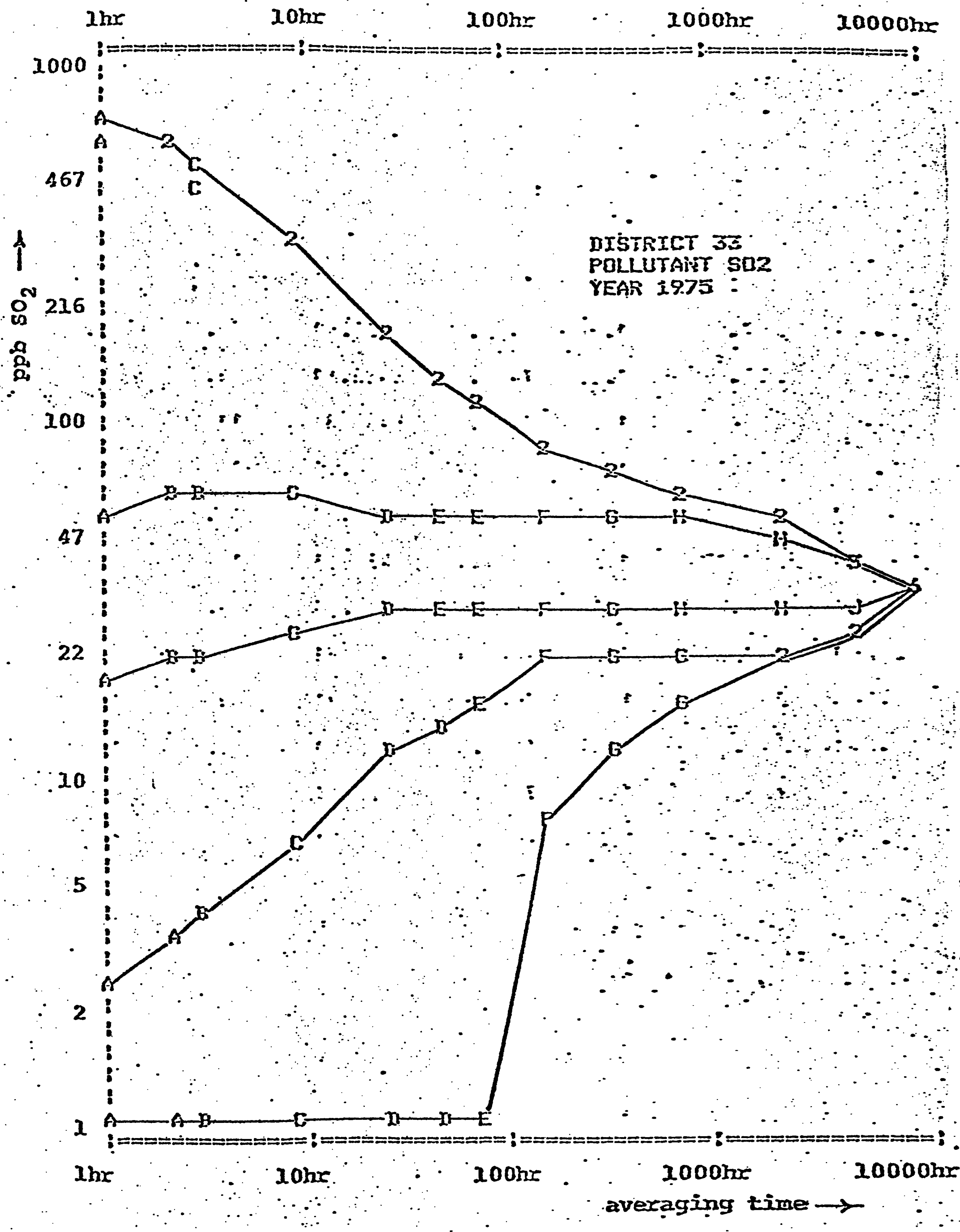

Figure 2-4 Exposure Profile, including 100%, 84%, 50%, 16%, and Minimum values of pollutant concentrations for various averaging times at center of district 33 for year 1975.

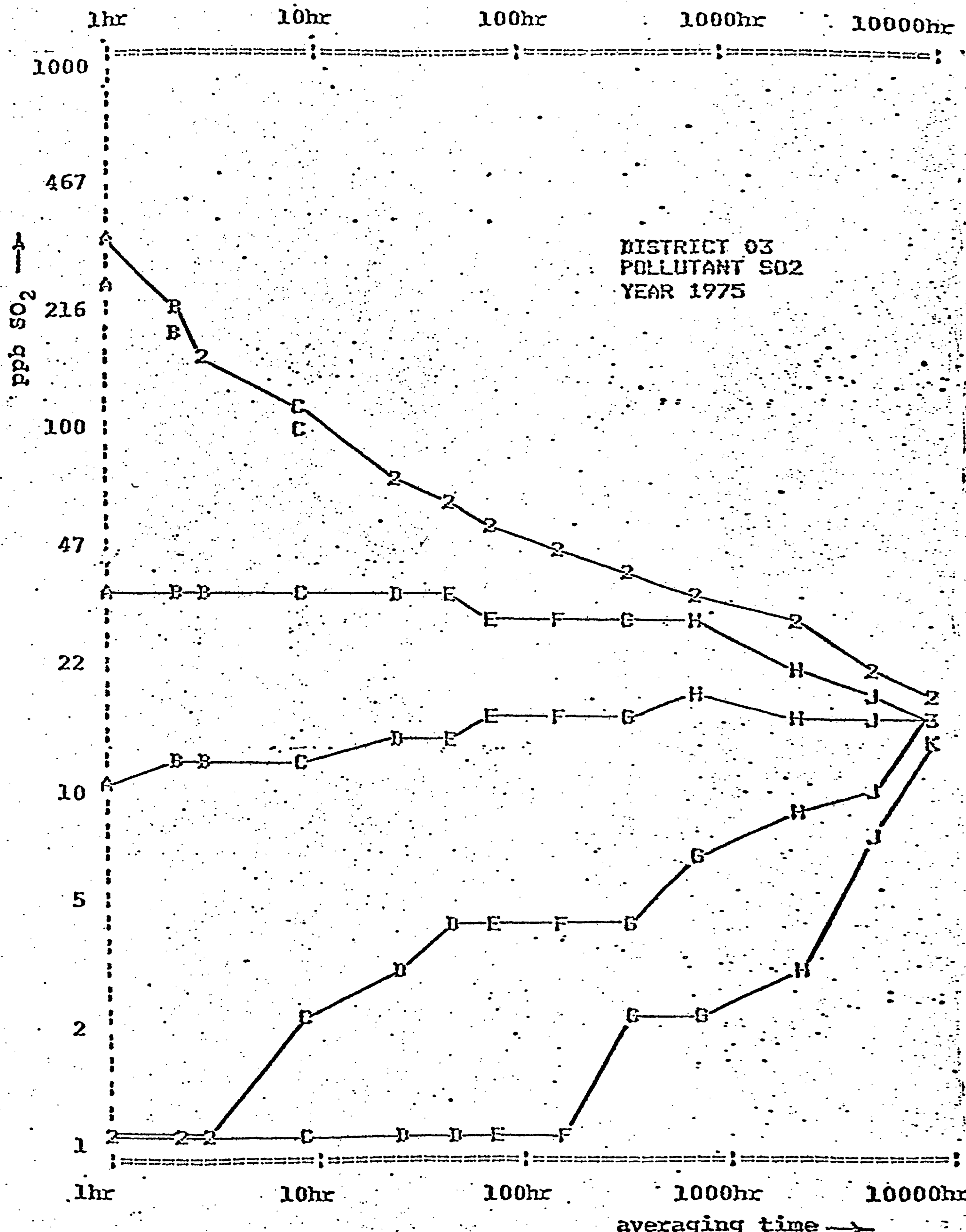

Figure 2-5 SO_2 Exposure Profile, district 3 for year 1975, much blunter arrowhead with significant long-term cleansing periods.

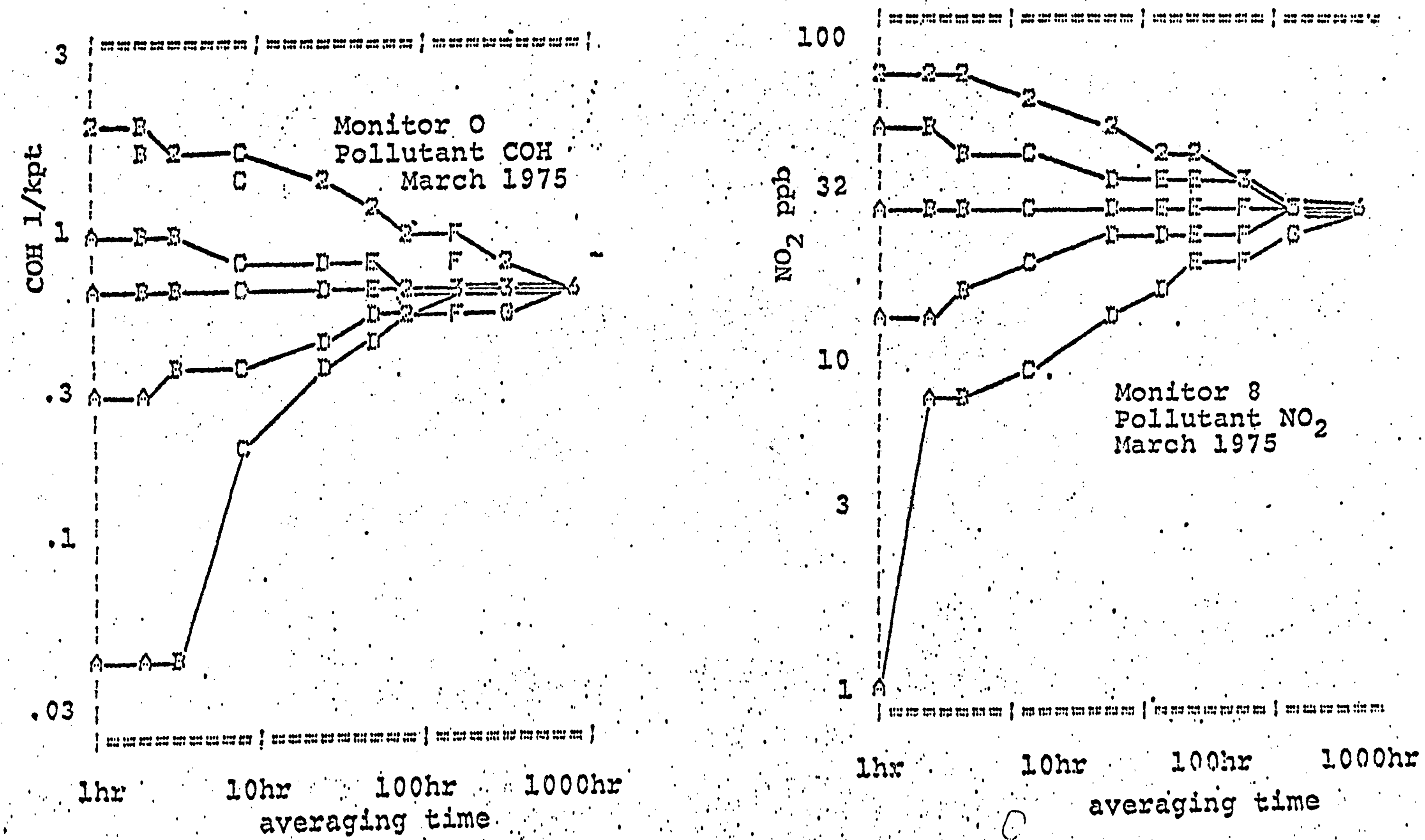

Figure 2-6 Exposure Profiles for some of the other pollutants in the air pollution data base.

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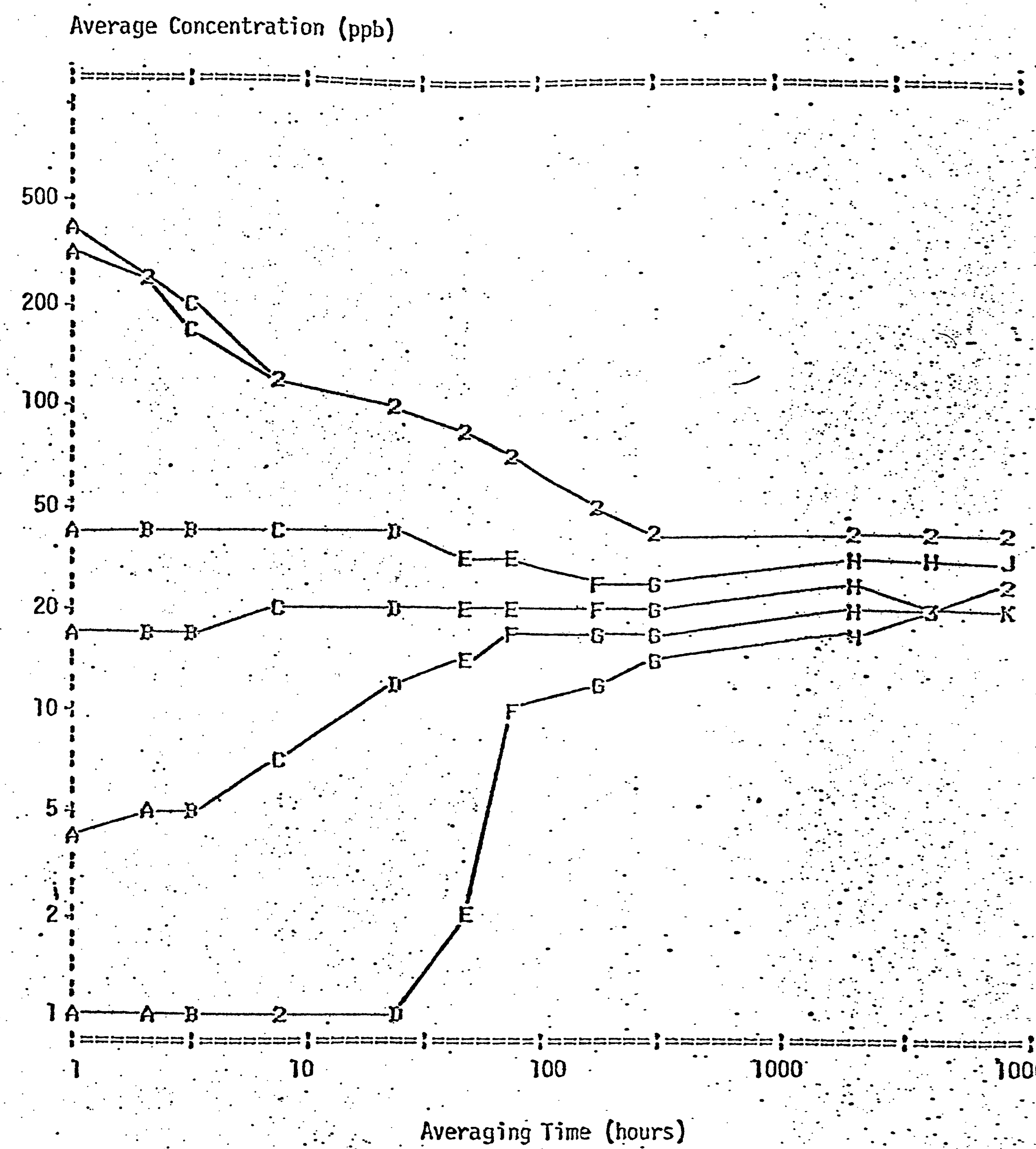


Figure 2-7 Monitor 6 Arrowhead Profile -

1975 SOx Concentrations.

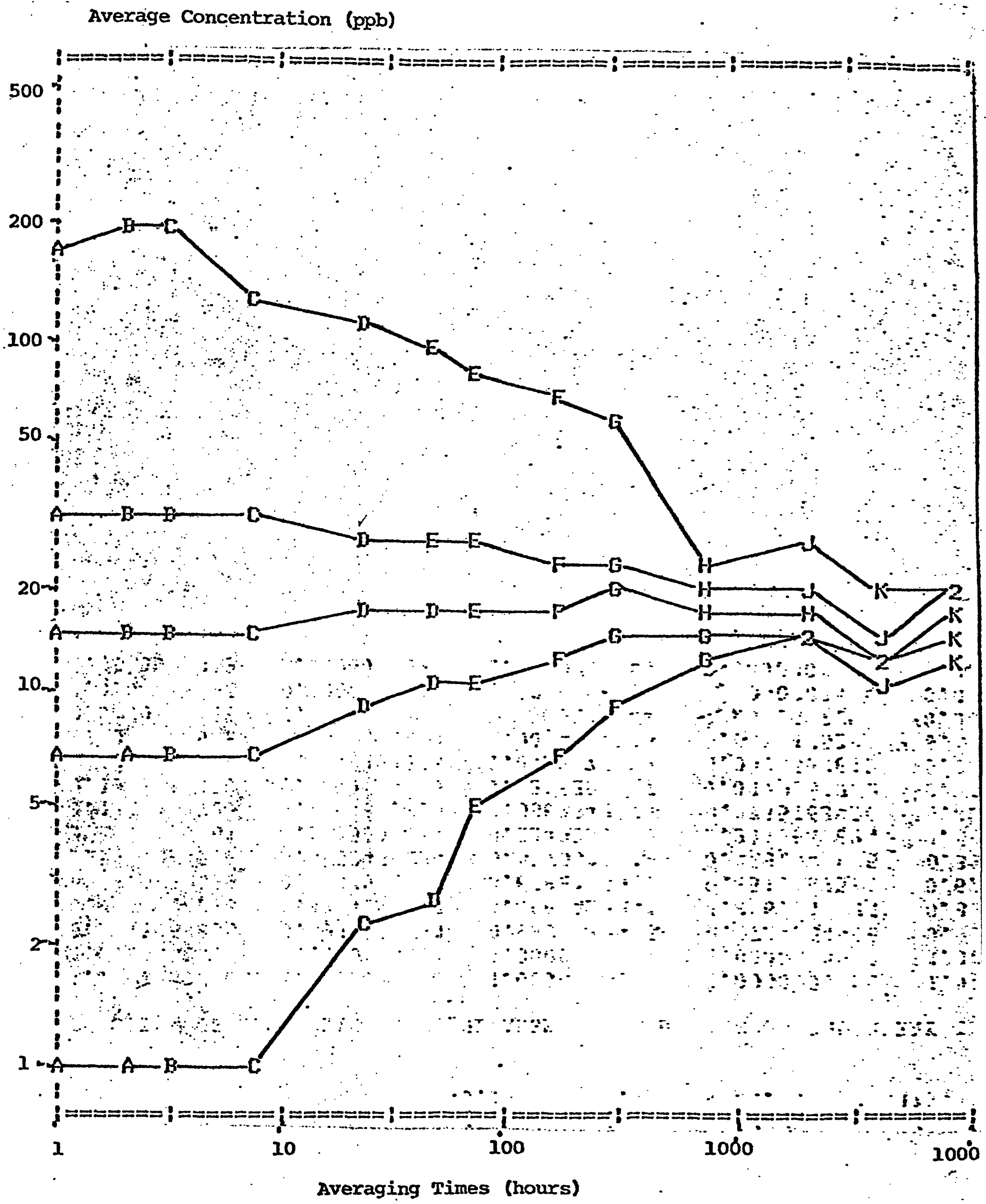


Figure 2-8 Monitor 6 Arrowhead Profile

1978 SOx Concentrations

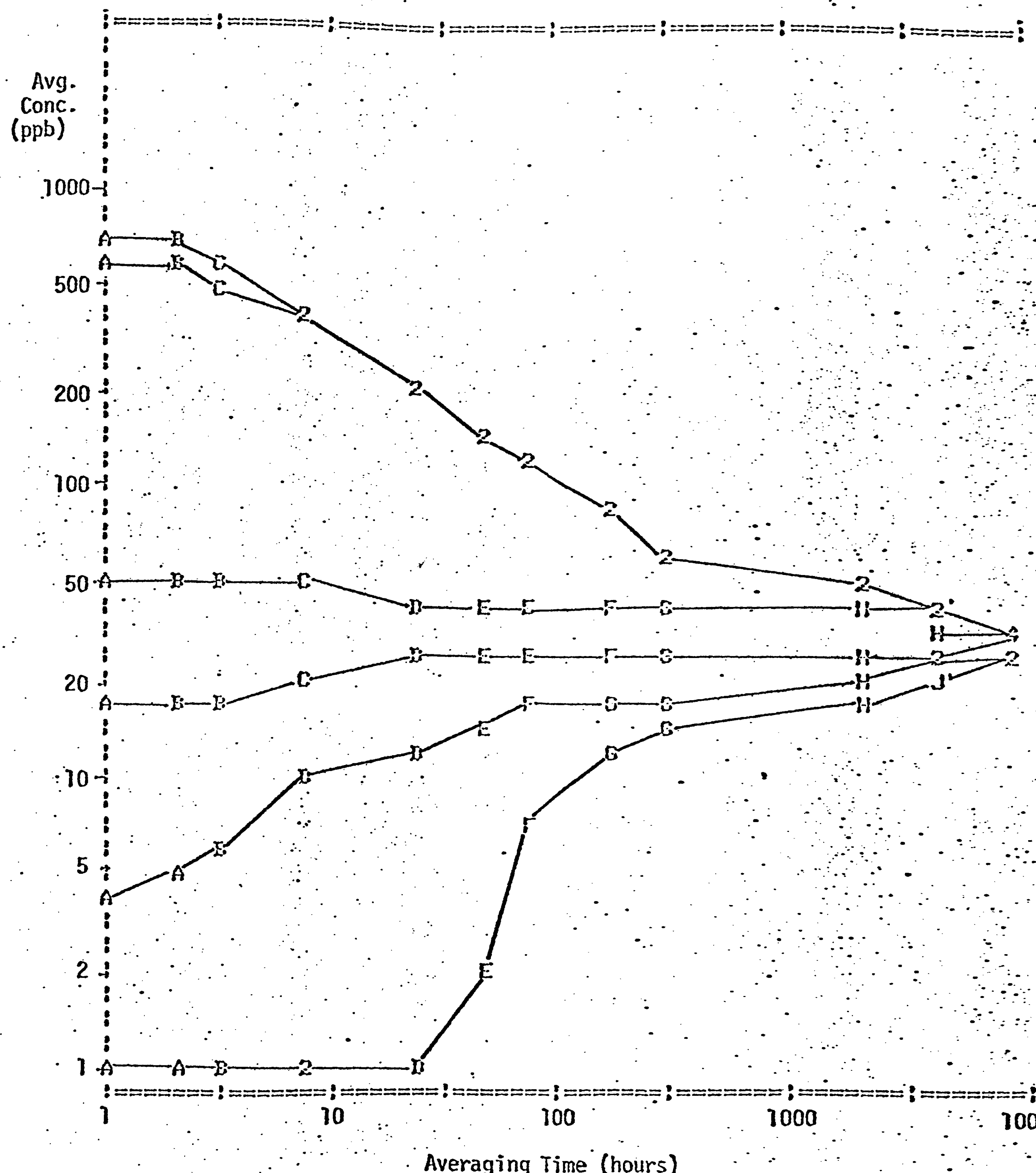


Figure 2-9 Monitor 7 Arrowhead Profile -

1975 SOx Concentrations

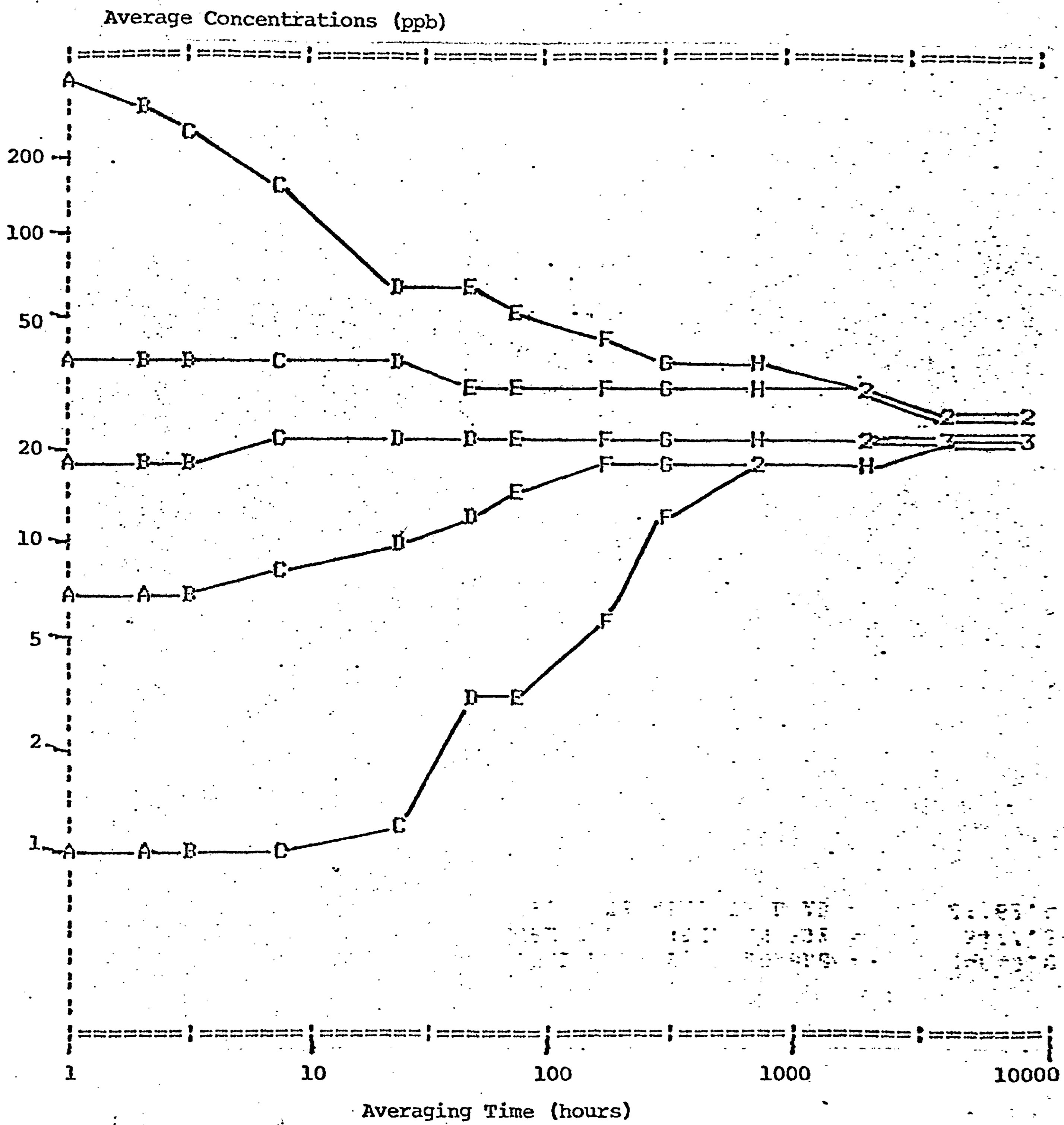


Figure 2-10 Monitor 7 Arrowhead Profile
1978 SOx Concentrations

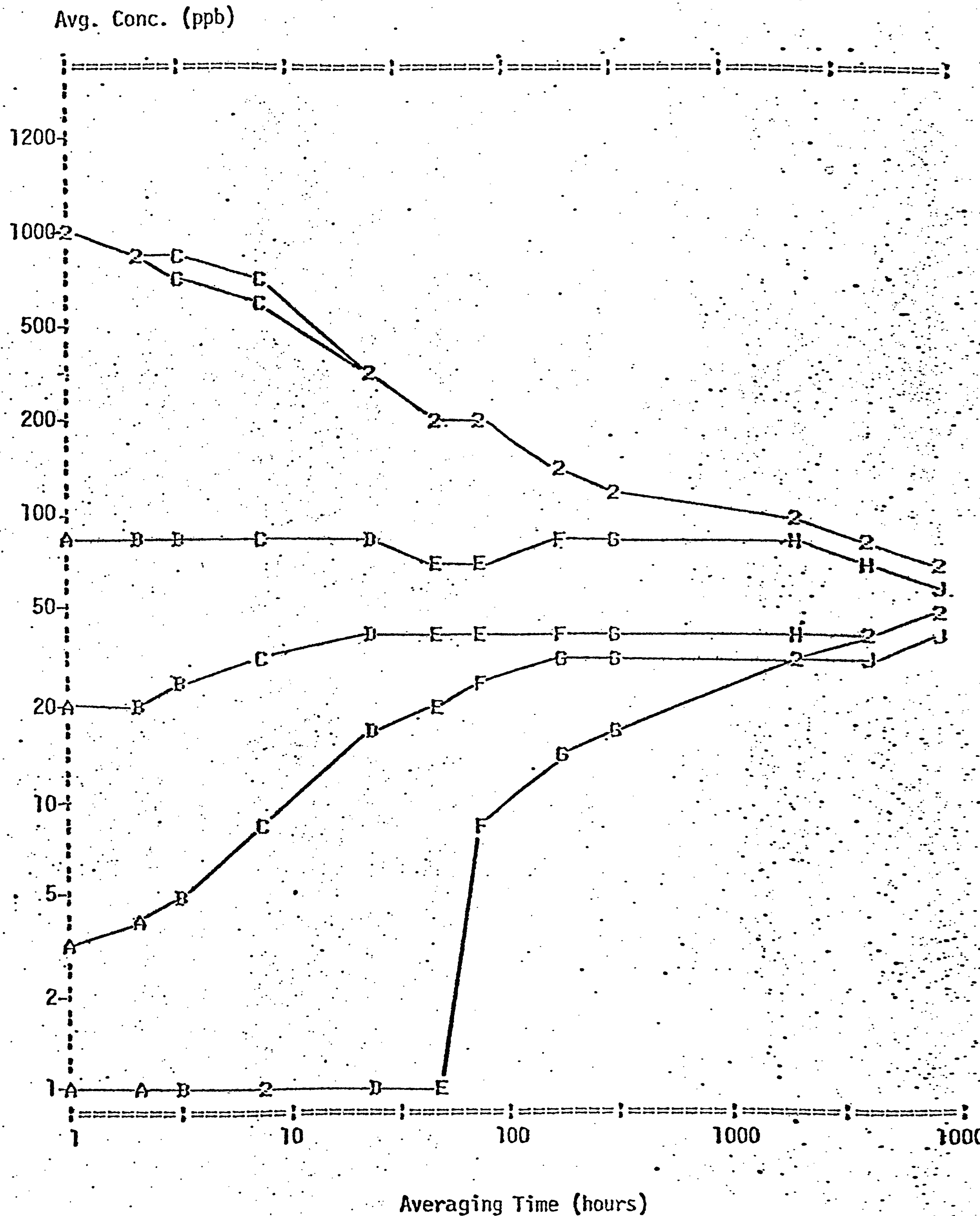


Figure 2-11 Monitor 8 Arrowhead Profile -

1975 SOx Concentrations

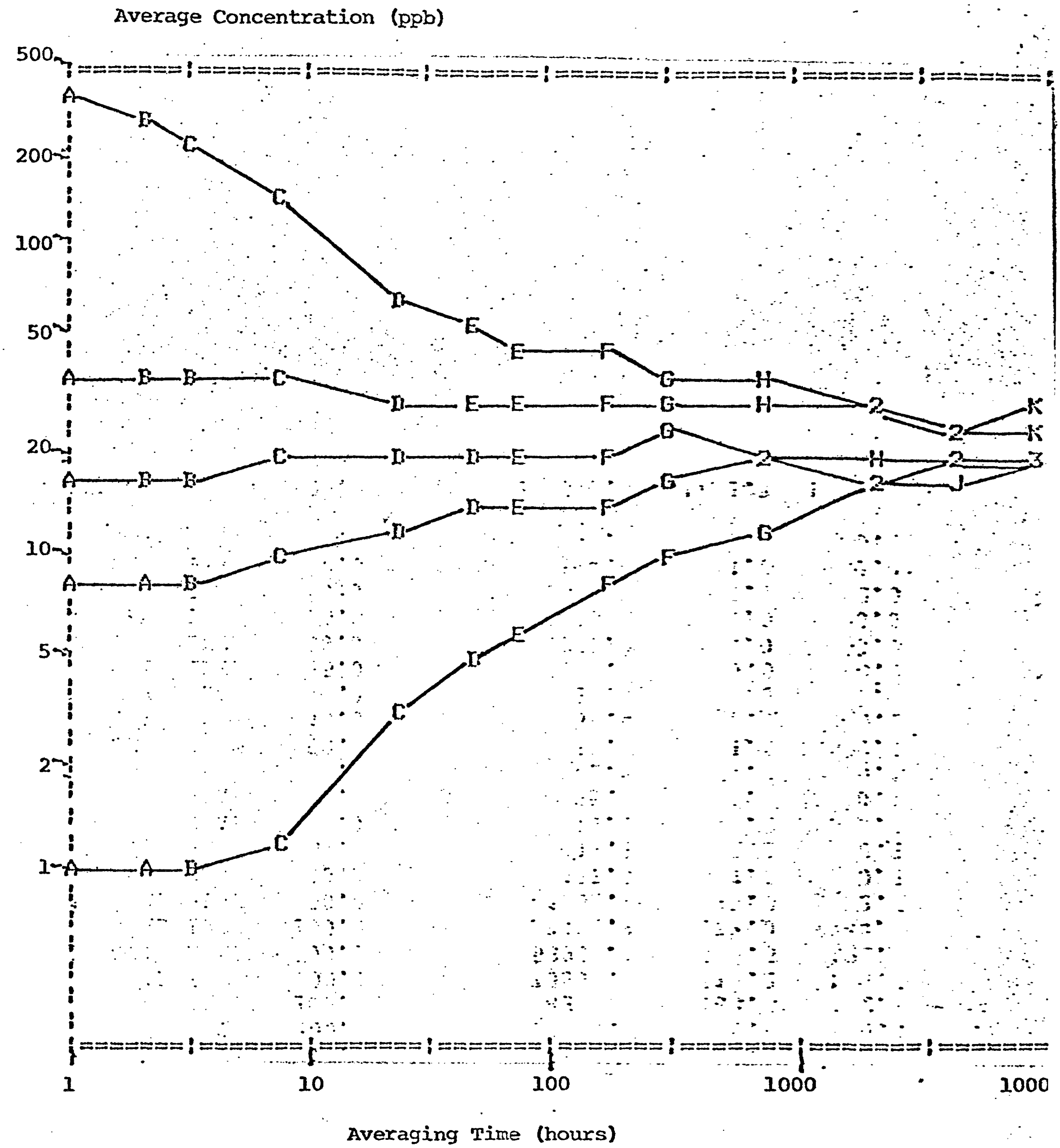


Figure 2-12 Monitor 8 Arrowhead Profile
1978 . SOx Concentrations

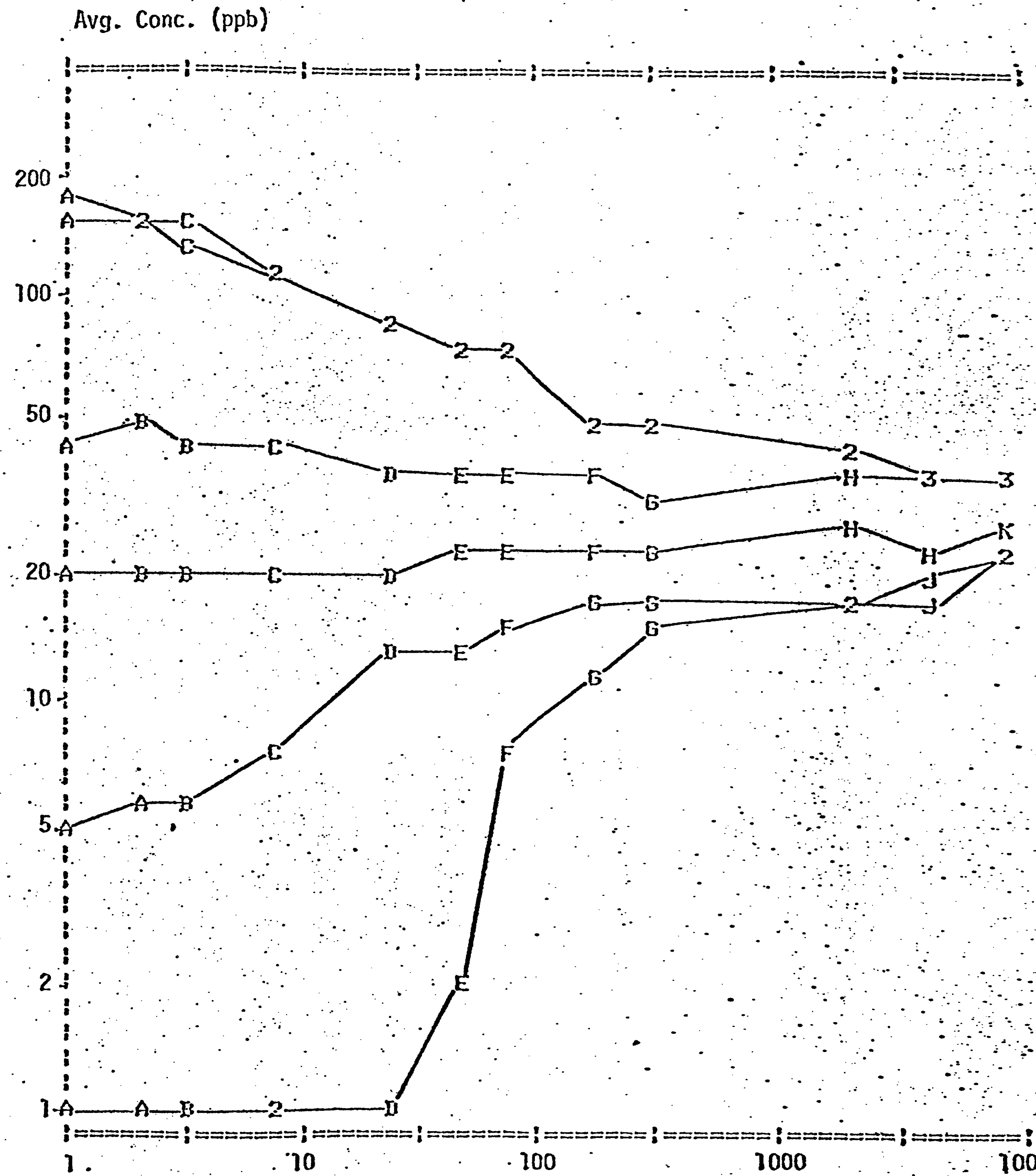


Figure 2-13 Monitor M Arrowhead Profile -

1975 SOx Concentrations

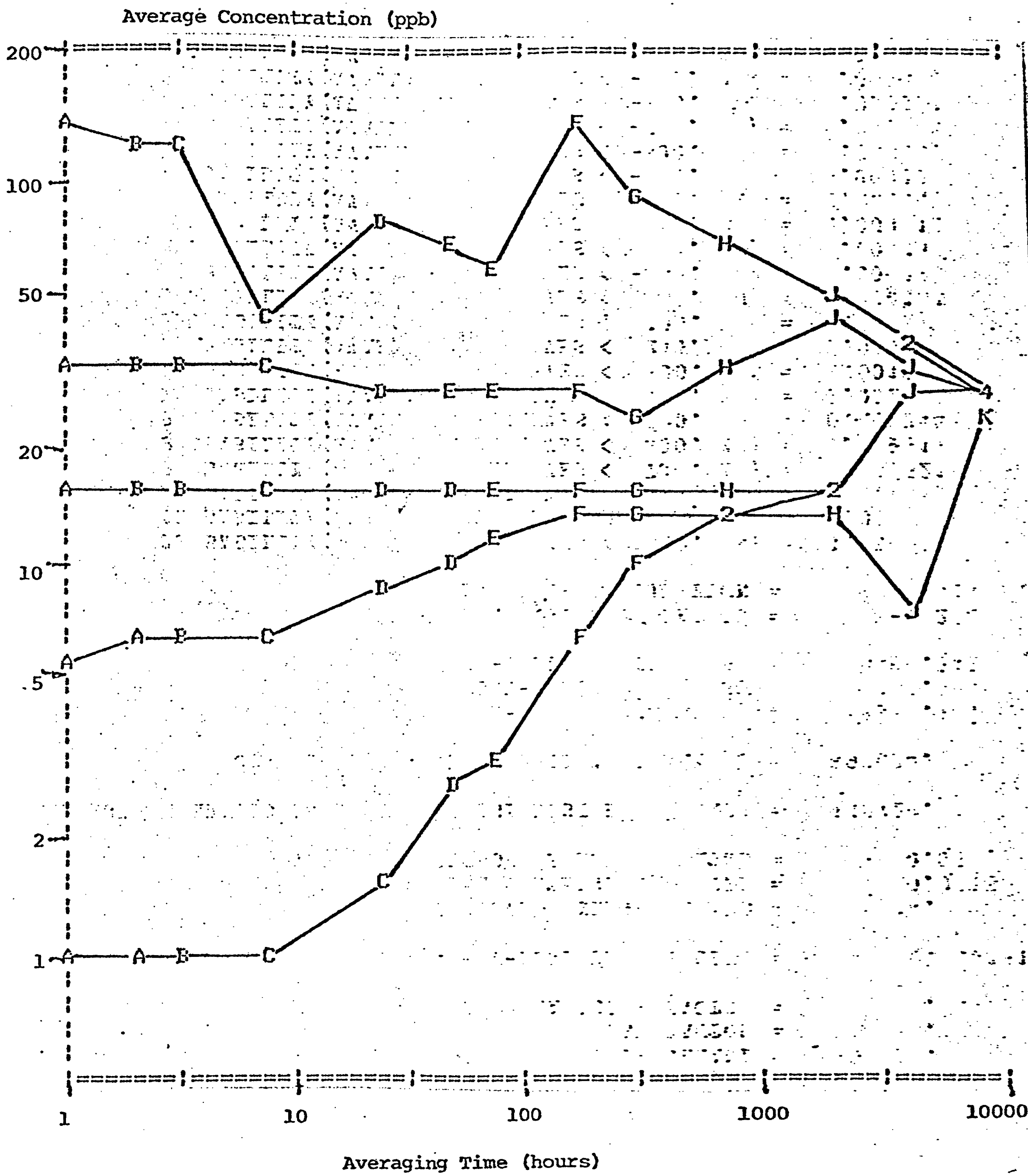


Figure 2-14 Monitor M Arrowhead Profile

1978 SOx Concentrations

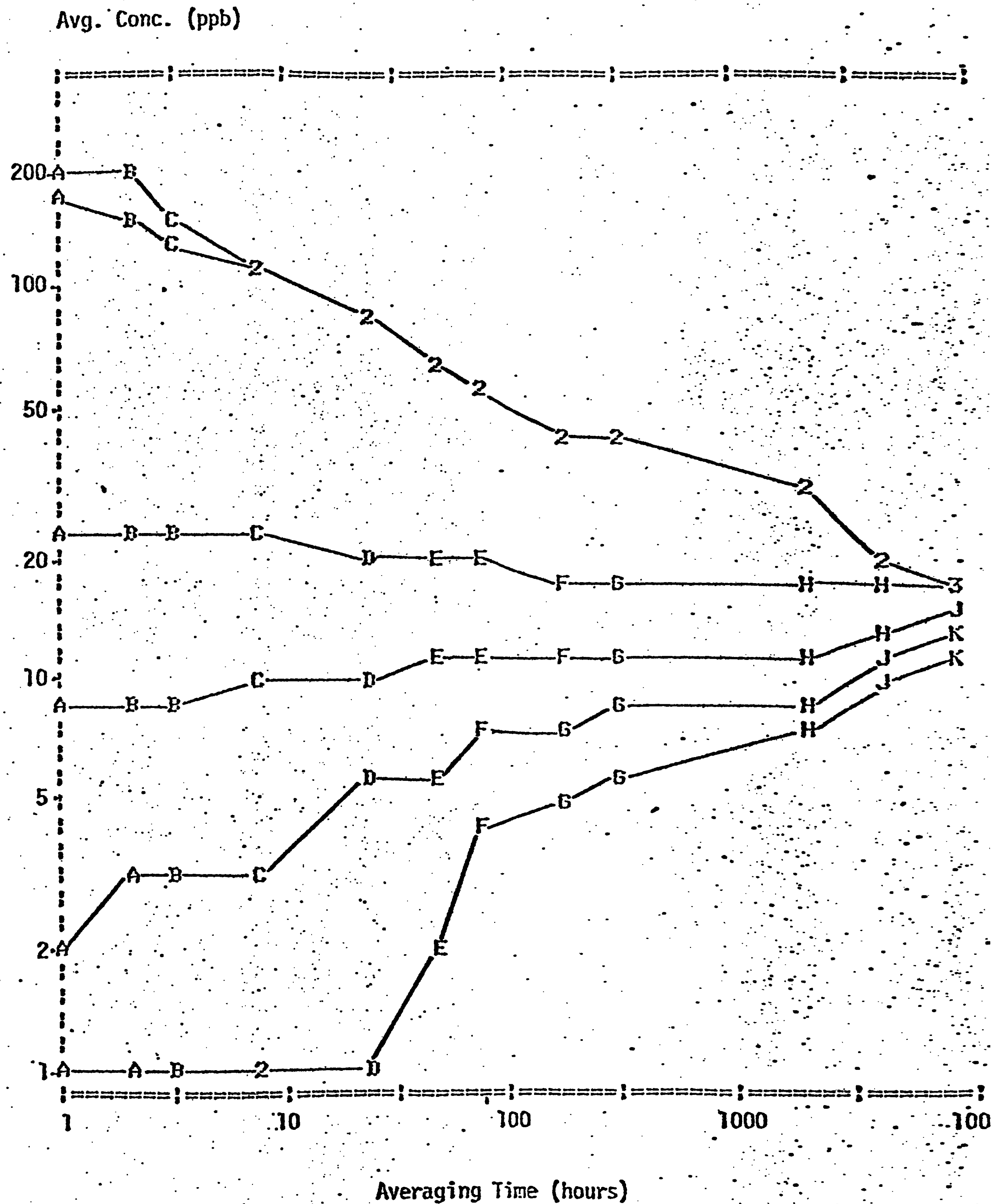


Figure 2-15 Monitor O Arrowhead Profile -

1975 SOx Concentrations

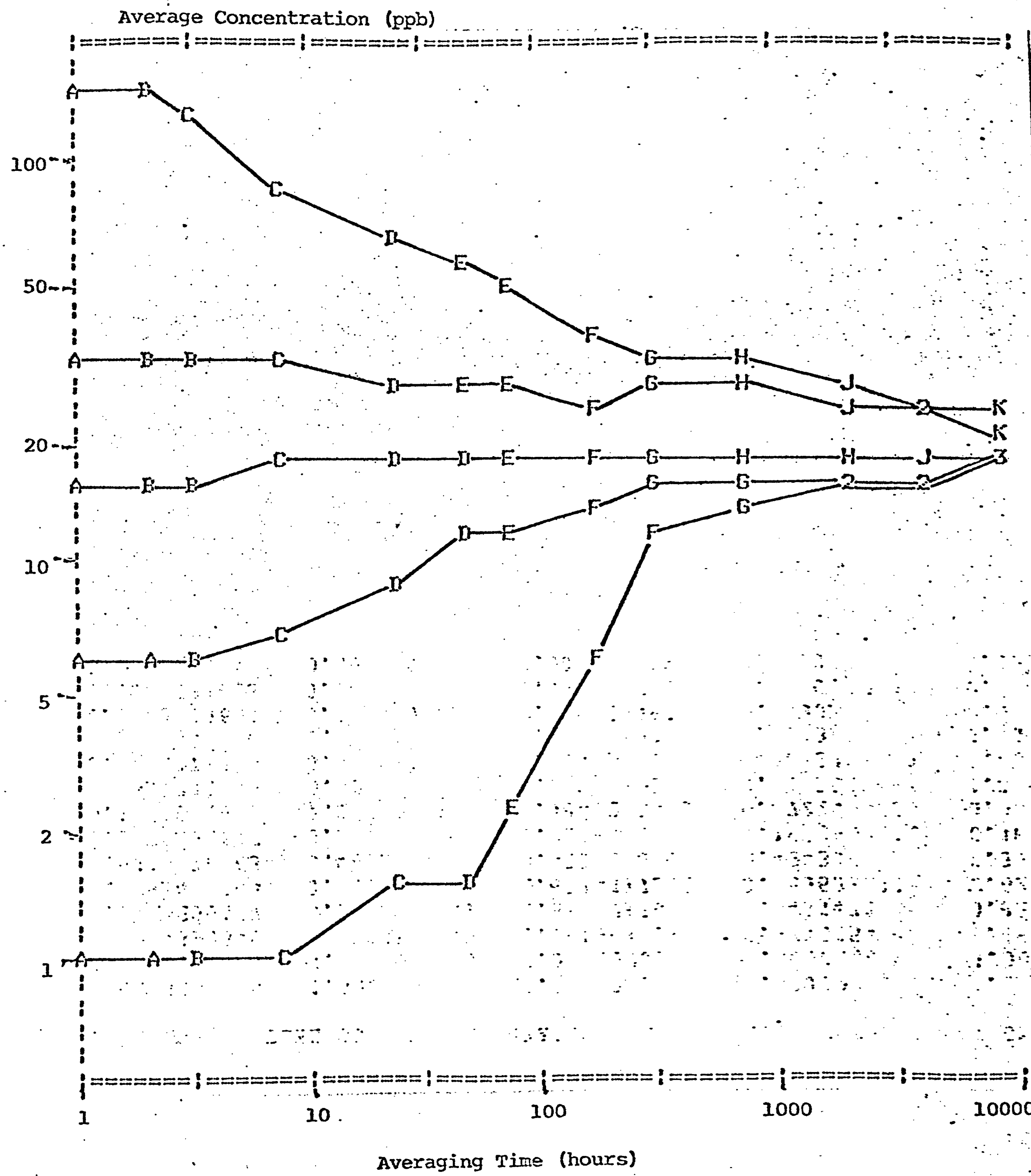


Figure 2-16 Monitor O Arrowhead Profile

1978 SOx Concentrations

2.3 Analysis of Pollutant Dispersion

The recent project report (Maher,1980) is primarily aimed at the analysis of pollution data. Thus this report will offer a few of the findings in the other document, but will concentrate mainly on newer material. The end result of this analysis is to be the annual exposure profiles for several pollutants in each of the Chestnut Ridge area. Table 2-3 shows some of these various exposure profiles that will be attempted. In addition there may be successful attempts at separating the sources into separate exposure profiles for each of the districts. This would have the natural advantage of providing an important tool for predicting exposure profiles for proposed energy facilities at new sites.

The possibility for estimating and separating exposure profiles depends upon a knowledge of the mathematics of time-collapsed representations. For example, if two time-collapsed exposure profiles are perfectly correlated in the time domain then their values can be added on a pointwise basis to determine their sum. Scalar multiples of time-collapsed representations are obviously the appropriate way to represent scalar multiples of the chronologic waveforms. The (Maher,1980) document deals more extensively with the 'arrowhead' mathematics, and hopefully this will later lead to a development of an arrowhead dispersion formula. This would make possible the development of exposure profiles directly, and more accurately, from the time-collapsed representations of mixing depth, wind speed, turbulence, and so on. Emission patterns that come in sine or square waves, such as intermediate power plants, have peculiarities to their emissions arrowhead curves, see Figures 2-17 and 2-18. Methods are being investigated for pushing these time-collapsed emissions representations, and their correlation characterization (to meteorological processes) through time-collapsed dispersion representations.

One of the key advantages of operating in time-collapsed formats, besides computational speed and ease of data handling, is the greater accuracy with which interpolations can be made between monitors. The reason for this is that even closely neighboring monitors have surprisingly uncorrelated concentrations. That is, a peak occurs at one but

Table 2-3. Different Types of Resolution That Would Be Ideal for Exposure Profile Characterization (Arrowhead Curve Type Profiles)

Averaging Times:

1 hour, 2 hours, 3 hours, 8 hours, 1 day, 2 days, 3 days, 1 week, 1 month, 3 months, 6 months, 1 year

Years:

Great detail and accuracy: 1974, 1975, 1978, 1979
Lesser detail and accuracy: 1968-1973, 1976, 1977
Coarser estimations: 1949-1967

Pollutants:

Initial effort: SO_x
Next effort: Particulates
Lesser detail: NO, NO_2, NO_3, O_3, sulfates
Estimations: CO, trace elements, hydrocarbons

Source Separation:

4 - Individual Coal-Fired Power Plants
1 - CO_2-Acceptor Gasification Plant
20 - Local Sources
6 to 10 - Background Sources

Regions

36 - Local
4 - Generic Outside Situations

Probabilistic Discretization:

Maximum - 100% lower than this level
2nd highest value over course of year
1 Deviation High - 84% lower than this level
Median - 50% lower than this level
1 Deviation Low - 16% lower than this level
Minimum - 0% lower than this level

Quality of Data:

Deterministic Estimate
One Geometric Deviation

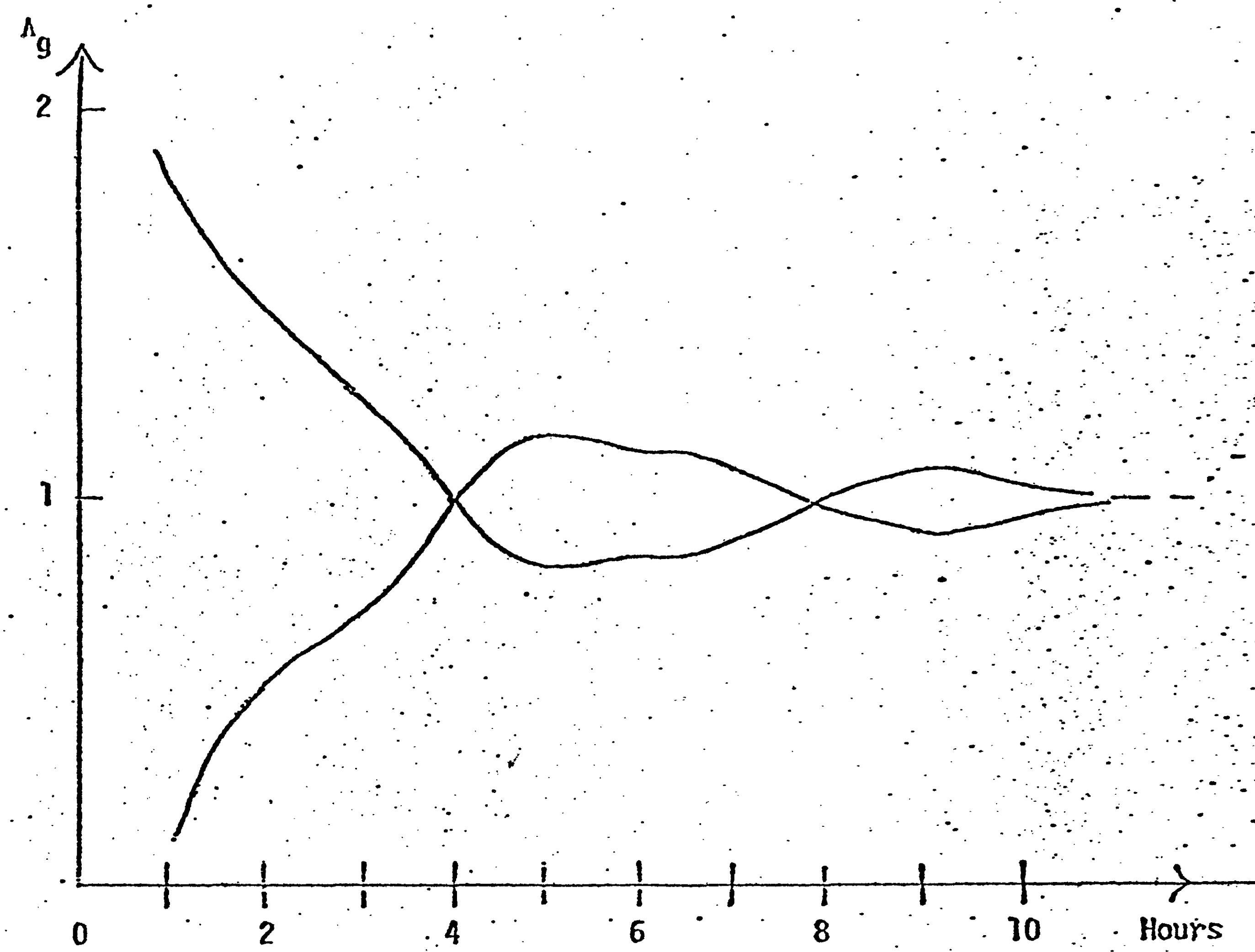


Figure 2-17 Arrowhead Envelope of a Sinusoid g(t)

$$g(t) = 1 + \sin(2\pi t/4)$$

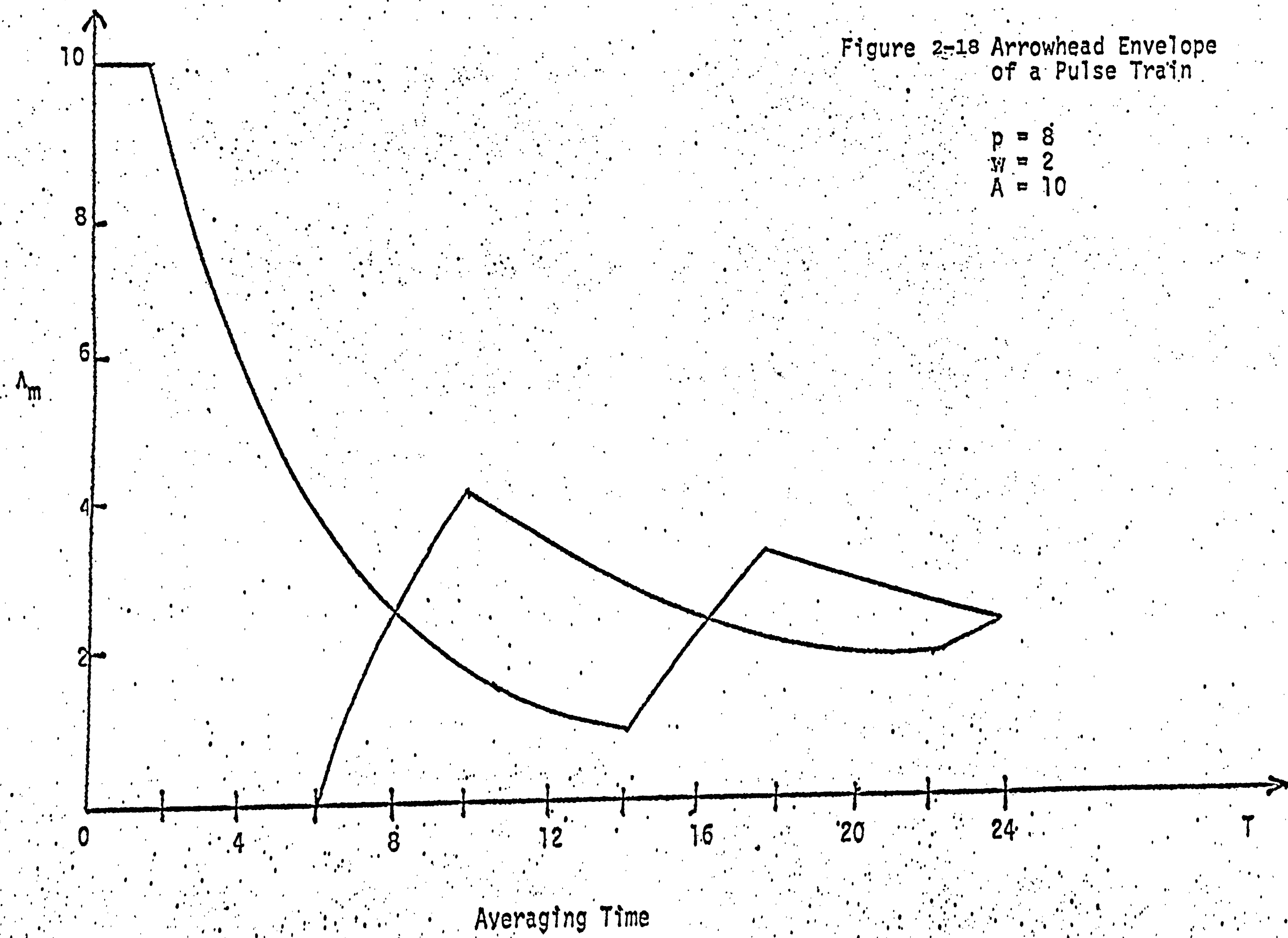
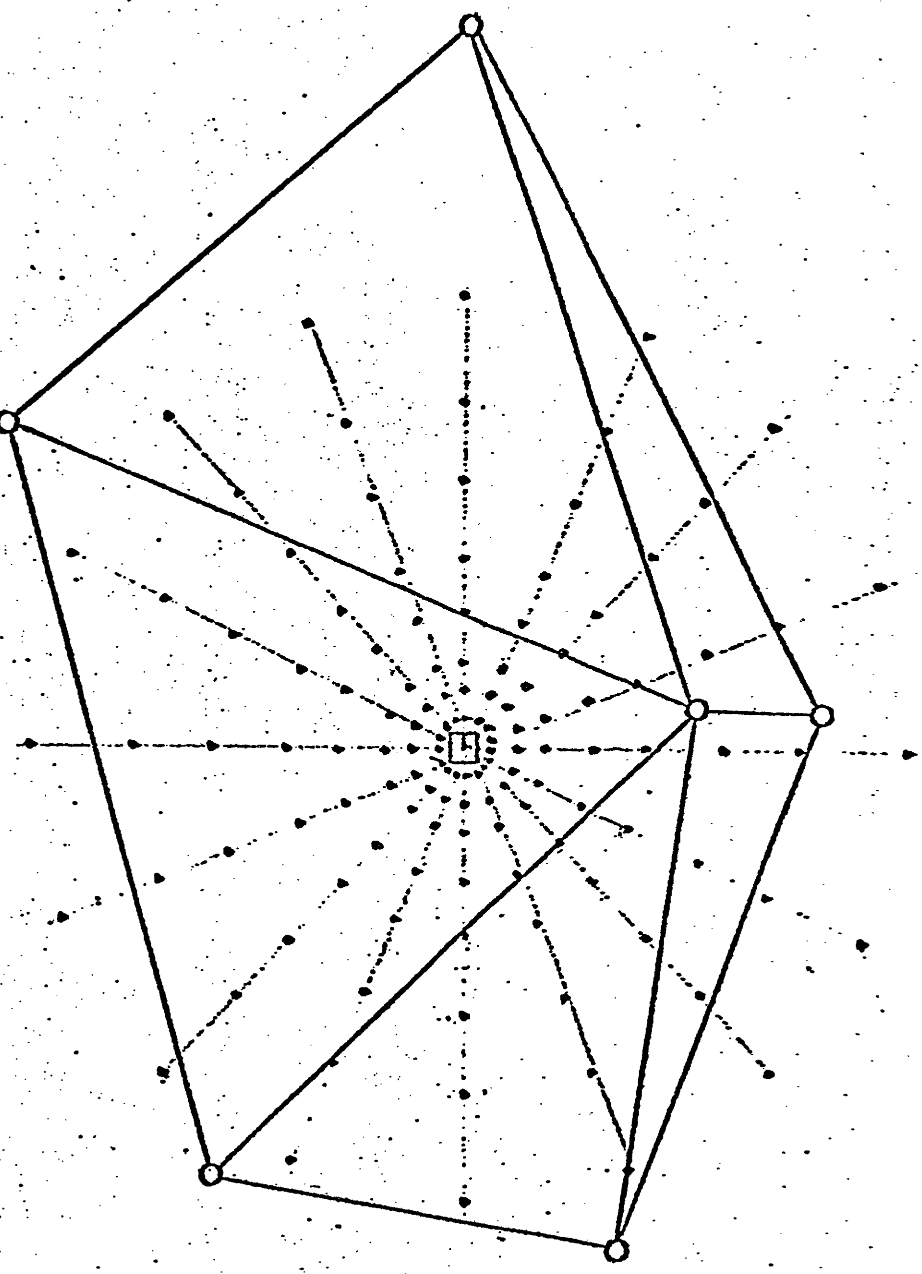


Figure 2-18 Arrowhead Envelope of a Pulse Train

not at the same time at the other monitor. Chronologic interpolators would thus grossly underestimate the peaks. On the other hand, interpolation in the time-collapsed format would tend to preserve the annual statistics displayed by neighboring monitors, which are mostly quite similar.

The interpolation schemes compared in (Maher,1980) range from chronologic, to time-collapsed linear (3 nearest monitors or 3 closest surrounding monitors), to time-collapsed nonlinear. These interpolation schemes can be useful not only for estimating past exposures in unmonitored areas, but also for estimating the exposure profiles of prospective sites for new energy facilities, see Figure 2-19. Another interesting conclusion presented in the (Maher,1980) document discusses the advantages of various resolutions in the collapsing of chronologic functions, see Table 2-4.

Given the exposure profiles for the various years, the next step in the analysis is to devise 'air scores.' These air scores can be functions of any of the points in any of the years for any of the pollutants. A first set of air scores was created in one of the monthly joint MIT-Harvard project meetings. These scores relate only to 1978 and only to SOx, and were created based upon hypotheses about persistancies and durations of concentrations that were probably important for human health, see Table 2-5. One of the consistent assumptions in epidemiological work in the past has been that human exposure can be accurately characterized by a 24-hour maximum or an annual average. If this assumption is correct then regardless of the 'air score' used the districts should not shift much in their cleanest-to-dirtiest rankings. Amazingly, as shown in Table 2-6 the rankingS vary tremendously. District 32 is one of the cleanest disticts using the 24-hour maximum, but one of the dirtiest annual averages. And district 36 is vice versa. District 1 is dirty on the annual basis, medium for mid-term and clean for short-term. District 32 is dirty for the annual, clean for the midrange and dirty for the short-term. Cleansing periods are sometimes consistent with acute levels, in terms of rankings, but they are sometimes opposite. The conclusion here is that the assumption of 'air score' will drastically affect the rank of regions. In the follow-on work we intend to carefully examine



O existing monitoring data

• district centers

[1] point source

Figure2-19 For each pollutant, background levels are available at a set of area monitors. Interpolation will probably be linear within triangles [defined as triangles with minimum closure(largest edge) that encloses or comes closest to enclosing the center to be estimated]. Extrapolation will probably be optional, among options of linear, flat, or half-linear extrapolations from nearest triangle.

Table 2-4

Running versus Sparse Uniform Averaging

1975 SOx Concentrations - Monitor A

Averaging Time (Hours)	Averaging Scheme	Averages Calculated	Maximum Value (ppb)	Percent Difference
3	243[1]	215	93	60
	Running[2]	7287	196	
8	243	206	90	31
	Running	7272	130	
24	122	100	75	6
	Running	7180	81	
168	182	152	45	6
	Running	7283	48	
730	52	47	37	5
	Running	7596	39	
8760	1	1	27	0
	Running	5327	27	

Notes

1. Sparse averaging scheme - these averages are distributed uniformly throughout the year.
2. 8760 running averages are ideally calculated.

Table 2-5 Trial Pollution Indexes for SO_x

Index	Names	Description
1	General	-Sum of 99, 84, 50, 16, and 0 percentiles for 1hr, 3hr, 8hr, 1 day, 3 day, 1 week, 1 mo, 3 mo, and 1 year
2	Short-Term Acute	-Sum of 99 and 84 percentiles for 1hr, 3hr, 8hr, 24hr,
3	Short-Term High	-Sum of 99, 84, and 50 percentiles for 1hr, 3hr, 8hr and 24hr
4	3Hr Standard	-Ratio of 99 percentile to 3hr thres hold standard
5	24Hr Standard	-Ratio of 99 percentile to 24hr threshold standard
6	Annual Standard	-Ratio of 99 percentile to 1yr threshold standard
7	Short-Term Cleansing	-Sum of 16 and 0 percentiles for 1hr, 3hr, 8hr, and 24hr averaging times
8	Long-Term Cleansing	-Sum of 16 and 0 percentiles for 3 day, 1 week, 1 mo, 3 mo averaging times

* Note in all cases 99 percentile means second highest value, as written into the threshold standards

Table 2-6 Comparison of the Rankings of Each District for the Various Different Sample Indexes (lowest ranks are cleanest)

District	Rank for Index 1	2	3	4	5	6	7	8
1	17	6	6	7	17	31	22	19
2	15	11	11	5	22	27	14	12
3	20	18	18	16	28	22	4	7
4	16	8	8	10	15	29	23	20
5	13	7	7	6	13	25	20	16
6	34	32	32	32	29	33	29	28
7	8	3	3	1	18	16	9	15
8	2	na	na	na	3	4	25	29
9	9	4	4	4	10	20	17	10
10	7	5	5	8	7	7	16	18
11	5	1	1	2	6	12	13	4
12	1	na	na	na	1	3	5	2
13	29	28	28	28	25	8	15	26
14	27	24	24	25	20	28	18	14
15	3	2	2	3	5	2	2	3
16	10	12	13	14	12	6	11	21
17	14	15	15	11	14	23	7	5
18	11	13	12	9	9	17	8	6
19	6	10	9	13	2	10	3	1
20	12	14	14	15	8	9	12	8
21	35	33	33	33	35	34	34	35
22	33	31	31	31	33	19	28	27
23	na	na	na	na	na	na	na	na
24	4	9	10	12	11	1	1	13
25	22	20	20	19	26	32	24	32
26	32	26	26	21	34	35	35	34
27	18	16	16	18	32	13	10	24
28	28	27	27	27	24	24	26	23
29	31	30	30	30	27	14	30	31
30	19	17	17	17	31	11	27	22
31	21	19	19	20	19	21	32	25
32	25	22	22	23	4	30	31	33
33	23	21	21	22	16	26	33	30
34	26	25	25	26	23	18	21	17
35	24	23	23	24	21	15	19	11
36	30	29	29	29	30	5	6	9

the types of 'air scores' that most closely correlate with 'health scores.' There is of course some danger in this selection process, given enough 'air scores' there are bound to be near perfect fits to 'health scores.' We will attempt to use data splitting and hypothesis testing techniques to avoid invalid associations.

The air scores themselves have been normalized and 7 of the 8 air scores are printed on the regional map in Figure 2-20. The interpolation scheme used here was the linear, 3 nearest monitor, technique. A comparison of these scores and rankings is underway based on the other two important interpolation techniques.

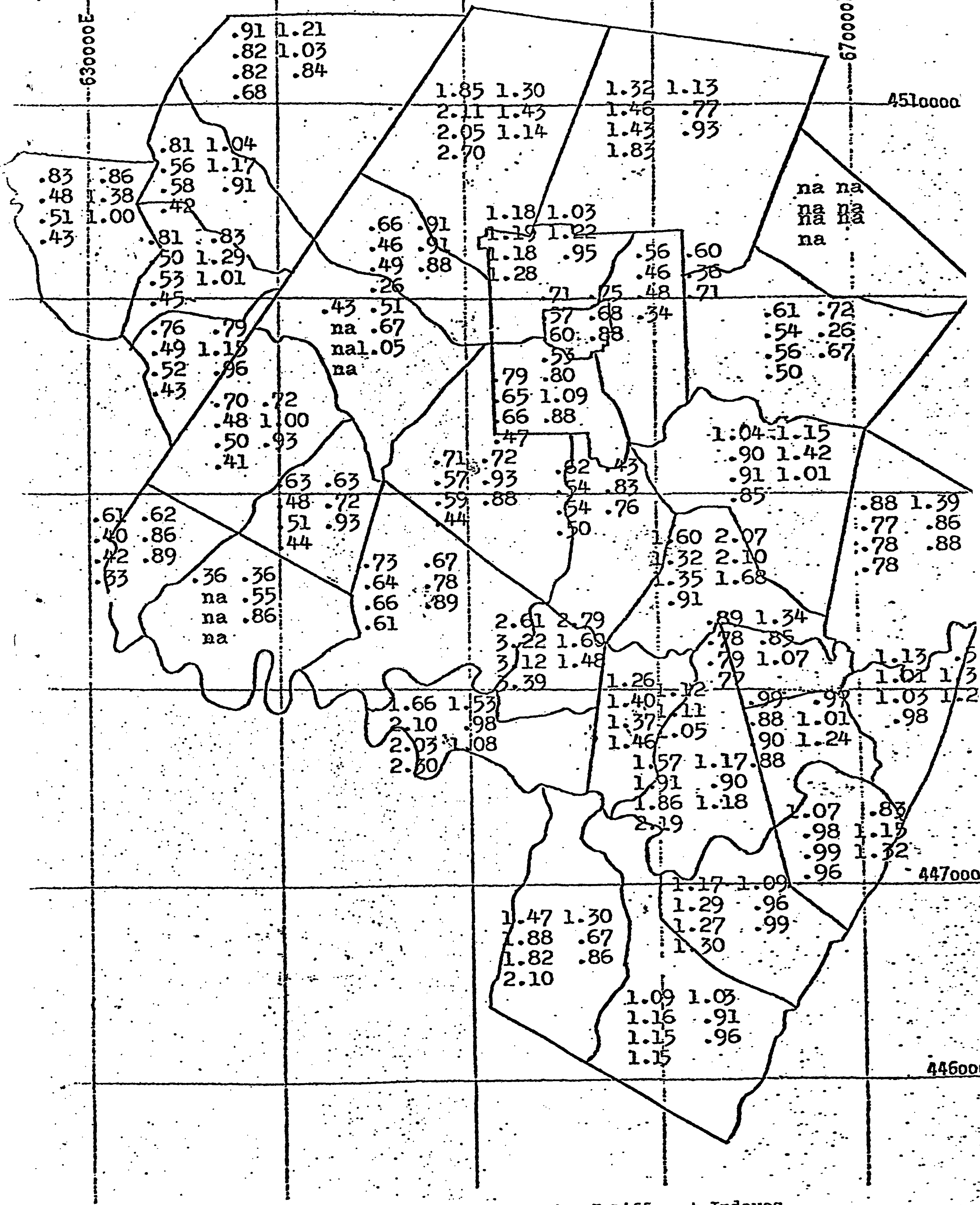


Figure 2-20 Normalized Air Scores Using 7 Different Indexes

2.4 Analyzing Air Pollution, Health Impacts and Energy Sources

As discussed in (Gruhl, et al, 1979) the 'health scores' will be held on disk at the MIT Information Processing Center. These 'health scores' will be a priori specifications of the manner in which the health data to be collected and weighted will represent a particular health effect. Associated with each 'case' there will then be a 'health score' or set of scores and a residence history. Given the formula for the 'air score', using the residence history for information about the relevant districts in the past years, an 'air score' can be developed for each individual. The TROLL statistical and graphics packages are intended for use in modeling relationships between the health and air scores. Some of the modeling has been accomplished, and in fact there are examples in (Gruhl, et al, 1979)

Additional progress has been made on the AEGIS, Alternative Electric Generation Impact Simulator. Table 2-7 shows a crude population density situation that has been set up for AEGIS. Tables 2-8 through 2-12 show performances for a hypothetical coal plant. Additional detail on the meteorologic dispersion for the Chestnut Ridge area, additional health models, and refined plant data are all on the agenda for the next six month time period.

Table 2-7

Population Density Model,

AEGIS Example

r - Radial Distance From Power Plant Site (km)	Population within r (km) of Plant Site
4	1,125
8	9,750
16	49,500
24	72,000
36	135,000
48	260,000
64	405,000
80	800,000

ASSUMPTIONS

SIZE<MWE>	1200.0
YEAR COMPL	1980.0
FUEL TYPE	MIDWEST PENN BITUM COAL
PRECL TYPE	NONE
GENERATYPE	COAL DIRECT CONV COMBUST
DES CAPAC FAC<%>	72.000
STORAGE CAP<MWH>	.0
SORBENT TYPE	NONE
ABATE TYPES:	
PART TYPE	96% ELECTROSTATIC PRECIP
SCRUB TYPE	NONE
STACK HT<M>	256.00
MET SITE TYPE	STANDARD DILUTION SCALE
AEROCHEM MODELS:	
SULFATION TYPE	NO SULFATION
SMOG TYPE	NO HC NOX OR OXID COMBIN
DENSITY PATTERN	HOMER CITY IN 1980 ESTIM
SCALED BY	1.0000
HEALTH/IMPACTS:	
CHEM HEALTH MOD	LAMM-LIN ADD MORT MODEL
RAD HEALTH MOD	NONE
POLLUTION INDEX	NONE

Table 2-8 Input assumptions for AEGIS simulation of a hypothetical 1980 conventional coal-fired power plant.

CUMULATIVE PROB MEASURES PROB VALUE < THIS VALUE	MINIMUM .0000	1 DEV LO .1587	MEDIAN .5000	1 DEV HI .8413	MAXIMUM 1.0000
ECONOMIC FACTORS					
INVEST COST<MIL $>	458.40	488.40	566.40	668.40	740.40
NORMALIZED INVEST<$1000/MWE>	382.00	407.00	472.00	557.00	617.00
OPERATING COSTS:					
FIXED OPER COST<$/MWE/YR>	65700.	70080.	81468.	96360.	.10687E+06
VARIABLE OPER COST<$/MWH>	8.4240	9.4413	10.530	12.536	14.211
OP&MAIN<$/MWH>	1.6000	1.9000	2.0000	2.3000	3.0000
FUEL<$/MWH>	6.8240	7.5413	8.5300	10.236	11.211
COST OF ELECT<MILS/KWH>	26.950	28.662	31.556	35.724	39.265
CAP COST<MILS/KWH>	11.527	12.221	14.027	16.388	18.054
OP COST<MILS/KWH>	1.6000	1.9000	2.0000	2.3000	3.0000
FUEL COST<MILS/KWH>	8.1240	8.8413	9.8300	11.536	12.511
PERFORMANCE FACTORS					
OPER CAP FAC<%>	63.000	68.000	72.000	75.000	80.000
ENERGY EFF ONSITE<%>	35.000	36.000	36.800	37.100	37.500
APPLICABILITY					
COMMERC YR<2000MWE ONLINE>	1978.0	1978.0	1978.0	1978.0	1978.0
INSTALLED CAP<MWE>	.10000E+06	.10000E+06	.10000E+06	.10000E+06	.10000E+06
LARGEST FACILITY<MWE>	1800.0	1800.0	1800.0	1800.0	1800.0
RESOURCE REQUIREMENTS					
LAND USE.ONSITE<ACRES>	180.00	252.00	324.00	420.00	612.00
LAND DISTURB FUEL<ACRES/YR>	55.093	83.531	98.247	279.77	782.13
LAND DISPOSE WASTE<ACRES/YR>	43.200	60.480	86.400	103.68	138.24
WATER CONSUMP<MIL GAL/YR>	2332.8	3110.4	3715.2	4924.8	6220.8

Table 2-9 AEGIS simulation results, showing probabilistic format and predicted parameters of the power plant.

ENVIRONMENTAL CONSEQUENCES	Min	1 Dev Lo	Med	1 Dev Hi	Max
AIR EMIS ONSITE<GM/MIN>:					
SOX	34873.	47273.	73604.	.11741E+06	.15233E+06
SULFATES	24.202	34.508	54.166	87.072	115.02
SULF ACID AEROS	1.5127	2.4264	3.8235	6.1507	8.3871
NOX	14520.	21840.	26400.	30720.	36120.
NO	14520.	21840.	26400.	30720.	36120.
O3, OXID	.40800E-03	.13200E-02	.40000E-02	.12000E-01	.40800E-01
PART TOTAL	29760.	60000.	79200.	.11232E+06	.18240E+06
PART RESPIR	6691.2	22848.	27744.	38352.	44880.
CO	3720.0	4800.0	7200.0	12000.	30000.
CO2	.25200E+07	.33600E+07	.38400E+07	.50400E+07	.96000E+07
HC TOTAL	192.00	624.00	1920.0	6240.0	14400.
INERT HC	168.00	600.00	1740.0	6120.0	14160.
REACTIVE HC	16.800	24.000	96.000	108.00	144.00
OXYG HC	1.6800	2.4000	9.6000	10.800	14.400
POLY ORG MAT	6.7200	9.6000	38.400	43.200	57.600
TRACE ELEM:					
ARSEN	4.3219	19.171	34.313	78.579	245.88
BERYL	2.1206	3.5946	5.4702	8.7646	12.815
CAD	.17576E-03	.38472E-02	.71874E-02	.12782E-01	.21607E-01
CHROM	.0	6.5901	14.706	24.556	52.074
COP	.14406	1.9171	3.7684	8.7747	25.005
LEAD	.0	5.7910	14.706	28.812	58.345
MANG	.0	10.185	25.735	39.290	58.345
MERC	.36304	.88188	.87316	1.3476	14.077
NICK	.0	7.5727	27.718	110.01	254.43
SELEN	.34575	4.1937	7.1911	15.716	41.320
TIN	.0	4.6970	18.607	45.105	62.575
VANAD	2.7660	28.457	36.764	65.483	152.81
ZINC	.57625E-01	3.4267	7.0318	22.002	87.518
RADIOACT TO AIR<CUR/YR>	.0	.61851E-01	.32681	1.3776	1.7534
WATER EMIS ONSITE<TONS/YR>	14462.	20883.	28071.	43042.	66407.
INORGANIC<TONS/YR>	10330.	15314.	21053.	35060.	55339.
ORGANIC<TONS/YR>	4132.0	5568.7	6526.4	7173.6	11060.
THERMAL<10**12 BTU/YR>	33.745	35.501	36.713	39.455	42.058
RADIOACT TO WAT<CUR/YR>	.0	.0	.0	.0	.0

Table 2-10 Predicted environmental impacts of the power plant.

ATMOS DILU FAC<UG/M3/G/MIN>	Min	1 Dev Lo	Med	1 Dev Hi	Max
GASEOUS:					
1 HOUR	.71983E-06	.20126E-05	.42379E-05	.71187E-05	.11066E-04
3 HOUR	.16403E-05	.35890E-05	.75610E-05	.12675E-04	.19733E-04
8 HOUR	.21401E-05	.46826E-05	.98648E-05	.16563E-04	.25746E-04
24 HOUR	.27417E-05	.57988E-05	.12638E-04	.21218E-04	.32783E-04
3 DAY	.34412E-05	.75274E-05	.15862E-04	.26632E-04	.41399E-04
1 MON	.45695E-05	.99780E-05	.21063E-04	.35364E-04	.54972E-04
ANNUAL	.55054E-05	.12046E-04	.25377E-04	.42607E-04	.66231E-04
PARTICULATES:					
1 HOUR	.63003E-06	.11157E-05	.23012E-05	.36437E-05	.50478E-05
3 HOUR	.11235E-05	.17897E-05	.41037E-05	.64978E-05	.70017E-05
8 HOUR	.14659E-05	.25763E-05	.53542E-05	.84777E-05	.11745E-04
24 HOUR	.19779E-05	.33261E-05	.68571E-05	.10861E-04	.15046E-04
3 DAY	.23570E-05	.41747E-05	.86072E-05	.13632E-04	.18885E-04
1 MON	.31298E-05	.55434E-05	.11432E-04	.18101E-04	.25076E-04
ANNUAL	.37709E-05	.66798E-05	.13773E-04	.21807E-04	.30212E-04

Table 2-11 Dilution factors for the air pollutants emitted by the simulated plant.

	Min	1 Dev Lo	Med	1 Dev Hi	Max
OCCUP HEALTH:					
MORT ONSITE<PER YR>	.13773E-01	.20883E-01	.42106E-01	.57309E-01	.73706E-01
MORB ONSITE<PER YR>	.72999	.83531	.98247	1.1478	1.3072
DAYS LOST ONSITE</YR>	143.24	160.10	210.53	243.90	324.66
MORT OFFSITE<PER YR>	.30301	.64040	.92633	1.1406	1.4314
MORB OFFSITE<PER YR>	5.7848	27.565	49.474	54.591	65.764
DAYS LOST OFFSITE</YR>	64.046	105.16	318.60	2660.6	6277.1
PUBLIC HEALTH<ROUTINE>:					
MORTALITIES<PER YR>	.36539E-01	.78044E-01	.14322	.32654	.60417
CANCER<TOTAL>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
CARDIOVAS	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
BRONCHOPULM	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
CNS	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MUTATIONS<TOTAL>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MORBIDITIES<PER YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
RESPIR	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
ASTHMA	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
PNEUM	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
CHRONIC	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
CHILDREN	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
THYROID	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
CARDIOVAS	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MANDAYS LOST<PER YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
PUBLIC HEALTH<OFFSITE>:					
MORTALITIES<PER YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
CANCER<TOTAL>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MUTATIONS<TOTAL>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MORBIDITIES<PER YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MANDAYS LOST<PER YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
PUBLIC HEALTH<CATAST>:					
PROB OF OCCUR<PER YR>	.68066E-07	.33412E-06	.56141E-06	.71822E-06	.11006E-05
MORTALITIES<PER YR>	.55093	1.0441	1.2632	1.5065	2.0660
CANCER<TOTAL>	.41320E-04	.41765E-04	.42106E-04	.43042E-04	.44271E-04
BRONCHOPULM	.17217E-03	.17402E-03	.17544E-03	.17734E-03	.18446E-03
CARDIOVAS	.68867E-03	.69609E-03	.70176E-03	.71736E-03	.73706E-03
MUTATIONS<TOTAL>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MORBIDITIES<PER YR>	5.5093	14.618	19.649	25.108	30.252
THYROID	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MANDAYS LOST<PER YR>	550.93	1461.8	1764.7	2510.8	3025.2
INDEXES AND COSTS:					
PUBLIC HEALTH COSTS<$/YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
BIOTA COSTS<$/YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
MAT DAMAGE COSTS<$/YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
AESTH COSTS<$/YR>	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000
SUBJECTIVE INDEXES	-1.0000	-1.0000	-1.0000	-1.0000	-1.0000

Table 2-12 Health effects of plant operation,

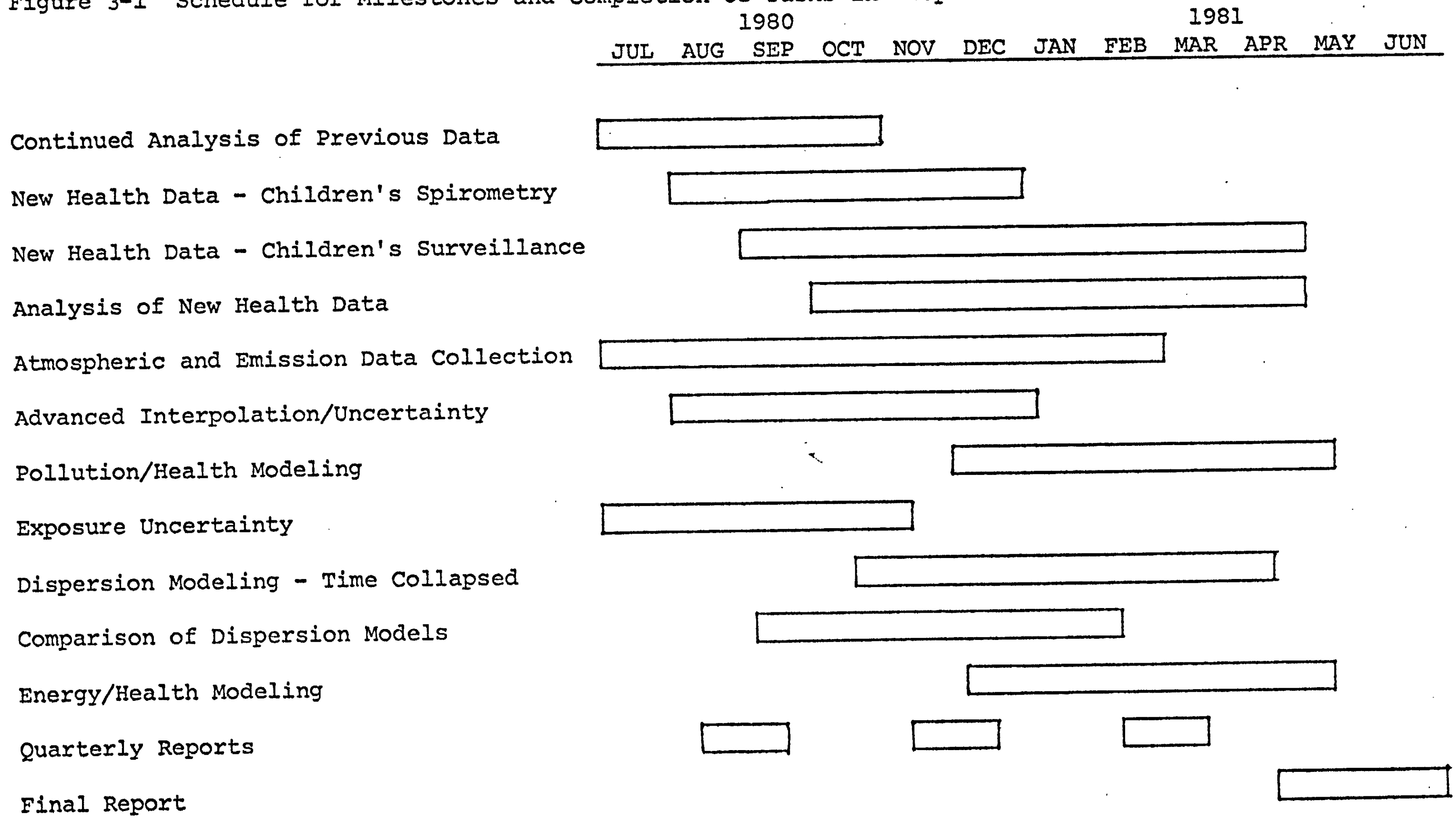
3. Schedule for Completion of Research

The tasks represented in the proposed research are listed and numbered in table 4-1. The lead institutions for each of these tasks are also mentioned, although many of the tasks will involve considerable interaction. Figure 4-1 shows the proposed time schedule and milestones for the proposed third year.

Table 3-1 Tasks for the Proposed Third Year

1.	Continued analysis of previous health data	Harvard/MIT
2.	New health data collection - Children's spirometry	Harvard
3.	New health data collection - Children's surveillance	Harvard
4.	Analysis of health data	Harvard/MIT
5.	Atmospheric and emission data collection	MIT
6.	Advanced interpolation schemes and uncertainty measures	MIT
7.	Pollution/health analysis in TROLL	Harvard/MIT
8.	Uncertainty in exposure characterization	MIT
9.	Dispersion modeling in time-collapsed format	MIT
10.	Comparison of different dispersion formulas	MIT
11.	Energy/health model assessments	MIT/Harvard

Figure 3-1 Schedule for Milestones and Completion of Tasks in Proposed Third Year



4. Plan of Approach, Tasks, and Rationale

The Chestnut Ridge region emissions sources and dispersion patterns are well characterized, and extensive monitoring equipment are available. This presents the opportunity to identify health impacts in a region where air pollution exposures of the general population are relatively well known. Dose-response relationships may become apparent and with modeling could be used to direct further health research, direct searches and choices of new technologies, and direct energy policy decisions.

The general plan for approaching this project has been to begin with a listing of the pollutant and non-pollutant health effects variables. From this list strategies have been devised for collecting the appropriate air pollution and demographic data. In addition, specific or systemic targets have been identified, and strategies devised for collecting information about these impacts. Once all of the collection of the air pollutant variables and the health and confounding variables has been completed then a search will be conducted to find particular functional combinations of pollutants that are both reasonable and validly correlated with the otherwise unexplained health impacts that have been observed.

4.1 Rationale for 3rd year Activities on Health Data.

To complete the above-mentioned studies and bring the data analyses to their full potential will require a considerable period of programming and data analysis time. We recognized further that many of these analyses will raise additional questions for which the Chestnut Ridge region may be a useful resource in which to pursue answers. However, if we were to wait until the completion of the analyses before proposing some of these questions we might miss some unique opportunities for further data collection. For example, even without knowing the outcome of the Acute Children Study, we can say categorically that it would be worth repeating the study just to be sure that whatever the results may be they are not due to a possible intercurrent "miniepidemic" of viral illness. These kinds of "epidemics" are common among children, but the chance of a similar episode occurring two years in a row is relatively small, and one would have more confidence in the results if they were consistent over 2 years.

Similarly because these children have been identified, and the pollution monitoring is on-going, additional study of those children who might be considered most susceptible (i.e. those with historically reported respiratory disease) would provide useful data.

Therefore, in spite of there being sufficient existing data already available which we believe would justify extension of the contract we are proposing additional data collection to be carried out over the next year while we continue to examine the data we have collected thus far.

4.2 New Data Acquisition

Acute Effects of Air Pollution in Children

Background: In several recent studies of acute air pollution episodes, investigators serially monitored the pulmonary function of cohorts of children. Stebbings initiated spirometry at the time of the 1975 Pittsburgh air pollution episode and found that the forced vital capacity increased on successive days as pollution levels declined (1). He interpreted these data as demonstrating a reversible effect of pollution on small airways function. A similar technique was utilized by the investigators in the six cities study in Steubenville, Ohio with similar findings (2). Children appear to be ideal candidates for such studies. They can be feasibly studied in the school setting. There is no occupational respiratory hazard and most are non-smokers. Additionally, they may be more likely than adults to have demonstrable changes in pulmonary function after pollution exposure. Because the diameter of children's small airways is less than that of adults', mucosal injury with swelling results in a proportionally greater loss of airways area in children.

We propose to conduct a study, modeled after those above, to detect acute changes in pulmonary function in children. We conducted a similar study from September through December, 1979. The data are not yet analyzed, but follow-up was over 95% complete in the 120 children tested.

Methods:

Air pollution monitoring: The on-line monitoring of air pollutants in the Chestnut Ridge region will provide notification of levels. We will initiate testing for levels exceeding Federal standard values for TSP and/or SO_2 and a meteorological pattern which predicts stagnant air.

Pulmonary function testing: Personnel trained to perform spirometry currently reside in the area. After obtaining appropriate consent, baseline spirometric testing and respiratory questionnaires will be obtained for approximately 100 children who attend a single school. The chosen school will be in the Seward-New Florence area which we anticipate will experience the highest pollution levels.

Upon notification of an alert, the field personnel will begin spirometric testing of the children at the school. The testing will be carried out during the duration of the episode and then weekly for 3 - 4 weeks. We were able to execute this technique successfully in the fall of 1979.

Additionally, we plan follow-up and testing in the home of non-attendees during the episode. While this may only be a few subjects, the recent investigation in Steubenville suggested that the pulmonary function effects in these sick children may be greater than in their healthy peers.

Analysis: If pollution affects the pulmonary function of the study children, we anticipate a decline from baseline followed by improvement. We will thus calculate the serial changes in each spirometric parameter (including FVC, $FEV_{0.75}$, FEV_1, FEV/FVC, V_{50}, V_{25}) and determine the pattern of change during the study period. The questionnaire data will be used to identify characteristics of susceptible and non-susceptible subgroups.

Children's Surveillance Study

Introduction: In the U.S., most people spend most of the day indoors. Their actual time of potential exposure to outdoor, ambient air pollutant levels is thus far less than their exposure to indoor pollutant levels. The latter are jointly determined by outdoor concentrations, rate of air turnover, and indoor sources. At this time, identified domestic pollutant sources include cigarette smoking, a source of particulates, and gas cooking stoves, a source of NO_2. Both exposures have been associated in children with small decreases in ventilatory function and increases in respiratory morbidity. (3,4) The implications for health of the patterns of interaction between indoor and outdoor pollution are currently unclear.

The purpose of this proposed study of children in the Chestnut Ridge region is to assess the relationship between several respiratory parameters and ambient air pollution in children selected from homes with differing domestic pollutant sources. Additionally, we plan to select subjects with a varying range of airways reactivity or disease: children who reported persistent wheezing or were physician diagnosed asthmatics on the 1979 questionnaire, children who reported chronic cough or phlegm production on the 1979 questionnaire, and asymptomatic children.

Methods: The cohort for this study will be selected from the 3954 children on whom completed questionnaires and spirograms were obtained in the cross-sectional classroom survey in 1979. To select children in the geographic area with the highest air pollution levels and for practical considerations in reaching subjects in their homes, only children living in the lower half of Indiana county will be considered. This will reduce the sample to approximately 2000 children. This population will be further reduced to 1700 by selection of only children 8 through 12 years old.

A preliminary frequency distribution of 1000 children surveyed in 1979 in the cross-sectional classroom survey has yielded the following frequencies. The projected number available is based on a population size of 1700.

Symptom or diagnosis	Rate	Projected number available
Persistent wheeze	6.9%	117
Asthma, M.D. diagnosed	3.1%	53
Chronic cough	7.0%	119
Chronic phlegm	5.0%	85

While these diagnostic categories are not mutually exclusive, there appears to be an adequate number of subjects for 60 children in each of two categories: 1) persistent wheeze or asthma, and 2) chronic cough or phlegm. These two categories correspond to the two major categories of adult chronic lung disease and represent subjects most probable to show increased sensitivity to air pollution. An equal number of control children matched for age, sex, area of residence and indoor pollution factors (number of smoking parents, gas cooking stoves) would also be selected.

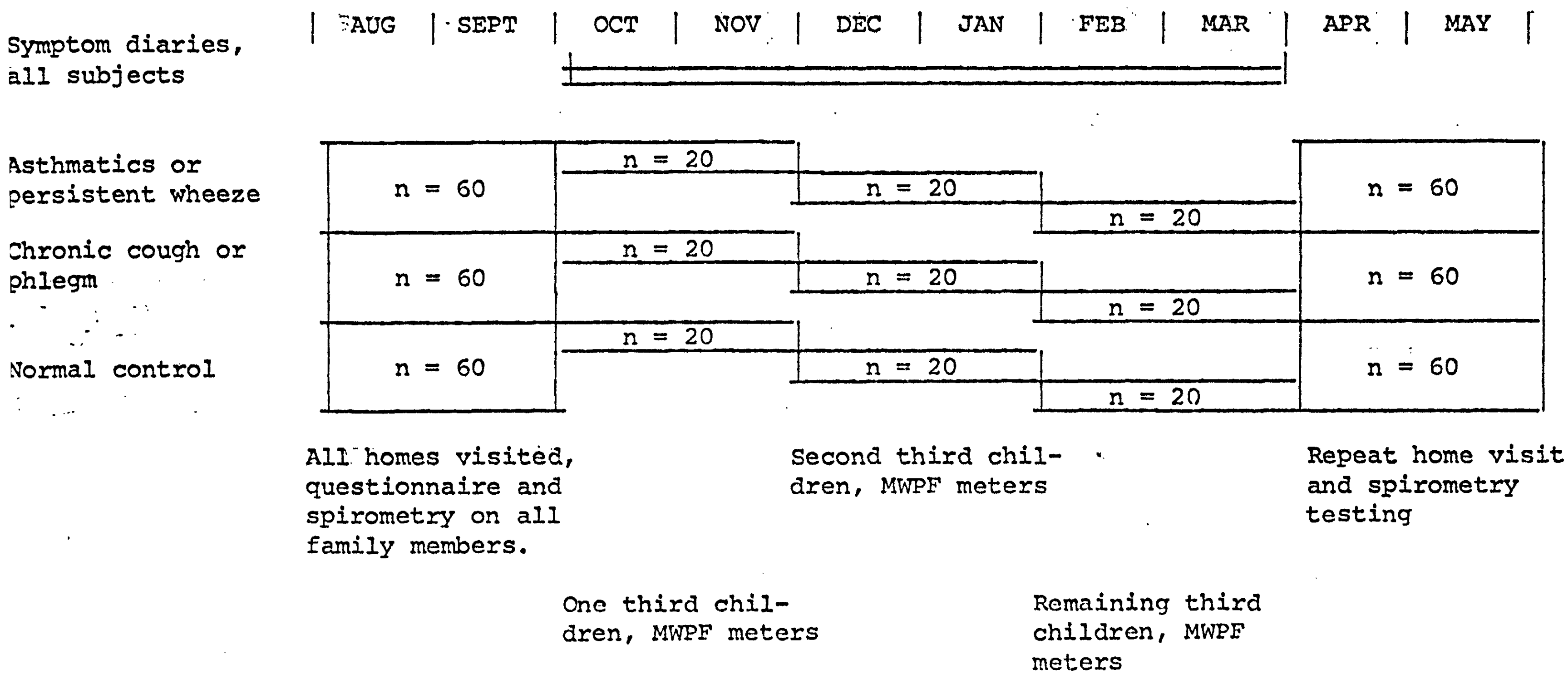
Parents of all potential subjects would be contacted in mid-summer by a letter briefly describing the proposed study. This would be followed by a telephone call requesting permission for a home visit. At the home visit, pre-mailed respiratory questionnaires will be completed and spirometry will be performed on Stead-Wells portable spirometers by all family members ages 6 through 75. The field worker will also assess relevant aspects of the indoor environment such as type of fuel used for cooking and use of wood or coal stoves for heat.

All subjects will have symptom diaries left for completion over the succeeding six months (September through February). These diaries will focus on symptoms of lower respiratory tract infection and airway obstruction. Criteria for lower respiratory tract infection will be those developed for the Tecumseh studies (5,6) and used in the East Boston children's lung studies (7). (See sample diary attached.)

In addition, one third of the families will have Mini-Wright Peak flow (MWPF) meters left to be used by the child twice-daily for a two month period. The MWPF meters will be collected (by home visit or mail) and rotated to the other two-thirds of the cohort for two months each. After the six-month period each child and family member would have repeat spirometry on a Stead-Wills portable spirometer.

At two-week intervals each of the families will be contacted by telephone to ascertain symptoms not recorded on the diaries and to determine if problems exist in using and recording results with the MWPF meters. Telephone monitoring has been found to be necessary in similar studies on children (7).

The children's surveillance study will thus have the following design:


AUG
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
Symptom diaries, all subjects
Asthmatics or persistent wheeze
Chronic cough or phlegm
Normal control
n = 60
n = 20
n = 20
n = 20
n = 60
n = 60
n = 20
n = 20
n = 20
n = 60
n = 60
n = 20
n = 20
n = 20
n = 60
All homes visited, questionnaire and spirometry on all family members.
One third children, MWPF meters
Second third children, MWPF meters
Remaining third children, MWPF meters
Repeat home visit and spirometry testing

Prior to the actual study a pilot evaluation of the use of Mini-Wright flow meters in children will be undertaken. This will consist of a comparison of measurements made at the same time on different aged children with an Mini-Wright peak flow meter, repeated on two occasions within the same week and a Stead-Wills water-filled spirometer. A pilot study would provide data on reproducibility of the Mini-Wright flow meters in different age children and appropriate instructions for the use of these meters in children. The prospective adult women's study has shown that the Mini-Wrights are able to withstand daily repeated measurements in the home. Published studies have been done demonstrationg their accuracy in the range of peak flows that will be seen in children over the age of eight (8).

Analysis:

The analyses will focus on demonstrating correlation between changes in peak expiratory flow rates (PEFR) and pollutant levels. Because the pollutant data are time-series observations, the successive observations may be correlated (auto-correlation) and time series techniques, rather than standard statistical methods, may be needed. The initial step in the data analysis will thus be an assessment of the extent of autocorrelation in the pollution measurements. Subsequent analyses will be determined by the results.

If serious auto-correlation is absent, standard techniques of correlation will be used. For each day, we will have 6 measurements each for 60 children. One approach is to calculate the individual correlation coefficients and combine them utilizing the Fisher Z statistic. An alternative is to calculate the interclass correlation of pollutant with PEFT measurements (as with familial data). Procedures are available for significance testing (9).

If the pollution data demonstrate auto-correlation, we will choose appropriate time series techniques with assistance from our statistician.

4.3 Air Pollution Data Collection

The principal task in the area of further air pollution data collection would be the continued compilation of the several air pollutant concentrations that are available from the various monitors. These efforts would be primarily aimed at the completion of the 1979 data base and the collection of 1980 and 1981 data. In addition there would be short term tasks involving the collection of real-time pollutant information, in direct support of the specific health data collection projects.

Previous research on this contract has shown the possible potential of schemes for the use of time-collapsed data, such as arrowhead curves for meteorological data, in air pollutant dispersion formulas. There would be additional data collection requirements to support this modeling task, namely the assemblage of chronological and time-collapsed characterizations of:

(1) air pollutant concentrations,
(2) wind speeds,
(3) wind directions,
(4) mixing depths,
(5) stability classes,
(6) local pollutant emissions, and
(7) background pollutant levels.

Enough of this data would be collected to provide sets of data for empirical calibration of the dispersion models and sets of data for validation.

4.4 Analysis of Pollutant Dispersion

The principal analysis tasks proposed for the continuation of this project would be the time-collapsing of the new pollutant data and the interpolation between the 17 monitors so as to provide continued pollutant profiles for each of the 36 districts. In addition, several interesting data-splitting validation efforts were operated on the interpolation schemes in the previous contract work and it would be well worthwhile to continue these tasks so as to be able to quantitatively reflect the degree of validity of the more recent pollutant exposure profile characterizations. These validation efforts involve prediction of an exposure profile that has been set aside for validation purposes. Past validation exercises have shown that chronological interpolation schemes tend to be too conservative, with direct interpolation of profiles being superior. There is still room for analytic improvement of these interpolation schemes, and perhaps some new insights will come from the following task.

Previous research on this contract has suggested that there may well be an analytic foundation for simulating time-collapsed air pollutant concentrations using time-collapsed input data and time-collapsed analogues to the air pollutant dispersion formulas. The key to the solution of this problem lies in as yet undiscovered techniques for the characterization of the correlations of the various input time series. It is essential to know, for example, whether or not certain stability classes are correlated with wind directions. It seems beyond hope to expect enough randomness between these input data to allow for general uncorrelated assumptions, thus correlation characterization and measurement would be required. Time-collapsing the wind dir. data presents some unique problems. It might be possible to collect all other input data in arrowhead curves for just those times that are in each of the 16 wind directions. This, however, would necessitate 16 times the number of time-collapsed inputs, and would additionally raise the need for a peculiar type of data format that does not currently exist in any pollution data bases. It would thus appear that a more direct analytic approach to the characterization of wind directions should be sought.

Another analytic exercise that would be included in the proposed third year would be the characterization of uncertainty in the time-collapsed concentration profiles. An obvious format for characterization of uncertainty would involve the estimation and collection of a separate arrowhead curve of deviations. It would be desirable to seek a more analytically usable and accurate characterization of uncertainty.

Uncertainty measures could be developed to reflect the errors involved in the interpolation schemes used and to reflect the errors in the measurement or estimation of the input data. Another source of error in this modeling process is in the dispersion modeling itself. It would be desirable to make comparisons of several chronologic and time-collapsed dispersion formulas to gather estimates of the uncertainties associated with their use. Such uncertainties could then be appropriately introduced into the other uncertainties associated with the use of the exposure profiles.

4.5 Air Pollutant, Health Impact, and Energy Model Studies

There are two tasks that would be included in this section of the proposed project continuation, and they are identical to the tasks that are currently conducted in this category of research:

(1) air pollution and health impact data would be collected in a statistical and graphics program so as to facilitate the hypothesis testing and validation procedures associated with the pollutant/health modeling, and

(2) site-specific facility simulation would continue to be supported and updated as a result of the proposed project continuation.

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