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ENVIRONMENTAL STUDY METEOROLOGY

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ENVIRONMENTAL STUDY METEOROLOGY

INTRODUCTION

PURPOSE OF REPORT

The purpose of this report is to present the available data and the analysis thereof in regard to diffusion climatology for the vicinity of the proposed nuclear power station (Midland, Midland County, Michigan). A detailed investigation has been made of existing weather data from Saginaw Airport (Tri-City) and data from the Dow Chemical Plant at Midland, Michigan, which is adjacent to the proposed nuclear site. These data are used in estimating radiation dosage in normal or abnormal plant operation. Wind load design criteria are also developed.

ORGANIZATION OF THE INVESTIGATION

The basic aim in this investigation has been to acquire the relevant meteorology data, to assemble this data into suitable analytical form, and then to interpret it as it applies to the safety analysis of the nuclear power station.

SCOPE

The scope of this meteorological investigation includes the following:

- A description of general weather conditions.
- Analysis of diffusion climatology based on available data.
- The development of the following diffusion models:
    1. The two-hour model.
    2. The one-day model.
    3. The 30-day model.
    4. The annual model.
- Discussion of storms and tornadoes.
- Discussion of design winds.
- Conclusions and recommendations.

SUMMARY AND CONCLUSIONS

The meteorology and the diffusion climatology of the Midland site have been evaluated to provide a basis for estimating the effects of release of waste gas, estimates of exposure from a postulated accident, and design criteria for storm protection.

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The Midland site is on the flat land of the Lower Peninsula of Michigan. It lies too far from Lake Huron and Saginaw Bay to be affected by land-sea breezes, but close enough to the Great Lakes to have a higher than average amount of cloudiness in the late fall and early winter. About 30 inches of precipitation fall per year. Some of this comes from an average annual snowfall of 33 inches. Mean monthly temperatures range from 25 F in January and February to 72 F in July. The highest and lowest recorded temperatures are 106 F and -30 F, respectively.

TWO-HOUR MODEL

From five years of monthly wind data at Midland, nine months were identified as having the greatest air pollution potential. Hourly data from the Tri-City (Saginaw) Airport for these nine months were placed into Pasquill stability categories using Turner's method. The Dow data were not amenable to this method of treatment. Each night of these nine months was examined to find the two consecutive hours having the highest stability category (poorest diffusion). From these data, the probability of the first and second hour being stability Categories D, E or F was calculated. The average winds associated with each category were used to calculate relative concentrations, X/Q, as a function of distance. The relative concentration for each category was then weighted by its probability of occurrence and divided by a dilution factor of 4.2, due to the effect of the building, to give an average hourly X/Q of 1.9×10^{-4} s/m^3 at the exclusion boundary (500 m).

TWENTY-FOUR-HOUR MODEL

From the nine months identified as described above, 18 days were selected from which to develop the 24-hour model. Selection was based on those having the highest frequency of Pasquill Category F and the highest frequency of calms. Pasquill categories and winds for these days were averaged for each direction. That direction with the highest stability category (lowest diffusion) and the lowest wind speed was chosen. The X/Q for that wind direction was calculated, multiplied by the ratio of the average number of hours of continuous wind in one direction, from the 18-day sample, to 24 hours (7.5/24) and divided by the dilution factor of 4.2 at the exclusion boundary of 500 m to give an average hourly X/Q of 3.1×10^{-5} s/m^3.

THIRTY-DAY MODEL

The nine months of data were used to obtain an average stability category and wind speed for each direction; this is similar to the 24-hour model. That direction with the highest stability category and the lowest wind speed was chosen to calculate relative concentration. From five years of monthly wind data at Saginaw, the highest monthly frequency of any one wind direction was 19 percent. Thus, the calculated relative concentration was multiplied by 0.19 and divided by a dilution factor of 2.6 (for stability Category D) at the exclusion boundary (500 m) to give an average hourly X/Q of 1.1×10^{-5} s/m^3.

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The diffusion models are soundly based on data from Tri-City Airport located only eight miles away and data from Dow just across the Tittabawassee River. The models are conservative in that (a) no credit is taken for wind direction changes (in the two-hour model), (b) the 40 percent more dilution due to the Dow buildings, or (c) for the thermally induced turbulence due to about 1-1/3 square miles of hot water around the reactor site.

These data and models are believed to provide a sound basis for the design of the reactor facility.

SITE LOCATION AND CLIMATOLOGY DATA SOURCES

SITE LOCATION - DESCRIPTION

The site of the proposed nuclear power station is immediately south of the City of Midland, Michigan. The actual location lies south of the Tittabawassee River such that Dow separates the site from the residential parts of Midland. At the present time, the site is outside the boundaries of the City of Midland.

Midland is located in the east central part of lower Michigan, about 15 miles from Saginaw Bay. Figures 2A-1 and 2A-2 show the location of Midland within the State of Michigan and the location of the site in relation to the City of Midland, respectively.

The topography of the site is comparatively flat with elevations ranging from 600 to 634 feet above mean sea level. It is estimated that there are no changes in the topography greater than 50 feet within 50 miles. Thus, topographically induced or altered winds should not be important at this site.

The site is covered by grain types of vegetation and occasional groups of trees on the order of 50 feet high. Due to the poor drainage in the site vicinity, the grasses tend toward a type that can survive in saturated soils.

The nuclear power plant itself is to be surrounded by a large water cooling pond. In a relative sense, this pond will be warm compared to the surrounding countryside. Its extent is shown on Figure 2A-3. In some directions the pond edge is very close to the site boundary.

METEOROLOGICAL DATA SOURCES IN SITE VICINITY

Two main sources of data are used in this report. The Dow Plant nearby has recorded weather records for over ten years. The other source of data is the Saginaw (Tri-City) Airport, about eight miles southeast of the site (see Figure 2A-2).

In addition, some upper air data are used from Flint, Michigan, which is about 50 miles southeast of Midland.

There are two types of weather data at Dow. In 1925, the local Weather Bureau station recording precipitation and temperature for Midland was moved to Dow. Currently, a weighing rain gauge with a seven-day recorder, a seven-day thermograph, maximum and minimum thermometer, a U.S. Weather Bureau rain gauge of the dipstick type and a seven-day dew-point recorder are on the Dow property. This station is within the plant complex and is located on Figure 2A-3. The station is bordered from the west through north to east by a chemical manufacturing complex. To the south, it is bounded by waste control operations. A laboratory complex is located to the west-southwest at a distance of about 600 feet. The closest building (approximately 22 feet high) is located directly east at a distance of about 60 feet.

In the past ten years Dow has maintained two Bendix-Friez Aerovane wind systems. The locations are shown on Figure 2A-3. The instruments are the three-bladed propeller type with a starting speed of 2 to 3 mph. Continuous strip chart recorders are utilized with each instrument. One instrument is located on a 60-foot mast (telephone pole) alongside Building 417 within the plant complex. Building 417 is a flat roofed building about 15 feet high immediately east of the mast. About 50 feet south of the mast is a long building lying in the east-west direction about 30 feet high. There are less restrictions to the north and west. The general location is indicated on Figure 2A-3.

The other wind system is on the top of a 30-foot "TV" type triangular steel mast on the top of Building 47. This building is a large three-story building on the northwest edge of the Dow complex. Thus, total height aboveground is about 60 feet. The instrument is on the western edge of the flat roof. There would be little obstruction to airflow from the west. From the east, and particularly the southeast, other plant buildings, although none higher than Building 47, might have influence on the airflow.

Weather records began in Saginaw in 1896, the same starting date as Midland, and since 1947 have been taken by FAA personnel at the Tri-City Airport. Besides the usual climatological data on precipitation and temperature, there are also hourly airway observations of sky condition, visibility, weather, and winds. Although not summarized, these data are available as microfilm copies of original data. Wind velocity and direction are measured with a USWB Type F-420 C cup anemometer and wind vane set. Recordings are made by visual inspection of dials; there is no continuous analogue record.

At Saginaw, wind sensors are located on a 20-foot mast well away from any obstructions and on very flat grass covered land. Temperature and dew point are measured at the same location, but precipitation is measured with a standard dipstick type of rain gauge on top of the flight service building.

GENERAL SITE CLIMATOLOGY

TEMPERATURES AND PRECIPITATION

Although the Midland climatological data are certainly the closest to the proposed nuclear site, the Saginaw data will also be used in this discussion since it is more adaptable for analysis. A comparison of the climatology of these two stations will help to detect differences, if any, in climatic elements due to the added roughness and heat sources of Dow.

In a later section, some of the Tri-City Airport data are used in the diffusion climatology analysis.

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Tables 2A-1 and 2A-2 and the following associated descriptive paragraphs are taken directly from the Climatological Summaries prepared by A. H. Eichmeier, Michigan State Climatologist.

CLIMATE OF MIDLAND, MICHIGAN

Weather data for the Midland area show that the highest temperature ever recorded here is 106 degrees on July 24, 1934 and July 12 and 13, 1936. The lowest temperature of record is 30 degrees below zero recorded on February 10, 1912. Temperatures reach the 100-degree mark in about one summer out of six and days with 90 degrees or above average 14 per summer. At the other extreme, temperatures fall to zero or lower on an average of six times during the winter season. On the basis of mean temperature, January 1912 is the coldest month of record with a mean reading of 8.2 degrees. July 1935 is the warmest month of record with a mean temperature of 77.9 degrees. The average dates of the last freezing temperature in the spring and the first in the fall are May 12 and October 2, respectively.

Precipitation is heaviest during the crop season and averages 58 percent of the annual total during the six months of April through September. The heaviest rainfall is in June with an average of 3.15 inches. The largest monthly rainfall of record is 8.40 inches in April 1909 and the smallest monthly total is 0.01 inch in March 1910. The heaviest intensity of rainfall occurs in connection with summertime thundershower activity and the greatest recorded 24-hour amount is the 4.31 inches which fell on July 15, 1932. Hourly intensity of as much as 1.10 inches occurs with a frequency of once in two years and two hourly intensity of 1.40 inches or more occurs about once in two years. Two inches of rain in two hours will occur about once in 25 years. Twenty-four hourly amounts of as much as 3.7 inches and 4.2 inches will occur about once in 25 years and 50 years, respectively.

Snowfall totals 33.3 inches during an average winter at Midland. However, there has been considerable variation in seasonal totals with amounts ranging from as little as 11.8 inches in the 1932-33 season to as much as 72.4 inches in the 1951-52 season. Measurable amounts of snow have occurred on eight of the twelve months but there are usually only five or six months that record measurable amounts.

Cloudiness is greatest in the late fall and early winter, a condition accentuated in Michigan's Lower Peninsula by the presence of Lake Michigan on the west and, to some extent, Lake Huron on the east. Prevailing wind direction in the area is southwest and average hourly velocity is greatest in the early spring and lowest in late summer and early fall.

TABLE 2A.1

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU
IN COOPERATION WITH Michigan Weather Service
CLIMATOGRAPHY OF THE UNITED STATES NO. 20 – 20

LATITUDE 43° 37'
LONGITUDE 84° 15'
ELEV. (GROUND) 647 Feet

CLIMATOLOGICAL SUMMARY

STATION Midland, Michigan

MEANS AND EXTREMES FOR PERIOD 1932 - 1961

Month	Temperature (°F) Means: Daily maximum	Means: Daily minimum	Means: Monthly	Extremes: Record highest	Year	Record lowest	Year	Mean degree days **	Precipitation Totals (Inches): Mean	Greatest daily	Year	Snow, Sleet: Mean	Maximum monthly	Year	Greatest daily	Year	Mean number of days: Precip .10 inch or more	Temperatures Max: 90° and above	Max: 32° and below	Min: 32° and below	Min: 0° and below	Month
(a)	30	30	30	30		30		30	30	30		30	30		30		30	30	30	30	30	
JANUARY	31.9	17.3	24.6	61	1950+	-20	1959	1220	1.69	1.40	1949	8.4	23.3	1943	8.0	1954	5	0	15	29	2	JANUARY
FEBRUARY	33.0	16.4	24.7	59	19[illegible]2+	-21	1936	1180	1.77	1.50	1938	8.5	29.4	1946	12.5	1946	4	0	13	27	3	FEBRUARY
MARCH	41.6	24.2	32.9	79	1945+	-14	1948	980	2.04	1.68	1948	5.7	14.5	1948	[illegible]	1942	6	0	6	25	*	MARCH
APRIL	56.5	35.5	46.0	86	1935	11	1954	570	2.61	1.96	1961	1.3	8.4	1952	6.4	1952	6	0	*	12	0	APRIL
MAY	69.1	46.3	57.7	94	1934	25	1947	250	2.96	1.94	1955	T	1.0	1935	1.0	19[illegible]5	7	*	0	2	0	MAY
JUNE	79.3	56.5	67.9	104	1934	35	1941	60	3.15	2.69	1935	0.0	0.0		0.0		6	3	0	0	0	JUNE
JULY	84.1	60.4	72.3	106	1936+	41	1953	10	2.44	4.31	1932	0.0	0.0		0.0		5	6	0	0	0	JULY
AUGUST	82.1	59.0	70.6	99	1955	36	1934	20	3.00	3.54	1945	0.0	0.0		0.0		6	4	0	0	0	AUGUST
SEPTEMBER	73.8	51.8	62.8	98	1953+	26	1932	130	3.11	2.18	1947	T	T	1942	T	1942	6	1	0	1	0	SEPTEMBER
OCTOBER	62.8	41.9	52.4	86	1951	17	1936	390	2.70	3.96	1954	0.1	1.0	1943+	1.0	1943+	5	0	0	5	0	OCTOBER
NOVEMBER	46.6	31.5	39.1	79	1950	1	1949+	780	2.37	1.40	1952+	3.3	17.0	1951	10.0	1940	6	0	2	17	0	NOVEMBER
DECEMBER	34.8	21.4	28.1	64	1934+	-16	1951	1120	1.94	1.77	1942	6.0	21.0	1951	8.0	1951	5	0	12	27	1	DECEMBER
Year	58.0	38.5	48.3	106	July 1936+	-21	Feb. 1936	6710	29.78	4.31	July 1932	33.3	29.4	Feb. 1946	12.5	Feb. 1946	67	14	48	145	6	Year

TABLE 2A.2

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU
IN COOPERATION WITH CONSUMERS POWER COMPANY
CLIMATOGRAPHY OF THE UNITED STATES NO. 20 – 20

LATITUDE 43° 32' N
LONGITUDE 84° 05' W
ELEV. (GROUND) 662 Feet

CLIMATOLOGICAL SUMMARY

STATION SAGINAW, MICHIGAN

MEANS AND EXTREMES FOR PERIOD 1926 - 1955

Month	Temperature (°F) Means: Daily maximum	Means: Daily minimum	Means: Monthly	Extremes: Record highest	Year	Record lowest	Year	Mean degree days **	Precipitation Totals (Inches): Mean	Greatest daily	Year	Snow, Sleet: Mean	Maximum monthly	Year	Greatest daily	Year	Mean number of [illegible]: Precip .10 inch or more	Temperatures Max: 90° and above	Max: 32° and below	Min: 32° and below	Min: 0° and below	Month
(a)	30	30	30	30		30		30	30	30		30	30		30		30	30	30	30	30	
JANUARY	30.4	16.5	23.5	62	1950+	-17	1951	1250	1.60	1.26	1949	8.9	19.7	1943	5.5	1927	5	0	17	28	2	JANUARY
FEBRUARY	31.3	16.1	23.7	67	1930	-18	1934	1220	1.69	1.56	1930	8.8	23.4	1935	5.5	1942	4	0	15	27	2	FEBRUARY
MARCH	40.1	24.4	32.3	82	1938	- 8	1948+	980	1.95	1.86	1942	6.8	19.3	1947	12.8	1947	5	0	7	25	0	MARCH
APRIL	54.9	34.6	44.8	86	1942	11	1954	610	2.44	1.32	1941	1.9	11.3	1952	10.4	1952	6	0	*	13	0	APRIL
MAY	67.5	45.1	56.3	94	1934	25	1947	[illegible]90	3.14	2.19	1942	*	5.7	1935	4.5	1935	7	*	0	2	0	MAY
JUNE	78.1	55.6	66.9	104	1934	32	1942+	70	3.00	2.98	1935	0	0		0		6	3	0	0	0	JUNE
JULY	83.8	59.8	71.8	111	1936	41	1945+	10	2.31	3.29	1928	0	0		0		5	6	0	0	0	JULY
AUGUST	81.2	57.9	69.6	102	1931	42	1946	30	2.86	3.35	1945	0	0		0		5	5	0	0	0	AUGUST
SEPTEMBER	72.7	50.7	61.7	100	1953	27	1942	150	2.92	3.27	1945	T	T	1953+	T	1953+	6	2	0	1	0	SEPTEMBER
OCTOBER	61.4	40.8	51.1	86	1953+	20	1942	420	2.49	4.58	1954	7.6	5.0	1933	5.0	1933	5	0	*	5	0	OCTOBER
NOVEMBER	45.1	30.7	37.9	80	1950	- 3	1949	800	2.19	1.80	1935	3.9	17.0	1940	9.5	1940	6	0	4	18	*	NOVEMBER
DECEMBER	33.5	20.9	27.2	61	1951	-11	1951	1140	1.85	1.47	1929	8.7	26.7	1929	14.7	1929	5	0	14	28	1	DECEMBER
Year	56.7	37.8	47.3	111	JULY 1936	-18	FEB. 1934	6970	28.44	4.58	OCT. 1954	46.6	26.7	DEC. 1929	14.7	DEC. 1929	65	16	57	147	5	Year

(a) Average length of record, years.

T Trace, an amount too small to measure.

** Base 65°F

\+ Also on earlier dates, months, or years.

* Less than one half.

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CLIMATE OF SAGINAW, MICHIGAN

The city is far enough from Saginaw Bay and Lake Huron to be considered an inland location, but it sometimes comes under the local influence of Saginaw Bay if there is a relatively strong northeast wind blowing inland from the bay. The general climate is modified, as in other parts of the Lower Peninsula, by the prevailing westerly winds being warmed in the winter and cooled in the summer while crossing Lake Michigan.

Available weather data for the Saginaw area show that the highest temperature ever recorded here was 111 degrees on July 13, 1936, and the lowest of record was -18 degrees on February 9, 1934. About one out of seven winters does not have a temperature as low as zero. At the other temperature extreme, 100 degrees or higher is recorded in about one summer out of four, and days with 90 degrees or above average 16 per summer. The mean temperature of 12.4 degrees in February 1934 makes that month the coldest of record, and the mean temperature of 76.1 degrees in July 1935 gives that month the distinction of being the warmest. The average dates of the last freezing temperature in the spring and the first in the fall are May 5 and October 11, respectively.

Precipitation received during the growing months, or "crop season," (April - September) averages 59 percent of the annual total. Heaviest rainfall is in May, which has an average of 3.1 inches. The driest month of the year is January with an average of 1.60 inches. The greatest amount of rainfall ever received in any one month is 8.15 inches in September of 1945. The least amount ever received in a month is 0.18 inches and this amount was measured in two different months: November 1939 and October 1952. The heaviest recorded 24-hour amount is 4.58 inches, which fell on October 3, 1954. The second greatest 24-hour amount is 3.35 inches and fell on August 31, 1945.

Snowfall totals 46.6 inches, and seven months of the year have measurable amounts during an average winter. January has the most snow, averaging 8.9 inches, but February is a close second with 8.8 inches. The heaviest snowfall recorded for a single day is 14.7 inches, and this occurred on December 19, 1929. The heaviest monthly fall of record is 26.7 inches in December 1929.

Cloudiness is greatest in late fall and early winter, and least in spring and summer. This is accentuated, especially late fall cloudiness, by the prevailing westerly air currents passing over Lake Michigan. Temperature contrasts between the colder air and relatively warm water are greater at that time, and the result is the addition of warmth and moisture to the lower layer of the air, causing instability and later, condensation and cloudiness. Saginaw is not affected by this condition as much as localities near Lake Michigan. However, the entire Lower Peninsula has increased cloudiness from this action during this period of the year, but also enjoys warmer temperatures than would normally occur at this latitud

DISCUSSION

Although Midland has had colder record lows and Saginaw warmer record highs, it appears that Midland averages about 1 F warmer than Saginaw. The heating degree-day totals also indicate the warmer temperatures at Midland. Due to the similarity between these two stations as to topography and distance from the Great Lakes, it is believed that this temperature difference is possibly due to the Midland station being in the middle of a chemical manufacturing plant complex. An examination of average annual temperatures for only those years when the Saginaw station was either at the Saginaw Municipal Airport, 4.5 miles east of Saginaw, 1938-1947, or at the Tri-City Airport, 1947-to date, indicates this temperature difference is in the 1.5 F to 2.0 F range, 1938 through 1956.

Precipitation, annually, is 1.34 inches greater, or 4.5 percent, at Midland than at Saginaw, but the seasonal distributions are quite similar. Saginaw on the average gets more snow. In general, the amounts and frequencies of precipitation are quite similar at the two stations.

There is certainly nothing to indicate that these two locations are in different climatic regimes.

SEVERE WEATHER

STRONG WINDS AND THUNDERSTORMS

Strong winds and thunderstorms occur infrequently in the Lower Peninsula of Michigan. The mean annual number of days with thunderstorms[1] at Flint, 50 miles southeast, are 33. The surface wind roses are discussed elsewhere in this report. However, at Flint, the highest wind speed recorded was 81 miles per hour. No higher velocity is reported for the State of Michigan[1]. ASCE Paper No. 3269 gives 85 miles per hour maximum wind velocity in this area based on a 100-year period of recurrence.

TORNADOES

A number of tornadoes have occurred in Michigan. For 43 years of record between 1916 and 1958, three tornadoes have been observed in Midland County and two have been observed in the vicinity of the site[2].

About 23 tornadoes have been observed in the 43-year period of 1916 through 1958 in Midland County and the adjoining six counties of east central Michigan.

In the whole State of Michigan, in the years 1916-1958, 177 tornadoes were observed. The site lies within an area of frequency of ten tornadoes during the 40-year period of 1916-1955. In addition, the site is within an area reporting 13 tornadoes per 1 degree square between 1916-1961.

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DIFFUSION CLIMATOLOGY

SURFACE WINDS

Annual surface winds are summarized for Dow and the Tri-City Airport in Tables 2A-3 and 2A-4, respectively. The Dow data are from a six-year summary prepared for 1960-65 by Dow personnel and the Tri-City data are from a five-year summary prepared by the National Weather Records Center[3]. The data are not in the same period but should still be indicative of significant differences or similarities between the two locations.

The significant difference between Tables 2A-3 and 2A-4 is in the wind speed and frequency of calm. The average monthly speed at Dow is somewhat lower than that at Tri-City Airport. The principal difference is probably one of definition. The Dow hourly wind data are recorded manually each hour from an examination of the continuous wind speed and direction readings for the past hour. An "eye ball" average of this continuous record for the hour is recorded. The Tri-City data come from an "eye ball" average of the wind speed and direction dials on the hour. The averaging period at Tri-City is, at the most, a few minutes. The hour averaging method will "smooth out" the observable extremes: reported calms will be less frequent and the peak speeds will be reduced. Reported hourly calms are about three times as frequent at Tri-City as at Dow and even then were only 1.6 percent of the observations. However, the percentage frequency of wind speed in the range of 1-3 mph is greater at Dow. It should be pointed out that the hourly averaged data are more appropriate to the diffusion models to be employed later than are "spot" measurements of wind.

Table 2A-3

Annual Wind Speed (Mph) and Direction Frequency
Dow Chemical Company, Midland, Michigan

Wind Direction	Percent Wind at Velocities of 1-3	4-12	13-24	25+	Total	Ave Wind Velocity
N	1.4	3.1	0.3	+*	4.9	5.5
NNE	1.0	2.2	0.3	0	3.6	6.3
NE	0.9	2.7	0.7	0	4.4	7.2
ENE	1.1	5.3	1.3	+	7.9	7.8
E	0.6	3.6	0.4	+	4.7	6.8
ESE	0.4	1.7	0.5	0	2.1	5.7
SE	0.3	1.7	+	0	2.1	5.2
SSE	0.6	2.0	+	0	2.7	4.7
S	1.1	7.8	0.4	+	9.4	6.6
SSW	0.8	8.5	1.0	+	10.5	7.7
SW	0.7	6.9	1.2	+	9.0	8.0
WSW	0.6	5.6	0.8	+	7.1	7.6
W	1.3	10.0	1.7	0	13.2	7.6
WNW	1.1	5.4	1.0	+	7.6	7.4
NW	0.7	3.5	0.6	0	4.9	7.2
NNW	0.8	3.9	0.5	0	5.3	7.0
Calm					0.6	
Total	13.4	73.9	10 7	0.1	100	

NOTES: Mean Data for Years 1960-1965 from the anemometer at Building No. 417.

* Less than 0.1 percent

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Table 2A-4

Annual Wind Speed (Mph) and Direction Frequency
Tri-City Airport, Saginaw, Michigan

Wind Direction	Percent Wind at Velocities of 1-3	4-12	13-24	25+	Total	Ave Wind Velocity
N	0.4	2.4	0.5	+*	3.3	8.3
NNE	0.3	3.0	1.7	0.1	5.1	10.8
NE	0.4	3.3	2.1	0.1	5.8	11.2
ENE	0.2	2.6	1.3	0.1	4.3	10.7
E	0.2	1.3	0.5	+	2.0	9.3
ESE	0.4	3.0	1.0	+	4.4	9.3
SE	0.5	3.0	0.8	+	4.3	8.7
SSE	0.3	3.6	1.5	0.1	5.5	10.2
S	0.4	2.6	0.8	+	3.8	9.2
SSW	0.4	4.9	2.7	0.2	8.3	11.1
SW	0.7	6.6	3.6	0.3	11.3	10.9
WSW	0.5	6.9	5.6	0.9	14.0	13.1
W	0.5	4.7	1.8	0.2	7.2	10.0
WNW	0.3	4.3	3.0	0.3	7.9	12.0
NW	0.4	3.3	1.7	0.1	5.5	10.8
NNW	0.3	3.9	1.6	+	5.7	10.3
Calm	—	—	—	—	1.6	
Total	6.2	59.4	30.2	2.6	100	

NOTES: Mean Data for Years 1949-1953.

* Less than 0.1 percent.

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Southwest is the most frequent and southeast the least frequent wind directions at both places. This is also true under light winds (1-3 mph) at Tri-City but is not as clear a directional preference as under light winds at Dow. This, perhaps, is indicative of the influence of the plant buildings near the Dow anemometer. In no case is there a marked directional preference at either location nor is there a significant difference in wind direction frequency distributions for the two locations.

Tables 2A-5 and 2A-6 contain seasonal wind rose data for Dow and Tri-City. Figures 2A-4 and 2A-5 also show these data.

The same general comments in reference Tables 2A-3 and 2A-4 apply to Tables 2A-5 and 2A-6. We note that south and southwest directions are especially prevalent in the summer and that the southeasterly direction is particularly lacking in the fall and winter. The summer months have the lowest wind speeds with fall a close second. Similarly, summer and fall months have the highest frequency of calms.

DURATION OF CALMS

Table 2A-7 shows the duration and occurrence of calm, or zero wind, in the mean hourly wind speed data for Building 417 (Dow) for the summer and fall months in 1966 and 1967. These months were picked to study because the summer and fall seasons have the lowest mean wind speeds of the year. On a mean hourly basis the maximum duration of calm conditions is five hours in October 1966. The largest percentage of total hours of calm observed on this basis is two percent in September of both years. In July-November 1966, nine of the 16 occurrences of calm mean hourly wind speed were of one-hour duration; in 1967, 12 of the 18 occurrences of calm mean hourly wind speed were of one-hour duration.

Table 2A-5

Seasonal Wind Speed (Mph) and Direction Frequency
Dow Chemical Company, Midland, Michigan

Wind Direction	Spring % Wind	Spring Ave Speed	Summer % Wind	Summer Ave Speed	Fall % Wind	Fall Ave Speed	Winter % Wind	Winter Ave Speed
N	4.2	6.5	5.9	4.6	5.2	5.3	4.4	5.7
NNE	3.5	7.1	3.7	4.5	3.4	5.5	3.8	7.9
NE	5.9	8.5	4.5	6.1	3.2	6.8	3.9	7.6
ENE	12.0	8.8	8.1	6.8	3.8	6.9	6.2	8.5
E	7.0	8.1	4.8	5.8	3.2	6.2	3.6	7.5
ESE	3.1	7.0	2.1	5.3	1.7	5.0	1.7	5.8
SE	2.8	5.6	1.8	4.7	2.1	5.4	1.6	5.2
SSE	2.8	5.1	2.7	4.4	3.3	4.7	1.7	4.6
S	8.3	7.2	9.2	5.6	12.9	6.5	7.2	6.9
SSW	7.1	8.5	9.5	6.7	13.3	7.4	12.1	8.2
SW	7.0	8.8	7.6	7.1	9.6	7.6	11.8	8.6
WSW	6.5	9.1	7.6	6.2	6.8	7.3	8.0	7.6
W	10.3	8.3	12.9	6.1	12.7	7.5	16.6	8.4
WNW	7.3	8.5	7.8	5.8	6.5	7.2	8.7	8.1
NW	5.5	8.3	5.0	6.0	4.6	6.5	4.4	7.9
NNW	5.2	8.3	5.8	5.7	5.5	7.0	4.6	7.6
Calm	0.4		1.0		0.7		0.4	

NOTE: Mean Data is for Years 1960-1965. Spring is March, April and May.

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Table 2A-6

Seasonal Wind Speed (Mph) and Direction Frequency
Tri-City Airport, Saginaw, Michigan

Wind Direction	Spring % Wind	Spring Ave Speed	Summer % Wind	Summer Ave Speed	Fall % Wind	Fall Ave Speed	Winter % Wind	Winter Ave Speed
N	3.4	8.2	3.4	7.1	3.8	9.5	2.8	8.5
NNE	6.9	12.4	5.2	8.9	4.3	11.5	4.1	10.3
NE	8.8	12.7	6.2	9.7	3.5	10.9	5.0	10.7
ENE	5.8	12.1	4.7	9.1	2.6	9.5	3.9	11.2
E	3.1	10.2	3.4	7.1	1.2	9.0	2.0	9.9
ESE	5.6	10.5	4.3	7.4	2.7	8.1	5.2	10.3
SE	5.0	9.6	4.2	6.7	3.9	8.5	4.3	9.8
SSE	5.0	10.6	5.2	8.0	6.1	10.3	5.8	11.6
S	2.7	9.7	4.1	7.8	4.8	8.7	3.7	10.8
SSW	5.3	10.8	9.4	9.8	11.1	11.3	6.8	12.6
SW	6.6	11.6	12.1	9.1	14.7	10.8	12.0	12.7
WSW	13.1	14.7	12.8	10.9	13.5	11.9	14.7	14.7
W	6.5	10.5	6.5	8.4	7.9	9.8	8.0	11.3
WNW	8.9	12.5	6.3	10.2	7.4	12.3	8.8	12.4
NW	6.6	11.8	5.3	8.6	4.2	10.7	5.8	11.4
NNW	5.9	10.5	5.7	8.7	6.8	10.8	4.8	10.9
Calm	0.8		2.8		3.1		0.8	

NOTE: Mean Data is for Years 1949 through 1953. Spring is March, April and May.

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Table 2A-7

Frequency and Duration of Calm
Midland, Michigan
Calm = 0 Mph

		1966				1967			
Month	Duration Hours	Frequency Number	Total Hours of Calm	Fraction of Total Hours Recorded	Percent Calm of Total Recorded Hours	Frequency Number	Total Hours of Calm	Fraction of Total Hours Recorded	Percent Calm of Total Recorded Hours
July	1	1	1			1	1		
	2	0	0			0	0		
	3	2	6	7/744	1	1	3	4/408	1
Aug	1	4	4			5	5		
	2	0	0			0	0		
	3	0	0	4/702	1	1	3	8/734	1
Sept	1	4	4			4	4		
	2	2	4			2	4		
	3	1	3			2	6		
	4	1	4	15/720	2	1	4	18/710	2
Oct	1	0	0			1	1		
	2-4	0	0			0	0		
	5	1	5	5/738	1	0	0	1/744	0.1
Nov	1	0	0	0/710	0	1	1	1/711	0.1

Note: These data are from one-hour averages of wind speed recorded by the Guard at Building No. 417 of the Dow Chemical Plant.

The duration and occurrence of winds of 1 mph and less for the same location and period of record are shown in Table 2A-8. The October 1966 records show one period of such light wind of 14-hour duration; however, the summer months of July-September show a greater occurrence of wind of 1 mph than the fall months of October and November.

PRECIPITATION WIND ROSES, MIDLAND

Table 2A-9 shows the precipitation wind roses for Dow for the period of 1963-67. The winter months are characterized by two maximums of occurrence, namely, the NE quadrant and the SW quadrant, as should be expected as a result of normal extratropical cyclones (or winter storms) moving through the area. Precipitation models concerning this are published by many investigators.

During the late summer and fall months precipitation occurs most frequently with wind directions from the south to southwest. Synoptic scale storms occurring during the month of November appear to cause relatively few hours of precipitation when the flow is from the south to west-southwest.

Table 2A-8

Frequency and Duration of Calm
Midland, Michigan
Calm is 0 or 1 Mph

		1966				1967			
Month	Duration Hours	Frequency Number	Total Hours of Calm	Fraction of Total Hours Recorded	Percent Calm of Total Recorded Hours	Frequency Number	Total Hours of Calm	Fraction of Total Hours Recorded	Percent Calm of Total Recorded Hours
July	1	5	5			4	4		
	2	3	6			1	2		
	3	2	6			0	0		
	4	3	12			2	8		
	5	0	0			1	5		
	6	1	6			0	0		
	7	0	0			0	0		
	8	2	16			0	0		
	9	0	0			0	0		
	10	0	0			0	0		
	11	1	11	62/744	8	0	0	19/408	5
Aug	1	6	6			12	12		
	2	3	6			2	4		
	3	5	15			2	6		
	4	1	4			1	4		
	5	1	5			1	5		
	6	0	0			0	0		
	7	0	0			0	0		
	8	0	0			1	8		
	9	0	0	36/702	5	1	9	48/734	7
Sept	1	5	5			10	10		
	2	4	8			4	8		
	3	0	0			1	3		
	4	3	12			1	4		
	5	0	0			2	10		
	6	3	18			3	18		
	7	2	14			1	7		
	8	1	8			1	8		
	9	1	9	74/720	10	0	0	68/710	10

Table 2A-8 (Contd)

Frequency and Duration of Calm
Midland, Michigan
Calm is 0 or 1 Mph

		1966				1967			
Month	Duration Hours	Frequency Number	Total Hours of Calm	Fraction of Total Hours Recorded	Percent Calm of Total Recorded Hours	Frequency Number	Total Hours of Calm	Fraction of Total Hours Recorded	Percent Calm of Total Recorded Hours
Oct	1	8	8			5	5		
	2	1	2			3	6		
	3-13	0	0			0	0		
	14	1	14	24/738	3	0	0	11/744	1
Nov	1	2	2			1	1		
	2	1	2			3	6		
	3	1	3	7/710	1	0	0	7/711	1

NOTE:
These data are from one-hour averages of wind speed recorded by the guard at Building No. 417 of Dow.

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Table 2A-9

Monthly Percent Occurrence of Wind Direction When Some Form of Precipitation Is Present Dow Chemical Plant, Midland, Michigan 1963-1967

	N	NNE	NE	ENE	E	ESE	SE	SSE
Jan.	14.8	7.1	9.9	3.5	14.1	2.1	1.4	4.9
Feb.	9.3	11.6	3.9	7.7	7.7	0	0	2.3
Mar.	0.8	1.6	8.5	19.0	14.6	6.5	3.6	6.5
Apr.	4.8	6.1	14.5	13.5	20.5	13.5	7.9	4.8
May	0.7	1.4	12.6	20.9	10.5	7.7	3.5	7.0
June	7.7	15.4	13.5	7.7	1.9	5.8	1.9	0
July	3.5	2.3	1.2	4.6	9.3	7.0	2.3	1.2
Aug.	5.4	7.0	2.1	5.9	7.5	7.0	6.4	4.2
Sept.	3.7	2.8	6.5	5.6	0.9	2.8	2.8	6.5
Oct.	4.7	3.5	3.5	4.7	7.1	1.2	0	2.4
Nov.	11.7	0.8	1.6	1.6	0	0	0	6.2
Dec.	2.4	2.4	7.3	18.3	22.0	3.7	2.4	4.9

	S	SSW	SW	WSW	W	WNW	NW	NNW	Σ %
Jan.	2.1	6.3	14.8	2.8	3.5	0.7	5.7	6.3	100.0
Feb.	8.5	10.1	10.9	3.9	2.3	3.1	4.7	14.0	100.0
Mar.	6.5	6.1	4.9	6.1	7.3	2.0	3.6	2.4	100.0
Apr.	4.8	2.6	0.9	1.7	2.2	0.9	0	1.3	100.0
May	8.4	8.4	1.4	12.6	4.2	0.7	0	0	100.0
June	1.9	0	7.7	9.6	5.8	7.7	1.9	11.5	100.0
July	9.3	12.8	7.0	5.8	13.9	11.6	1.2	7.0	100.0
Aug.	16.6	11.8	4.2	4.8	7.5	2.7	2.7	4.2	100.0
Sept.	20.4	8.3	19.4	4.6	5.6	4.6	3.7	1.8	100.0
Oct.	16.5	21.2	10.6	8.2	7.1	4.7	2.3	2.3	100.0
Nov.	4.7	7.0	4.7	1.6	24.9	8.6	10.2	16.4	100.0
Dec.	7.3	9.8	11.0	1.2	1.2	2.4	0	3.7	100.0

NOTE: Shows percent of the time, during precipitation, when the wind is from the indicated direction, computed separately for each month.

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DOW MONTHLY SUMMARIES OF WIND SPEED AND GUSTINESS

a. The average one-hour wind speed (mph) as a function of time is shown for each month in Table 2A-10 for 1966. Inspection of the table indicates that slow wind speeds, 3.5 to 5.0 mph, occur during the nocturnal hours of June to September. The diurnal distribution of winds in all months shows higher daytime winds than at nighttime, as should be expected. The minimum hourly wind speed occurs at 0500 local time in July and August.

b. Dow has observed the average "gustiness" of the wind for several years at Building 417. Table 2A-11 shows the results of these observations. The "guard-observer" noted and recorded each hour the range of azimuth of the wind direction in degrees. These are converted to a Dow gustiness category as follows:

Dow Gustiness Category	Range	(Slade) $\sigma\theta$	Pasquill Category
1	$>60^\circ$	$>10^\circ$	A, B, C
2	30° to 60°	5° to 10°	D, E
3	15° to 30°	$2\text{-}1/2^\circ$ to 5°	E, F
4	$<15^\circ$	$<2\text{-}1/2^\circ$	F

The above table also indicates the corresponding value of $\sigma\theta$ in accordance with the diffusion studies of Slade,[4] and the corresponding Pasquill category. The highest hourly Dow category (poor diffusion) of 2.33 occurs at 0700 local time in September with a mean speed of 4.23 mph; this corresponds to a Pasquill Category E. Inspection of Table 2A-11 indicates that the season for poor diffusion climatology in Midland is late summer and early fall.

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Table 2A-10

Wind Speed Monthly Summary
Dow Chemical Plant, Midland, Michigan, 1966
(Miles per Hour)

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
100	6.35	5.43	7.94	5.63	5.35	3.77	3.74	4.20	5.07	7.29	7.83	6.52
200	6.23	5.29	7.74	5.63	5.23	3.37	3.77	4.19	4.93	7.16	7.97	6.45
300	6.42	5.14	7.13	5.87	5.52	3.97	3.55	3.81	4.67	7.23	7.60	6.55
400	6.45	5.39	7.00	6.20	5.81	4.33	3.60	3.61	4.43	7.42	6.97	6.48
500	6.74	5.64	7.16	6.40	5.81	4.40	3.45	3.45	4.03	7.42	6.77	6.71
600	6.97	5.32	7.16	6.80	5.68	4.33	3.52	3.52	.400	7.55	7.33	6.65
700	6.8[illegible]	5.57	6.87	6.40	6.10	4.90	3.84	4.06	4.23	7.55	7.33	6.45
800	7.39	5.32	6.94	6.77	6.61	5.27	4.26	3.97	4.50	7.61	7.60	6.48
900	7.74	6.07	7.74	7.93	7.19	6.03	5.61	4.48	5.60	8.68	7.67	6.61
1000	7.90	6.68	8.26	8.67	7.55	6.90	5.97	5.45	6.73	9.84	8.23	7.45
1100	8.06	6.79	8.58	8.90	8.08	7.93	6.68	5.61	7.77	10.84	8.53	7.81
1200	8.45	6.79	9.06	9.50	8.59	8.03	7.00	6.10	8.00	11.32	8.53	8.55
1300	9.03	7.29	9.61	9.80	8.94	8.23	7.23	6.77	8.33	12.19	9.07	8.68
1400	8.61	7.11	9.45	9.73	9.39	8.77	7.74	6.94	8.67	12.61	9.07	8.71
1500	8.48	7.46	9.65	9.93	9.90	8.77	8.00	7.84	8.50	12.65	9.27	8.52
1600	8.39	7.43	9.84	9.77	9.97	8.97	5.16	7.35	8.27	11.81	9.40	8.00
1700	7.90	7.46	10.23	[illegible].30	10.26	9.17	8.48	6.84	8.10	11.16	8.80	7.48
1800	6.97	7.50	9.61	9.00	9.45	8.17	8.19	6.89	7.47	9.26	8.40	7.32
1900	6.87	6.75	9.61	7.90	8.71	6.93	7.39	5.35	6.33	7.68	8.47	7.42
2000	6.81	6.32	8.61	7.23	7.10	5.50	6.13	4.74	5.77	7.39	8.30	7.10
2100	6.97	6.21	8.19	6.53	6.06	5.43	4.81	4.45	5.97	7.32	7.93	7.10
2200	6.94	6.39	7.87	6.03	5.55	4.63	4.39	4.52	5.83	7.[illegible]6	7.70	7.19
2300	6.68	6.14	7.48	6.07	5.06	4.37	4.00	4.81	5.47	7.61	8.43	7.13
2400	[illegible]9	5.68	7.77	5.73	5.26	3.93	4.10	4.61	5.23	7.48	7.87	6.94

Table 2A-11

Average Gustiness Monthly Summary, 1966
Dow Chemical Plant, Midland, Michigan

HOUR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
100	2.06	1.93	2.03	2.20	2.06	2.00	2.06	1.84	1.97	2.29	1.77	2.06
200	2.10	1.89	1.94	1.93	2.03	1.97	2.06	2.03	2.13	2.29	1.80	2.03
300	2.16	1.89	1.77	2.03	2.16	1.97	2.13	2.03	1.83	2.26	1.70	2.06
400	2.10	1.89	1.90	1.97	2.13	2.00	2.10	1.90	1.87	[illegible]	1.73	2.03
500	2.10	1.96	1.94	2.00	2.16	2.00	2.10	2.06	2.10	2.26	[illegible]	1.94
600	2.03	2.07	2.03	2.03	1.87	1.93	2.00	2.10	2.30	2.13	[illegible]	2.00
700	2.06	2.04	1.97	2.03	1.90	1.90	2.00	1.87	2.33	2.00	2.10	2.03
800	2.23	2.11	2.10	2.10	1.94	1.87	1.81	1.68	2.23	2.03	2.20	2.03
900	2.16	2.07	2.06	2.00	1.68	1.77	1.65	1.61	2.13	1.87	2.00	2.03
1000	2.16	1.95	1.90	1.90	1.65	1.60	1.58	1.61	1.93	1.77	2.00	2.00
1100	2.03	1.79	1.84	1.80	1.52	1.57	1.45	1.39	1.67	1.61	1.83	1.90
1200	1.84	1.64	1.71	1.70	1.42	1.47	1.39	1.29	1.57	1.55	1.90	1.74
1300	1.74	1.68	1.71	1.73	1.48	1.40	1.45	1.26	1.53	1.48	1.90	1.71
1400	1.87	1.61	1.58	1.77	1.45	1.47	1.48	1.32	1.53	1.52	1.77	1.71
1500	1.81	1.64	1.65	1.97	1.55	1.47	1.48	1.39	1.60	1.48	1.80	1.77
1600	1.87	1.75	1.68	2.03	1.65	1.53	1.55	1.55	1.53	1.58	1.77	1.87
1700	1.94	1.71	1.74	1.83	1.68	1.70	1.65	1.61	1.63	1.74	1.83	1.90
1800	2.00	1.86	1.94	1.90	1.68	1.73	1.77	1.81	1.73	1.65	1.80	2.00
1900	2.10	1.96	2.00	1.90	1.81	1.80	1.84	1.84	2.07	1.74	1.80	1.94
2000	2.10	1.93	2.00	1.93	1.97	1.90	1.81	1.84	2.23	1.77	1.73	1.94
2100	2.06	1.89	1.90	1.83	2.13	1.93	1.87	1.94	2.03	1.84	1.73	1.94
2200	2.16	1.93	2.00	2.03	2.03	2.03	1.87	1.84	2.07	1.84	1.77	2.03
2300	2.10	1.89	1.87	2.07	2.13	2.13	2.03	1.97	1.97	1.90	1.80	2.00
2400	2.06	1.93	1.94	2.03	2.00	2.10	2.06	1.81	1.97	2.00	1.83	2.00

MEAN SOUNDING ANALYSIS, ANNUAL AND SEASONAL, FLINT, MICHIGAN

Data for the construction of the annual and mean seasonal 1,200 GCT vertical temperature distribution at Flint, Michigan, have been obtained from the National Weather Record Center for the period of 1966 and 1967. The corresponding vertical temperature distributions are shown in Figures 2A-6 - 2A-10. The annual morning sounding (the mean for the year) shows that there is in the mean a slight temperature inversion from 990 millibar (mb) to 950 mb. Reference to the four mean seasonal soundings shows that this feature of the annual sounding is determined by the mean fall and summer season conditions. In a later section wherein the nine worst months in a five-year sample are identified for diffusion climatology at Midland, it is found that these months lie between August and November inclusive. This finding is entirely consistent with the character of the seasonal soundings discussed above.

The power plant design includes the use of a man-made cooling pond as a heat sink. This pond has an area of approximately 1-1/3 square miles, surrounding the plant on three sides, west, south and east (see Figure 2A-3). It is estimated that, during the summer, the mean temperature of the pond during a 24-hour period is about 106 F and, during the winter, about 71 F. If these pond temperatures are plotted on the mean seasonal soundings, it is seen that on a still day a dry adiabat lapse rate would develop to 610 mb in winter and to about 590 mb in summer in the absence of any condensation. In the case of air moving over the hot pond from the west or south, this heat source would induce thermal turbulence and hence increase the vertical diffusion rates. However, in our analysis here, we have not taken any credit for these effects which must be considerable. Air moving from the Dow plant (an aerodynamically rough, heated surface) to the power plant site should contain enhanced levels of mechanically and thermally induced turbulence. This, as will be shown in a later section, increases the dilution power of the atmosphere.

COMPARATIVE CLIMATOLOGY

INVERSIONS AND LOW WIND SPEEDS

In considering the diffusion climatology of Midland, Michigan, it is useful to be able to compare that part of the United States with other areas which have been studied previously. Because the two-hour diffusion model is of prime importance and because the meteorological conditions which go into this model are typically nighttime conditions, it is most useful to examine nighttime statistics on low wind speeds, temperature inversions, and cloud cover. This has been done by Hosler[15].

The percentage frequency (day and night) for which a temperature inversion occurs below 500 feet is shown in Figure 2A-11a (reproduced directly from Hosler[15]). As expected, minimum percentage frequencies occur in the spring and summer. The Rocky Mountain States, the Central States, and the Southeast States have the greater number of hours of inversion. The Great Lakes and Coastal areas have the lowest percentage of hours with inversions at altitudes of less than 500 feet. For example, during fall (normally the season with the greatest air pollution potential), about 35 percent of the total hours at

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Midland have inversions below 500 feet. This frequency at Midland is at least 10 percent lower than that over the Rocky Mountain States and large portions of the Central States.

CLOUD COVER

Particularly relevant to the two-hour model is the distribution, by season, of percent of time that the wind speed is equal to or less than 7 mph in association with nighttime cloud cover equal to or less than 3/10. This distribution is shown in Figure 2A-11b. As shown in the figure, the Coastal and Great Lakes areas have the lowest frequencies of light winds and clear nights. For instance, in the fall, this is about 45 percent whereas, for most of the United States, it is above 50 percent. In the Southwest, Southeast, and Appalachia, the values are greater than 70 percent.

REMARKS

The diffusion climatology, in a gross sense, is more favorable at Midland, Michigan, than in much of the United States. Hosler[15] summarizes as follows:

> "This (the Great Lakes) area is characterized by frequent storm passages with their associated cloudiness and high winds, particularly from late fall to early spring, which result in relatively low frequencies of nocturnal radiation inversions. An analysis of climatological data for specific stations in this area shows a high occurrence of cloudiness during nighttime hours, which apparently reflects the effects of the Great Lakes imparting moisture to the air in its trajectory over the lake water. Summer and fall months show slightly higher frequencies of low-level stability than do the winter and spring months."

STABILITY WIND CATEGORIES

GENERAL

Over the last 30-40 years, many investigators have worked both experimentally and theoretically on the problem of atmospheric diffusion (see Sutton[5] and Pasquill[6] for review). The theoretical solution most applicable here is the solution for a continuous point source at the ground surface in an unidirectional wind field of constant speed. This is

$$X = \frac{Q}{2\pi\sigma_y\sigma_z\bar{u}} \exp\left\{-\frac{1}{2}\left[\frac{y^2}{\sigma_y^2} + \frac{z^2}{\sigma_z^2}\right]\right\} \qquad (1)$$

where X = concentration, units/m^3

Q = release rate, units/s

σ_y = crosswind standard deviation, m

σ_z = vertical standard deviation, m

$\bar{u}$ = mean wind speed, m/s

In Fickian diffusion, σ^2 can be identified with 2Kt where K is a constant diffusivity and t is time. For ground level release, the concentrations given by Equation (1) should be multiplied by 2 for the reflection boundary condition, and h (height of release) replaces z. An elevated release would reduce the ground level concentration within a distance of a few stack heights from the release point but has little effect beyond the point downwind where $\sigma_z^2 \gg h^2$.

It should be noted that such a point source solution is applicable only if the time of release is long compared to the time of arrival at some point downwind. In addition, only the concentration at the center line of the cloud will be considered in this report; hence, the exponential term in Equation (1) is unity.

In Nuclear Safety[7], the plume-axis form of Equation (1), assuming a reflection boundary condition, is modified to

$$\frac{X}{Q} = \frac{1}{(\pi\sigma_y\sigma_z + CA)\bar{u}} \qquad (2)$$

where C = an experimentally determined constant (range 1/2 to 2)
A = cross-sectional area of building complex from which source is being emitted, m^2

This modification to Equation (1) accounts for the increased dilution in the wake of a building. The constant C is usually assumed to be between 1/2 and 2 although explicit measurements in all stability categories are lacking.

Equation (2) represents one method of calculating the relative concentration, X/Q, including the additional dilution effects on the source from the building wake.

A second method, however, may be employed in which experimentally determined dilution factors are used to modify the point source value of X/Q obtained from Equation (1) for a given downwind distance x and Pasquill category. In this study, this second method of including the effects of cavity diffusion is used in the calculation of the relative concentration. This subject is discussed in greater depth in the next section.

A variety of methods have been used to predict σ_y and σ_z as a function of distance downwind, but the basically empirical scheme proposed by Pasquill[8] is used here. Pasquill proposed six weather classification categories ranging from unstable conditions with light winds through neutral condition and wind to stable conditions and light winds. The classification into six categories (A to F) depends on surface wind speed, insolation in daytime and cloud cover at night.

In these classifications, horizontal spreading was represented by an included angle for the different categories. Vertical standard deviation was given as a function of distance downwind for the different categories. The experimental diffusion data that were used in Pasquill's correlation were reasonably complete from categories B through D. However, for categories A, E and F and for distances greater than one kilometer, the chart is essentially extrapolations.

00013

Turner[9] provided a quantitative method for categorizing the diffusion conditions characteristic for a particular hour of the day. This method uses the regular Weather Bureau surface hourly observations. Near the ground, stability depends primarily on net radiation and wind speed. During daytime hours, with clear skies, insolation (incoming radiation) depends on solar altitude, which is a function of time of day, time of year and latitude. Clouds inhibit both insolation and radiation. In Turner's system, insolation is estimated by solar altitude and modified for the effect of cloud cover and ceiling height. The Turner number depends on wind speed and net radiation index. The stability categories as determined by the method of Turner are related to Pasquill categories (A to F) as follows:

Atmospheric Condition	Pasquill Letter	Turner Number
Extremely Unstable	A	1
Unstable	B	2
Slightly Unstable	C	3
Neutral	D	4
Slightly Stable	E	5
Stable	F	6
Extremely Stable	-	7

For convenience, Turner No. 6 and No. 7 are both called Pasquill Letter F for purposes of estimating diffusivity. Recently, Slade[4] has summarized much experimental data on continuous point source plume diffusion. The summary includes the data used by Pasquill but also makes use of more recent data. Curve of σ_y and σ_z are presented as a function of downwind distance and different Pasquill stability categories. Slade has also given a method for estimating the stability categories from a continuous record of wind direction.

For a continuous plume extending downwind from its source, it is possible for its vertical growth by diffusion in the "mixed layer" to be inhibited by the presence of an inversion. Hence, a "vertical mixing value," σ_z, developed from experimentally obtained data, may apply only where no other restraint to mixing exists. This inversion imposes an additional restraint on σ_z, for daytime stability categories, which may be significant as downwind distance increases. By definition, categories E and F have surface-based inversions included in the empirically determined σ_z's. Holzworth[10] evaluated mean radiosonde observations and normal maximum surface temperature and used the assumption of a dry adiabatic lapse rate to estimate monthly mean maximum mixing depth (MMD). This analysis was done for 45 stations in the United States.

As discussed in the following section, the construction of the two-hour and 24-hour model for the Midland site, Pasquill E and F stability predominate; hence, there is no need to discuss the inclusion of MMD in these models.

DILUTION DUE TO BUILDING EFFECTS

The continuous point source diffusion equations are only applicable to flow over flat unobstructed terrain; the diffusion studies which have led to the summarization of Pasquill and Slade for σ_y and σ_z as a function of distance and atmospheric stability were done over flat unobstructed terrain.

Various approaches have been used to account for the effect of buildings on airborne concentrations downwind. These are: (1) the "virtual point source" which moves the theoretical point source far enough upwind so that the plume has about the same dimensions as the building, at the location of the building; (2) the addition of a "cavity diffusion" term to the point source equations (ie, CA); (3) the use of a cavity diffusion equation per se (ie, $X = QK/L^2\bar{u}$) where K is an empirically determined constant and L is either length downwind or L^2 is building cross-sectional area; and (4) empirically determined dilution factors from full-scale diffusion tests.

It is believed that the latter approach is the correct one to use because: (1) there are some full-scale data, (2) this method accounts for the difference due to atmospheric stability, and (3) this method reflects directly the effect on airborne concentrations.

A variety of these kinds of data is summarized in Table 2A-12. Dickson, Start, and Markee[11] data come from surface releases of a tracer on the downwind side of the Experimental Breeder Reactor II at the National Reactor Test Station (NRTS). The cross-sectional area of 665 square meters is for the reactor building itself, although there are other buildings in the complex. The Pasquill categorizations in Table 2A-12 are based on stability comments of the author plus observed wind speeds.

The data from Islitzer[12] come from diffusion studies of a tracer released just downwind from the main MTR reactor building at NRTS.

Munn and Cole's data[13] are from studies conducted at the Central Heating Plant at the National Research Council, Ottawa, Canada. Releases were from a 10-foot high stack on top of the 60-foot high Central Heating Plant. This building does have other large buildings crosswind of it.

Crosswind arcs were from 500 feet to 1,150 feet downwind and dilution factors ranged from 2.5 to 40 over the eleven tests. Detailed information is not given for each test, but a median dilution factor of 10 is reported at a median distance of 700 feet (213 meters). At these distances, the releases from the short stack on top of the building would give the same result as from a ground level release due to the mixing within the wake of the building.

00045

TABLE 2A-12
SUMMARY OF BUILDING DILUTION FACTORS

AUTHOR	TEST AREA, METERS^2	PASQUILL CATEGORY A	B	C	D	E	F
Dickson, Start, and MarKee	665	-	-	4.4[1](7)[2]@ 100m[3] 2.8(7)@ 200m 1.8(7)@ 400m 1.4(7)@ 600m	3.5(6)@ 100m 4.2(6)@ 200m 3.9(6)@ 400m 3.2(6)@ 600m	-	-
Islitzer	2400	-	3.2(11)@ 118m 2.9(11)@ 350m 3.2(11)@ 550m 2.4(11)@ 850m	-	-	50(1)@ 118m	-
Munn and Cole	725	-	-	10(11)@ 213m	-	-	-
Martin	-	-	1.9(2)@ 152m	-	9.6(6)@ 152m	21(2)@ 183m	-

NOTE:

1. The building dilution factor
2. The number in () is the number of cases available to establish the dilution factor
3. Downwind distance from release to dilution measurement

Martin's data[14] are measured concentrations downwind of the Ford Nuclear Reactor Building on the north campus of The University of Michigan, of Kr^{85} emitted from the 9.5-foot high stack on top of the 45.5-foot tall buildings. The crosswind width of this building is not given but presumably it is of the same order of magnitude as the building in the above tests. As is the case above, there are other buildings in the vicinity of this reactor building also.

Only Martin's measurement at distances greater than 100 meters are used in this analysis.

The data from Table 2A-12 are plotted on Figure 2A-11 according to stability category and distance. It is evident that dilution factors increase with an increase of stability, and that dilution factors decrease with distance. Dilution factors must approach unity as distances increase. Consequently, there is some tendency for dilution factors under stable conditions to decrease faster with distance than those under unstable conditions.

The solid lines on Figure 2A-11 are the dilution factor relationshi which are used in the 2-hour model (which is mostly the F stability category), the 24-hour model (which is mostly E stability) and the 30-day model (which is D stability category). The dilution factors were allowed to equal unity at 50 kilometers. This gives a dilution factor of 1.? at 2 kilometers and 1.03 at 10 kilometers. The upper curve in Figure 2A-1. is consistent with the E category data and are probably conservative at 1000 meters.

DIFFUSION MODELS

SELECTION OF DIFFUSION MODELS

For the purpose of selecting data to use in determining the input parameters to the diffusion models ($\overline{U}$, stability category, etc), the five-year period 1962 to 1966, inclusive, was chosen since meteorologic data exists for both the Dow Plant and the FAA Saginaw Airport, and some wind strip charts exist at Buildings 47 and 417 at the Dow Plant, for 1966 and 1967.

On the basis of average wind speed, average "gustiness," and the frequency of calms obtained from monthly summaries from Building 417 of the Dow Plant, the worst nine months of the five years (ie, 15 percent of the sample) were identified. This was done for three sectors, defined in Table 2A-13, selected for the shortest distance to the site boundary. This table shows the average monthly $\overline{U}$, Dow gustiness category, and frequency of calms. On the basis of lowest $\overline{U}$, highest Dow gustiness category (note that sigma theta decreases with gustiness), and highest frequency of calms, the nine worst months were selected. The final selection was as follows:

1. August 1962
2. November 1962
3. October 1963
4. November 1963
5. July 1965
6. August 1965
7. July 1966
8. August 1966
9. September 1966

TABLE 2A-13

ANALYSIS OF MONTHLY DIFFUSION, FIVE YEARS, 1962-1966

MIDLAND, MICHIGAN

1962	080° - 101° E Ū	080° - 101° E Gust	169° - 191° S Ū	169° - 191° S Gust	237° - 259° WSW Ū	237° - 259° WSW Gust	360° Percent Calms
JANUARY	8.0	2.4	6.0	2.0	5.6	1.9	1.0
FEBRUARY	8.7	2.4	6.4	1.7	7.5	2.0	0.3
MARCH	8.3	2.4	10.2	2.0	6.2	1.8	0.6
APRIL	7.9	2.2	6.7	1.8	8.5	1.8	0.3
MAY	7.5	2.0	7.9	2.1	9.5	2.0	0.9
JUNE	6.6	2.1	6.5	2.0	6.3	2.0	0.6
JULY	6.9	2.1	5.2	2.0	5.3	2.0	1.3
AUGUST*	7.1	2.1	5.6	1.8	5.2	2.0	2.9
SEPTEMBER	5.7	2.2	5.8	1.9	9.1	2.1	0.8
OCTOBER	7.5	2.4	6.9	1.9	6.9	1.9	0.5
NOVEMBER*	4.4	2.9	6.4	2.1	7.3	2.0	1.6
DECEMBER	9.4	2.4	7.3	1.8	7.2	2.0	0.1
1963							
JANUARY	11.6	2.1	8.2	1.9	8.3	1.9	0.5
FEBRUARY	4.9	2.4	7.7	2.0	7.[illegible]	2.0	0.7
MARCH	8.7	1.9	6.8	1.6	7.6	1.9	0.9
APRIL	6.9	2.1	7.5	1.6	12.4	1.8	0.4
MAY	6.9	2.0	6.4	1.7	8.7	1.9	0.7
JUNE	4.8	2.0	5.5	1.6	6.5	1.7	0.8
JULY	5.9	2.0	5.3	1.5	5.0	1.9	0.4
AUGUST	5.3	2.0	5.1	1.6	5.9	1.6	0.7
SEPTEMBER	5.8	2.3	5.2	1.8	6.7	2.1	0.7
OCTOBER*	6.0	2.6	5.3	2.1	6.1	1.9	1.5
NOVEMBER*	1.3	3.3	8.2	2.0	8.9	2.0	0.0
DECEMBER	7.3	2.5	7.3	2.0	6.9	2.1	2.1

TABLE 2A-13 (Continued)

1964	080° - 101° E Ū	Gust	169° - 191° S Ū	Gust	237° - 259° WSW Ū	Gust	360° Percent Calms
JANUARY	12.3	2.2	7.6	1.9	9.4	2.1	0.1
FEBRUARY	6.2	2.5	6.8	2.0	9.2	1.8	0.0
MARCH	9.6	2.4	9.5	1.9	11.5	1.8	0.2
APRIL	9.5	2.2	10.7	2.0	13.5	1.8	0.0
MAY	6.3	2.1	6.7	1.6	12.8	2.0	0.0
JUNE	6.6	2.0	6.7	1.6	9.1	1.9	0.7
JULY	6.1	2.0	6.3	1.6	5.8	1.4	0.4
AUGUST	8.1	2.0	7.3	1.7	7.3	1.7	0.5
SEPTEMBER	6.5	2.2	6.2	1.8	8.2	1.8	0.8
OCTOBER	5.5	2.0	7.3	2.0	7.2	2.0	1.2
NOVEMBER	6.5	2.3	6.6	1.9	8.3	2.0	0.2
DECEMBER	6.0	2.6	7.1	1.8	7.3	1.9	0.0
1965							
JANUARY	9.0	2.0	6.7	1.6	7.1	1.9	0.0
FEBRUARY	10.6	2.4	7.9	1.8	9.7	1.9	0.0
MARCH	12.2	1.9	5.1	1.5	8.5	1.9	0.1
APRIL	6.4	2.0	4.8	1.8	8.2	1.9	0.0
MAY	6.1	2.0	5.9	1.8	9.7	1.6	0.4
JUNE	5.9	2.0	6.0	1.7	7.1	1.6	0.2
JULY*	5.0	1.6	5.8	1.6	5.7	1.8	2.2
AUGUST*	5.1	1.9	4.8	1.9	6.9	1.8	0.3
SEPTEMBER	6.8	2.2	7.3	1.8	6.8	1.6	0.3
OCTOBER	5.5	1.8	5.6	1.7	7.7	1.9	0.4
NOVEMBER	10.0	2.0	6.2	1.6	10.3	2.0	0.2
DECEMBER	4.9	2.6	6.7	1.9	7.0	1.9	0.1

TABLE 2A-13 (Continued)

1966	080° - 101° E		169° - 191° S		237° - 259° WSW		360°
	Ū	Gust	Ū	Gust	Ū	Gust	Percent Calms
JANUARY	8.6	2.3	7.5	1.7	6.9	2.0	0.0
FEBRUARY	5.6	1.9	7.1	1.8	6.9	1.6	0.1
MARCH	7.3	2.5	7.3	1.8	7.2	1.7	0.1
APRIL	8.4	2.0	7.9	1.7	7.7	1.5	0.8
MAY	5.3	2.0	6.2	1.5	8.4	1.6	0.2
JUNE	5.5	1.8	6.5	1.9	6.5	1.7	0.6
JULY*	4.5	1.6	4.3	1.6	5.7	1.6	0.5
AUGUST*	4.7	2.1	4.9	1.9	5.3	1.7	0.4
SEPTEMBER*	5.5	2.2	5.6	1.6	4.8	1.7	2.0
OCTOBER	5.4	2.3	9.8	1.9	12.1	1.3	0.1
NOVEMBER	5.0	2.4	6.6	1.7	7.0	1.8	0.0
DECEMBER	9.9	2.1	7.0	1.8	7.2	1.9	0.1

NOTE: 1. * Indicates selected "worst" months for further analysis.

2. Gust means gustiness, a stability rating. Average monthly values are shown.

Data from these nine identified worst months are used to develop the inputs to the diffusion models. Normally, this may be done either by the methods suggested by Turner or Slade. Nevertheless, the Dow data as recorded by the guard-observer are not suitable for either method for the following reasons:

1. The Dow data include no cloud cover or cloud ceiling data. This eliminates use of Turner method.

2. The Dow data have incomplete detail in the "gustiness" category to assign a Slade or Pasquill category.

3. The raw Dow data are too incomplete to use Slade's method.

For these reasons, the method of Turner on meteorological data from the FAA weather station at the Tri-City Airport was used in the analysis of the nine worst months identified above. In this regard, it is probably conservative to use the data from the Tri-City Airport, for air passing over the plant complex to Building 417 probably contains more mechanical and thermally induced turbulence than at a more favorably exposed station, like the Tri-City Airport. In order to illustrate this, selected portions of 24 nights during which the wind was light and southerly, at Building 47 on the southern border of the present Dow site were studied. A southerly trajectory brings air from a pastoral area to Building 47, whereas the southerly trajectory at Building 417 brings air over the heated plant. For the sample shown in Table 2A-14, hourly values of $\overline{U}\ \sigma_\theta$ have been calculated at these two locations. The mean ratio of $\overline{U}\ \sigma_\theta$ at Building 417 to $\overline{U}\ \sigma_\theta$ at Building 47 is 1.44.

00051

Table 2A-14

Comparison of Diffusion Factors, Light Southerly Winds,
Buildings 47 and 417, Midland, Mic igan,
Selected Periods - 1966

	Building 47				Building 417				
Date Hour	Range	Wind $\bar{U}/D^{\circ}$	σ_θ/CAT	$\bar{U}\sigma_\theta$	Range	Wind $\bar{U}/D^{\circ}$	σ_θ/CAT	$\bar{U}\sigma_\theta$	R
1-29									
2100	75	5/160	13/3	65	49	6/350	8/4	48	0.739
2-1									
1800	39	4/190	6/5	24	90	4/190	15/3	60	2.50
2-2									
1700	38	5/190	6/5	30	100	3/180	17/3	51	1.70
1800	30	5/190	5/5	25	84	2/170	14/3	28	1.12
2-5									
2000	31	5/170	5/5	25	69	5/180	11/4	55	2.20
2100	45	5/160	8/4	40	86	3/150	14/2	42	1.05
2300	43	5/160	7/5	35	81	3/160	14/2	42	1.20
2-6									
0000	42	4/150	7/5	28	81	2/160	14/3	28	1.00
0100	46	5/160	8/4	40	92	3/160	15/3	45	1.13
0200	36	5/160	6/5	30	98	4/160	16/3	64	2.13
0300	45	5/150	8/4	40	91	3/160	15/3	45	1.13
2200	48	5/160	8/4	40	94	4/170	16/3	64	1.60
2300	65	5/150	11/4	50	96	3/160	16/3	48	0.873
2-7									
1100	98	3/150	16/3	48	123	4/140	20/2	60	1.25
1300	65	4/190	11/4	44	108	3/190	18/2	54	1.229
2-27									
0000	33	2/190	5/5	10	53	4/190	9/4	36	3.60
0700	43	5/170	7/5	35	112	3/170	19/2	57	1.63
0800	53	4/180	9/4	36	114	3/190	24/1	72	2.00
1000	63	3/170	10/4	30	149	3/150	25/1	75	2.50
1100	80	3/180	13/3	39	74	4/130	12/4	48	1.23
1300	97	5/140	16/3	80	109	5/130	18/2	90	1.12
1400	136	4/110	23/1	92	116	4/130	19/2	76	0.826
2-28									
0500	41	2/190	7/5	14	61	3/200	10/2	30	2.14

0005

Table 2A-14 (Contd)

Date Hour	Building 47 Range	Wind $\bar{U}/D^{\circ}$	σ_θ/CAT	$\bar{U}\sigma_\theta$	Building 417 Range	Wind $\bar{U}/D^{\circ}$	σ_θ/CAT	$\bar{U}\sigma_\theta$	R
3-2									
0800	39	3/200	6/5	18	54	5/190	9/4	45	2.5
3-5									
0200	70	4/200	12/4	48	121	3/180	20/2	60	1.25
3-10									
0400	47	4/190	7/4	30	46	5/190	8/4	40	1.33
0500	42	4/200	7/4	28	50	4/200	8/4	32	1.14
0600	35	5/190	6/4	30	58	6/190	10/4	60	2.0
0800	109	3/160	18/2	54	106	3/160	18/2	54	1.0
1100	47	3/180	8/4	24	59	4/190	10/4	40	1.6
1200	40	5/180	7/5	35	71	5/190	12/4	60	1.7
3-11									
1400	62	5/160	10/4	50	111	3/160	18/2	54	1.08
1800	133	4/160	22/2	88	101	3/150	17/3	51	0.58
3-17									
0400	74	4/170	12/4	48	85	3/140	14/3	42	0.875
3-20									
1900	50	5/180	8/4	40	84	3/170	14/3	42	1.05
2000	61	4/180	10/4	40	75	4/180	12/4	48	1.20
2100	81	4/140	13/3	52	94	2/160	16/3	32	0.615
3-21									
0200	117	3/150	19/2	57	108	3/150	18/2	54	0.947
0300	81	5/160	13/-	65	86	4/160	14/3	56	0.892
3-30									
0600	71	4/200	12/4	48	69	4/190	12/4	48	1.00
5-7									
1200	180	2/170	30/1	60	78	3/200	13/3	39	0.65
1300	144	2/140	24/1	48	110	3/180	18/2	54	1.125
5-11									
0300	121	2/140	20/2	40	143	3/150	24/1	72	1.80
0600	99	3/160	16/3	48	93	4/150	15/3	60	1.25
0700	73	5/140	12/4	60	99	6/120	16/3	96	1.60
0800	95	4/160	16/3	64	69	6/150	11/4	66	1.03

Table 2A-14 (Contd)

Date Hour	Building 47 Range	Wind $\bar{U}/D^{\circ}$	σ_θ/CAT	$\bar{U}\sigma_\theta$	Building 417 Range	Wind $\bar{U}/D^{\circ}$	σ_θ/CAT	$\bar{U}\sigma_\theta$	R
5-13									
1400	173	4/200	29/1	116	68	15/40	11/4	165	1.42
1800	217	5/160	36/1	118	55	14/50	9/4	126	0.70
5-14									
1400	123	5/200	20/2	100	141	5/210	23/1	115	1.15
2000	57	5/190	10/4	50	62	4/350	10/4	40	0.80
5-15									
1200	175	4/190	29/1	116	319	4/260	53/1	212	1.83
1500	123	5/200	20/2	100	102	7/190	17/3	119	1.19
5-16									
0000	135	5/190	23/1	115	63	7/270	10/4	70	0.68
0100	96	4/160	16/3	64	52	5/320	9/4	45	0.865
5-17									
0600	92	3/160	15/3	45	54	13/210	9/4	117	2.60
1100	150	3/170	25/1	75	58	14/260	10/4	140	1.86
1200	191	4/160	32/1	128	71	16/250	12/4	192	1.50
1300	147	4/150	24/1	96	71	18/250	12/4	216	2.25
1400	96	5/190	16/3	80	84	16/270	14/3	224	2.80
1900	120	3/140	20/2	60	86	6/330	14/3	84	1.40
6-23									
0100	39	2/180	5/5	10	39	3/200	5/5	15	1.50
0200	42	1/170	7/5	7	50	2/190	8/4	16	2.28
0300	43	3/180	7/5	21	61	4/190	10/4	40	1.91
0400	54	3/190	9/4	27	69	3/200	11/4	33	1.12
								Avg	1.44

Notes:

1. Range is 30-minute variation in direction.
2. $\bar{U}$ is 30-minute average wind speed, miles per hour.
3. D° is 30-minute average wind direction.
4. σ_θ is range divided by 6.
5. CAT is Slade stability category.
6. R is ratio $(\bar{U}\sigma_\theta)_{417}/(\bar{U}\sigma_\theta)_{47}$.

00054

Hence, it is likely that under light southerly winds, dilution over the aerodynamically rough, heated Dow Plant is, on the average, more than 40 percent greater than over the flat natural terrain. No credit is taken in the analysis for this dilution effect over the rough heated plant, but data from Saginaw Airport were used.

Although the weather record for the worst nine months was used to develop input data to the diffusion model, it is also of interest to compare these data with those obtained from the complete five-year Tri-City weather history. The stability wind roses versus wind direction for the nine months considered in the model and for the whole five years are given in Tables 2A-14a and 2A-14b, respectively.

The results show that the nine-month average has considerably poorer diffusion conditions than the five-year average. For example, calms occurred 6.3 percent of the time in nine months and only 4.0 percent of the time in the five years. The Pasquill F stability category occurs 18.4 percent of the time versus 11.9 percent for the five years. In both cases, the most frequent wind direction for all stability categories, as well as for the Pasquill F category is from the west to southwest. However, the maximum frequency of occurrence of Category F from any one direction is only 1.2 percent based on the first-year history.

The wind speeds as a function of Pasquill category for the nine-month and five-year records were also compared. In the nine-month record, wind speeds of seven knots or less occurred about 55 percent of the time and only about 39 percent of the time when the five-year record is considered. In both records, wind speeds in the range of four to seven knots occurred about 33 percent of the time during Category F conditions. Category F wind speeds of three knots (1.5 meters per second) or less, including calms and all wind directions, occurred only about 3.9 percent of the time in the five years.

The five-year data from Saginaw show that the mean wind speed under Category F conditions is about 2.5 mps. This is the same as the weighted mean wind speed used in the two-hour model (taken from nine-month history). Thus, the five years of data substantiate the speed used in the two-hour model.

TWO-HOUR DIFFUSION MODEL

Hourly meteorological data, Saginaw, from the nine worst months (identified in the previous section) were used to determine the hourly Pasquill category (by the method of Turner) and mean wind speed, $\bar{u}$. Each of the nights in these nine months was examined, and the worst consecutive two-hour period was selected on the basis of Pasquill category. The Table 2A-15 shows the results of the examination of some 270 nights. The first hour of the two-hour model is constituted of 81 percent Category F, 12 percent Category E, and 7 percent Category D. The second hour is composed of 71 percent F, 17 percent E and 12 percent D. The average hourly value of X/Q for a continuous point source, cps, was calculated as a function of range.

Table 2A-14a

Percent Frequency: Pasquill Category Vs Wind Direction
Saginaw FAA Airport, Nine Months

Wind Direction	Pasquill Category						
	A	B	C	D	E	F	Total
N	0.02	0.32	0.45	2.27	0.57	0.89	4.5
NNE	0.03	0.23	0.56	3.28	0.30	0.71	5.1
NE	0.02	0.32	0.54	4.38	0.30	0.82	6.4
ENE	0.02	0.21	0.42	2.34	0.22	0.57	3.9
E	0.06	0.26	0.32	2.12	0.50	0.88	4.1
ESE	0.06	0.16	0.07	0.77	0.14	0.45	1.7
SE	-	0.24	0.23	1.45	0.23	0.70	2.8
SSE	0.02	0.21	0.27	1.81	0.59	0.48	3.4
S	0.06	0.39	0.53	2.26	0.51	0.62	4.4
SSW	-	0.61	1.03	4.73	0.86	1.53	8.8
SW	0.04	0.77	1.15	5.79	1.03	1.86	10.6
WSW	0.04	0.59	0.88	5.55	1.06	1.51	9.6
W	0.08	0.66	1.93	6.83	1.22	2.18	12.9
WNW	0.02	0.21	0.44	3.28	0.45	0.73	5.1
NW	0.01	0.44	0.50	3.52	0.41	0.89	5.8
NNW	0.03	0.21	0.32	2.68	0.35	1.09	4.7
CALM	0.71	0.56	1.48	1.04	0.03	2.46	[illegible].3
Total	1.2	6.4	11.1	54.1	8.8	18.4	100

Note: Includes 6617 of a possible 6624 observations.

00056

Table 2A-14b

Percent Frequency: Pasquill Category Vs Wind Direction
Saginaw FAA Airport, 1962-1966

Wind Direction	Pasquill Category A	B	C	D	E	F	Total
N	0.02	0.21	0.42	2.44	0.54	0.64	4.3
NNE	0.02	0.21	0.44	2.89	0.39	0.40	4.4
NE	0.01	0.24	0.58	4.06	0.47	0.49	5.9
ENE	0.01	0.17	0.40	2.77	0.40	0.39	4.1
E	0.04	0.05	0.44	2.59	0.53	0.63	4.3
ESE	0.03	0.14	0.14	1.33	0.27	0.34	2.3
SE	0.02	0.15	0.22	1.65	0.27	0.42	2.7
SSE	0.02	0.13	0.26	1.99	0.43	0.32	3.1
S	0.02	0.22	0.48	3.87	0.69	0.52	5.8
SSW	0.02	0.24	0.73	5.16	0.95	0.83	7.9
SW	0.03	0.35	1.07	7.80	1.37	1.22	11.8
WSW	0.03	0.25	0.97	6.93	1.15	0.85	10.2
W	0.02	0.29	0.90	8.17	1.44	1.13	11.9
WNW	0.01	0.15	0.44	4.29	0.84	0.51	6.3
NW	0.01	0.20	0.49	4.07	0.71	0.66	6.1
NNW	0.01	0.15	0.39	3.14	0.50	0.67	4.9
CALM	0.36	0.27	0.62	0.87	0.01	1.89	4.0
Total	0.7	3.4	9.0	64.0	11.0	11.9	100

Note: Includes 42,480 observations of a total possible of 43,824.

00057

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Table 2A-15

Pasquill Stability Categories,
Two-Hour Model, Saginaw, Michigan

Pasquill Category	Category Frequency	Average Wind Speed Knots	Average Wind Speed m/s
First Hour			
F	0.81	4.1	2.2
E	0.12	6.3	3.3
D	0.07	9.2	4.7
		Mean	2.5
Second Hour			
F	0.71	3.9	2.1
E	0.17	6.6	3.4
D	0.12	7.7	4.0
		Mean	2.5
			-
		Two-Hour Mean	2.5

The data from Dow Building 417 at Midland were not used to develop the two-hour model; however, it was evaluated and compared with the Saginaw data for the same period of time (1966 data). The result of this evaluation showed that Category F occurred 1.0 to 10 percent of the time (depending on the Pasquill F content of Dow gustiness Category 3) at Building 417 and 15.3 percent of the time at Saginaw. It was also found that the wind frequency in the 4 to 12 knot range was about the same for both locations. Wind speeds of 3 knots or less, including calms, occurred about 18 percent of the time at Building 417 as compared to 13 percent at Saginaw. Mean wind speeds of 1.5 mps during Category F conditions occurred only 1.5 percent of the time at Building 417.

As previously mentioned, the lower frequency of Category F conditions at Dow Building 417 is considered to be due to the roughened and heated surfaces of other buildings in the vacinity of Building 417. Similarly, it is reasonable to assume that the diffusion of winds flowing from the site to the town of Midland will be greater than that used in the models because the Dow complex with its roughened and heated surfaces lies between the site and Midland.

From this comparison, it also appears that the frequency of Category F and the two-hour mean wind speed shown in Table 2A-15 are conservative.

To obtain the average hourly value of X/Q, including the effect of cavity diffusion, the dilution factor was employed, Figure 2A-11, for Category E, which is a conservative choice since experimental data indicate that the dilution factor for Category F should be larger. Thus, the resulting two-hour model is

Distance, m	X/Q_{cps}	Dilution Factor	Two-Hour Model X/Q, s/m^3
500	8.04×10^{-4}	4.2	1.9×10^{-4}
1,000	2.1×10^{-4}	1.9	1.1×10^{-4}
1,170	1.75×10^{-4}	1.7	1.0×10^{-4}
1,600	1.12×10^{-5}	1.5	7.5×10^{-5}
2,000	7.98×10^{-5}	1.3	6.1×10^{-5}
10,000	8.5×10^{-6}	1.03	8.3×10^{-6}
16,000	4.5×10^{-6}	1.0	4.5×10^{-6}
50,000	1.31×10^{-6}	1.0	1.3×10^{-6}

Again, for comparison purposes, X/Q probability roses were developed at one specified distance downwind for a continuous point source (cps) using the five-year weather data at Saginaw. The results are shown in Tables 2A-15a and 2A-15b. This study reveals that the X/Q value obtained from the nine-month data is more conservative, in a diffusion sense, than that obtained from the five-year data.

The cumulative percentage probability of the relative concentration (X/Q) being less than a specified value for a continuous point source is plotted in Figure 2A-11c. These data are based on the five-year history and a distance downwind of 1170 meters. From this curve, it is seen that the diffusion conditions will be more favorable than those used in the two-hour model (X/Q at 1170 meters) 93 percent of the time.

The X/Q roses developed from the five-year record reveal that the percentage probability of the two-hour diffusion model being exceeded in any one direction, again assuming a unidirectional wind for two hours, is less than one percent. See the West direction. This is less than the probability of a calm, which is 3 percent.

If the value of X/Q lies in the asymptote of Figure 2A-11c, the probability of its occurrence is near zero. It should be noted that, at the Midland plant site, the X/Q associated with the F category and a wind speed of 1 m/s does lie on this asymptote and thus has a probability of occurrence of a small fraction of a percent. This means that it is either calm or has a velocity greater than 1 mps. This is reasonable since the stalling speed on most airport anemometer systems is about 1.0 to 1.5 mps.

Table 2A-15a

Percent Frequency: X/Q Vs Direction Sector
Saginaw FAA Airport, Nine Months

From Sector	X/Q, 10^{-4}, 1170 Meters, s/m^3 0.002 to 0.07	0.071 to 1.0	1.01 to 2.75	2.76 to 4.45	4.46 to 5.50	9.50 to 11	Total
N	0.36	3.1	0.83	0.091	0.091	-	4.5
NNE	0.46	3.8	0.64	0.152	0.106	-	5.1
NE	0.42	4.4	0.53	0.120	0.167	-	5.6
ENE	0.27	2.9	0.46	0.140	0.046	-	3.8
E	0.23	2.6	0.94	0.167	0.076	-	4.0
ESE	0.18	1.0	0.33	0.076	0.015	-	1.6
SE	0.23	2.0	0.58	0.120	0.076	-	3.0
SSE	0.21	2.6	0.44	0.076	0.030	-	3.4
S	0.46	3.3	0.38	0.200	0.091	-	4.4
SSW	0.64	6.5	1.05	0.360	0.200	-	8.8
SW	0.93	7.6	1.80	0.140	0.046	-	10.5
WSW	0.91	7.8	1.45	0.130	0.030	-	10.3
W	1.25	9.7	1.88	0.320	0.106	-	13.3
WNW	0.26	4.0	0.56	0.091	0.061	-	5.0
NW	0.50	3.9	0.68	0.120	0.076	-	5.3
NNW	0.38	3.6	0.85	0.200	0.061	-	5.1
Calm	-	-	-	-	-	-	6.2
Total	7.7	68.8	13.4	2.5	1.3	0.0	100

Note: Hours used for development of two-hour model include 6589 of 6630 possible observations.

Table 2A-15b

Percent Frequency: X/Q Vs Direction Sector
Saginaw FAA Airport, 1962-1966

From Sector	X/Q, 10^{-4}, 1170 Meters, s/m^3 0.002 to 0.07	0.071 to 1.0	1.01 to 2.75	2.76 to 4.45	4.46 to 5.50	9.50 to 11	Total
N	0.28	3.1	0.64	0.037	0.035	0.0046	4.2
NNE	0.33	3.5	0.39	0.138	0.025	-	4.4
NE	0.43	4.7	0.48	0.064	0.058	-	5.7
ENE	0.26	3.4	0.36	0.064	0.032	-	4.1
E	0.31	3.3	0.54	0.133	0.048	-	4.1
ESE	0.17	1.6	0.28	0.046	0.021	-	2.1
SE	0.20	2.2	0.34	0.062	0.046	-	2.9
SSE	0.16	2.5	0.32	0.055	0.018	-	3.1
S	0.36	4.8	0.47	0.081	0.032	0.0023	5.8
SSW	0.42	6.5	0.73	0.129	0.044	-	7.9
SW	0.67	9.6	0.99	0.087	0.039	-	11.4
WSW	0.58	10.8	0.78	0.090	0.023	0.0023	12.3
W	0.60	10.4	1.02	0.099	0.048	-	12.2
WNW	0.27	4.9	0.49	0.062	0.016	0.0023	5.8
NW	0.45	5.1	0.58	0.074	0.021	-	6.2
NNW	0.23	3.8	0.60	0.067	0.014	-	4.7
Calm	-	-	-	-	-	-	3.0
Total	5.7	80.2	9.0	1.3	0.52	0.01	100

Note: Includes 43,448 of 48,800 possible observations.

In Figure 2A-11c, the asymptote located at (100 percent - percent of calms) is of special interest in that the accumulated percentage probability of X/Q being equal to or less than a given value is very steep near this asymptote. The steepness reflects an important characteristic of the diffusion climatology of the plant site: namely, either the wind conditions are calm (3.2 percent probability) or there is a 93 percent chance that diffusion conditions for a cps are such that $X/Q \leq 1.75 \times 10^{-4}$ s/m^3 (the two-hour model without correction for cavity diffusion).

The (X/Q) cps probability distribution, percentage frequency of Pasquill F category, and the X/Q probability distribution, including the effects of cavity diffusion for a single reactor building as a function of Pasquill F category, is presented in Figure 2A-11d in a single frequency diagram. From this plot, it is seen that, during 93 percent of the time, diffusion conditions are more favorable than represented by the two-hour model. This diagram shows that, when the wind velocity, u, is greater than the stalling speed of the anemometer, the odds are 93 to 4 that the diffusion conditions are better than shown in the two-hour model. Pasquill F and 1 mps wind speed for two hours lead to a value of X/Q whose probability of occurrence is about 10^{-2}.

The previous discussion of X/Q probability distributions was based on Saginaw data and Turner classification of stability. It is now pertinent to compare, for a common time period, the X/Q distributions for Turnerized Saginaw data (Table 2A-15a) and Sladeized data from Dow, Building 47 (Table 2A-15b). Building 47 was selected instead of Building 417 because it is located on the edge of the Dow property instead of in the center of the plant and presumably is less affected by the plant.

An examination of the data in Tables 2A-15c and 2A-15d indicates that the X/Q distribution at Dow is shifted toward lower values of the relative concentration in comparison with Saginaw. This is reflected in an increase in percentage frequency from 5.9 percent at Saginaw to 50.4 percent at Dow for X/Q between 0.002 and 0.07×10^{-4}. This feature also occurs in the other columns. In the range of X/Q of 1.01 to 2.76×10^{-4}, the shift in frequency of occurrence is of particular interest in that this is the range in which the two-hour model lies.

The reduced percentage frequency at Dow in the directions of North-Northwest to East corresponds to flow over the town area, and presumably increased mechanical turbulence. The airflow from the directions East through South comes from over the Dow plant, a rough, heated area. The percentage frequency of the X/Q's at Dow for these directions is reduced in comparison with Saginaw.

Some of the differences between Tables 2A-15c and 2A-15d in the distributions of X/Q could be due to differences between the Slade and Turner methods of analysis; compare the distributions for the NW quadrant which, at Dow, is open. However, the reductions in the other quadrants cited above are much greater than this. They are probably real and result from increased diffusion in the air that passed over aerodynamically rough heated areas. It should also be

Table 2A-15c

Percent Frequency: X/Q Vs Direction Sector
Saginaw FAA Airport, 1968

From Sector	X/Q, 10^{-4}, 1170 Meters, s/m^3 0.002 to 0.07	0.071 to 1.0	1.01 to 2.75	2.76 to 4.45	4.46 to 5.50	9.50 to 11	Total
N	0.33	4.3	0.46	0.103	-	-	5.2
NNE	0.29	2.1	0.33	0.046	0.034	-	2.8
NE	0.25	4.0	0.37	0.057	0.023	-	4.7
ENE	0.23	3.4	0.31	0.091	-	-	4.0
E	0.38	3.5	0.43	0.068	-	-	[illegible].4
ESE	0.26	2.5	0.51	0.057	0.011	-	3.3
SE	0.18	2.6	0.19	0.023	-	-	3.0
SSE	0.21	3.2	0.32	0.034	0.011	-	3.8
S	0.67	8.0	0.57	0.057	0.023	-	9.3
SSW	0.48	7.6	0.74	0.068	-	-	8.9
SW	0.58	8.1	0.90	0.034	0.023	-	9.6
WSW	0.57	10.1	0.65	0.011	-	-	11.3
W	0.66	10.8	0.67	0.080	0.011	-	12.2
WNW	0.18	5.8	0.45	0.034	0.011	-	6.5
NW	0.33	5.5	0.41	0.023	-	-	6.3
NNW	0.27	3.4	0.51	0.068	0.023	-	4.3
Calm	-	-	-	-	-	-	0.4
Total	5.9	84.9	7.8	0.85	0.17	0.0	100

Note: Includes 8,762 of 8,784 possible observations.

00063

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$$(X/Q)_{24\ h\ model} = (X/Q)_{cps} \cdot \frac{7.5}{24} \div DIL_{CAT\ E}$$

where $(X/Q)_{cps}$ is equal to $1/\pi\ \sigma_y\ \sigma_z\ \bar{u}$ as a function of distance,

$DIL_{CAT\ E}$ is the dilution factor for Category E.

Thus, the resulting 24-hour model is

Range, m	$(X/Q)_{cps}$	Dilution Factor	24-Hour Model X/Q, s/m³
500	4.4×10^{-4}	4.2	3.1×10^{-5}
1,000	1.3×10^{-4}	1.9	2.2×10^{-5}
1,170	1.0×10^{-4}	1.7	1.8×10^{-5}
1,600	6.3×10^{-5}	1.5	1.3×10^{-5}
2,000	4.3×10^{-5}	1.3	1.0×10^{-5}
10,000	4.2×10^{-6}	1.03	1.3×10^{-6}
16,000	2.5×10^{-6}	1.0	7.8×10^{-7}
50,000	6.8×10^{-7}	1.0	2.1×10^{-7}

The X/Q values presented above were developed from the nighttime weather record because Turner's method of categorizing hourly weather data does not permit Pasquill F's to be determined in the daytime. Thus, an independent study was made on the 1966 radiosonde 7:00 PM data of Flint, Michigan, to develop information on daytime temperature inversions. This study revealed that there were 31 cases of daytime inversions during the year. This is 8.6 percent of the days. The highest frequency of daytime inversions occurs in winter (10 events) and spring (11 events) seasons. Examination of these 21 cases revealed that 18 had winds in excess of 2 mps; this eliminates them from the Class F category. This implies, therefore, that the chance of having daytime Pasquill Class F category is about one percent.

Table 2A-16

Pasquill Stability Categories, 24-Hour Model, for Saginaw, Michigan

Wind	A		B		C		D		E		F		All	
Dir	%f	ū	%f	ū	%f	ū	%f	ū	%f	ū	%f	ū	%f	ū
N	0		.2	5.0	0		.5	4.5	0		2.1	3.9		4.08
NNE	0		.2	4.0	.3	9.0	1.6	8.0	0		2.1	4.2	2.8	5.95
NE	0		.2	2.0	.7	2.7	1.6	7.0	.3	6.0	2.8	6.2	4.2	4.84
ENE	0		.2	5.0	.5	7.5	1.0	8.0	0		.9	4.5	5.6	6.32
E	0		1.0	4.25		6.3	2.1	6.1	.9	6.0	3.2	4.6	2.6	5.2
ESE	0		.2	6.0	[illegible]	6.0	.7	8.7	0		3.5	3.3	8.6	4.42
SE	0		.5	4.5	.7	3.67	.7	6.3	.2	5.0	2.1	4.3	4.9	4.61
SSE	0		.7	3.67	.2	4.0	.9	4.5	.2	7.0	.5	3.5	4.2	4.3
S	0		1.4	4.17	1.2	5.8	.2	8.0	0		1.6	3.4	2.5	4.52
SSW	0		1.2	5.4	.7	6.67	1.6	5.6	.3	9.0	2.5	3.6	4.4	5.0
SW	0		1.6	3.86	3.0	6.0	3.0	5.2	0		2.6	4.9	6.3	5.16
WSW	0		.5	4.5	2.3	6.4	1.0	5.5	.2	4.0	2.3	4.4	10.2	4.94
W	0		3.0	3.61	4.6	7.05	2.8	6.1	.5	5.5	4.4	3.9	6.3	5.26
WNW	0		0		.2	3.0	.7	5.3	0		1.6	3.3	15.3	3.82
NW	0		0		.9	3.5	.2	4.0	0		.5	3.0	2.5	3.43
NNW	0		0		.2	3.0	.2	15.0	0		2.1	3.4	1.6	4.43
Calm	1.2		1.6		3.2		.2		0		9.3		2.5	
													15.5	
%/ū	1.2		12.5	3.6	20.6	4.4	19.0	7.1	2.6	6.0	44.1	3.1	100.0	4.2

Notes:

1. 24 hours taken from 18 selected days from 5 selected years, 1962-1966.
2. ū is average wind speed, knots.
3. % is percent of total observations.
4. Total number of observations is 431.

00065

THE ONE-MONTH DIFFUSION MODEL

The one-month diffusion model is derived by a method similar to that of the 24-hour model. For the nine identified worst months, a Pasquill category rose and the associated $\bar{u}$ have been developed. This in turn, in a manner similar to that discussed for the 24-hour model, is converted to a continuous point source X/Q rose for 16 directions as a function range, x. See Table 2A-17. The poorest diffusion conditions are found to be Category D, $\bar{u}$ = 5.6 knots for an east-southeast direction. From monthly wind roses, it is found that the maximum frequency of a single wind direction is 19 percent for west-southwest in the month of December(3). Hence, at a given range x, the average hourly value of the relative concentration is

$$(X/Q)_{1\ month} = (X/Q)_{cps} \cdot \frac{19}{100} \div DIL_{CAT\ D}$$

where $(X/Q)_{cps}$ from the east-southeast has been calculated as a function of range x and $DIL_{CAT\ D}$ is taken from "faired-in" dilution factor curve in Figure 2A-11. The resulting one-month diffusion model is

Range, m	$(X/Q)_{cps}$	Dilution Factor$_{CAT\ D}$	One-Month Model X/Q, s/m^3
500	1.52×10^{-4}	2.60	1.1×10^{-5}
1,000	4.46×10^{-5}	1.75	0.5×10^{-5}
1,170	3.5×10^{-5}	1.60	0.4×10^{-5}
1,600	1.9×10^{-5}	1.2	0.3×10^{-5}
2,000	1.7×10^{-5}	1.30	0.2×10^{-5}
10,000	1.2×10^{-6}	1.03	0.2×10^{-6}
16,000	0.5×10^{-6}	1.0	0.1×10^{-6}
50,000	1.33×10^{-7}	1.0	0.2×10^{-7}

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Amendment No. 5
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Table 2A-17

Pasquill Stability Categories, One Month Model, for Saginaw, Michigan

Wind	A		B		C		D		E		F		All	
Dir	%f	$\bar{u}$	%f	$\bar{u}$	%f	$\bar{u}$	%f	$\bar{u}$	%f	$\bar{u}$	%f	$\bar{u}$	%f	$\bar{u}$
N	+	0.5	.3	4.0	.5	5.3	2.3	7.9	.5	8.3	.8	4.4	4.4	6.7
NNE	.1	4.5	.2	4.9	.5	7.2	3.3	9.4	.3	5.3	.8	4.8	5.2	7.7
NE	+	4.0	.3	5.0	.4	7.7	4.1	8.4	.2	5.7	.7	4.1	5.7	7.5
ENE	+	5.0	.2	4.7	.3	6.3	2.5	8.3	.2	5.6	.7	4.3	3.9	7.1
E	.1	4.0	.3	4.6	.3	5.6	2.1	6.9	.4	6.0	1.1	4.5	4.3	5.9
ESE	+	3.5	.2	5.3	.1	5.4	.8	6.5	.1	5.7	.5	4.5	1.7	5.6
SE	0	0	.2	4.5	.3	5.6	1.5	7.2	.2	5.5	.8	4.5	3.0	6.0
SSE	+	3.0	.2	5.3	.3	5.3	1.8	7.7	.6	7.1	.5	4.4	3.4	6.8
S	+	4.0	.4	4.8	.6	6.8	2.3	8.4	.5	7.4	.6	3.8	4.4	7.2
SSW	0	0	.6	5.2	1.0	6.7	4.1	8.6	.9	6.6	1.6	4.0	8.2	7.0
SW	+	4.5	.7	5.1	1.4	7.1	5.9	8.4	1.1	6.5	1.9	4.7	11.0	7.2
WSW	+	4.0	.5	5.2	1.2	7.6	5.8	9.4	1.1	7.4	1.6	5.0	10.2	8.1
W	.1	4.8	.8	4.8	1.9	7.2	7.2	8.5	1.2	7.5	2.2	4.7	13.4	7.3
WNW	+	5.0	.2	4.4	.4	5.2	3.1	10.2	.5	7.3	.6	4.4	4.9	8.5
NW	+	3.0	.4	5.1	.5	5.5	3.3	8.8	.4	6.1	.7	4.4	5.3	6.7
NNW	.1	4.0	.2	3.9	.3	6.1	2.7	9.4	.4	7.0	.9	4.5	4.6	7.7
Calm	.7		.6		1.5		1.1		0		2.5		6.4	
%/$\bar{u}$	1.2	1.6	6.3	4.5	11.5	5.8	53.9	8.4	8.6	6.9	18.5	3.9	100.0	6.8

Notes:

1. All days from nine selected months of five years, 1952-1966.
2. $\bar{u}$ is average wind speed, knots.
3. % is percent of total observations.
4. Total number of observations is 6,508.

ANNUAL MODEL

It is suggested, for simplicity's sake, that the annual model be constructed by scaling the average hourly value of X/Q by the ratio of the $\bar{u}$ values of the respective models; namely, $\bar{u}_{30\ day}/\bar{u}_{Annual}$: $(2.9/5.1)$ times the X/Q value from the 30-day model. Hence, the annual model is

Range, Meters	Annual Model X/Q, s/m^3
500	0.6×10^{-5}
1,000	0.3×10^{-5}
1,170	0.2×10^{-5}
1,600	0.1×10^{-5}
2,000	0.1×10^{-5}
10,000	0.1×10^{-6}
16,000	0.5×10^{-7}
50,000	0.1×10^{-7}

SUMMARY, SITE DISPERSION FACTORS

Table 2A-18 shows the site dispersion factors, average hourly X/Q versus distance, for the two-hour, twenty-four-hour, one-month and annual diffusion models. The exclusion boundary is 500 meters from the plant. The X/Q values shown in Table 2A-18 were all calculated as discussed in the earlier portions of this chapter.

Table 2A-18

Summary Relative Concentrations

Average Hourly $X/Q = 1/(\pi\ \sigma_y\ \sigma_z\ \bar{u})\ (f)/(DIL_{CAT})$

Distance, Meters	X/Q, s/m^3			
	2-Hour	24-Hour	1-Month	1-Year
500	1.9×10^{-4}	3.1×10^{-5}	1.1×10^{-5}	0.6×10^{-5}
1,000	1.1×10^{-4}	2.2×10^{-5}	0.5×10^{-5}	0.3×10^{-5}
1,170	1.0×10^{-4}	1.8×10^{-5}	0.4×10^{-5}	0.2×10^{-5}
1,600	7.5×10^{-5}	1.3×10^{-5}	0.3×10^{-5}	0.1×10^{-5}
2,000	6.1×10^{-5}	1.0×10^{-5}	0.2×10^{-5}	0.1×10^{-5}
10,000	8.3×10^{-6}	1.3×10^{-6}	0.2×10^{-6}	0.1×10^{-6}
16,000	4.5×10^{-6}	7.8×10^{-7}	0.1×10^{-6}	0.5×10^{-7}
50,000	1.3×10^{-6}	2.1×10^{-7}	0.2×10^{-7}	0.1×10^{-7}

f is frequency factor applied to all X/Q except 2-hour model.

Note: DIL_{CAT} is the dilution factor for the effect of the reactor building.

Calculations have also been made using the cavity dilution factors considered "reasonable" by the Environmental Meteorology Branch of ESSA, in its comments the meteorology analysis of the Zion Station Units 1 and 2. The dilution factors are compared with those used in the Midland models and are presented below.

	Zion	Midland Plant: 2-Hour, 24-Hour	Midland Plant: One-Month
300 Meters	4.8	Not Used	Not Used
415 Meters	3.3	Not Used	Not Used
500 Meters	(2.75)	4.2	2.6
600 Meters	2.4	(3.2)	(2.4)
1000 Meters	1.5	1.9	1.75

To determine the significance of the difference in these dilution factors, the relative concentration (X/Q) for Midland was calculated using the Zion cavity dilution factors. These values are compared with the X/Q values to be used in the Midland Plant radiological analysis in Table 2A-18a.

Table 2A-18a

Summary Relative Concentrations

Average Hourly $X/Q = 1/(\pi \sigma_y \sigma_z \bar{u})$ (DF)

Distance, Meters	2-Hour Orig DF	2-Hour Zion DF	24-Hour Orig DF	24-Hour Zion DF	1-Month Orig DF	1-Month Zion DF	1-Year Orig DF	1-Year Zion DF
	X/Q, sec/m^3							
400	2.1^{-4}	3.5^{-4}	3.4^{-5}	5.4^{-5}	1.3^{-5}	1.1^{-5}	0.7^{-5}	0.6^{-5}
500	1.9^{-4}	2.8^{-4}	3.1^{-5}	4.6^{-5}	1.1^{-5}	1.0^{-5}	0.6^{-5}	0.6^{-5}
1,000	1.1^{-4}	1.5^{-4}	2.2^{-5}	2.6^{-5}	0.5^{-5}	0.6^{-5}	0.3^{-5}	0.4^{-5}
1,170	1.0^{-4}	1.3^{-4}	1.8^{-5}	2.2^{-5}	0.4^{-5}	0.5^{-5}	0.2^{-5}	0.3^{-5}
1,600	$.5^{-5}$	9.0^{-5}	1.3^{-5}	1.5^{-5}	0.3^{-5}	0.3^{-5}	0.1^{-5}	-
2,000	6.1^{-5}	6.8^{-5}	1.0^{-5}	1.2^{-5}	0.2^{-5}	-	0.1^{-5}	-
10,000	8.3^{-6}	-	1.[illegible]$^{-6}$	-	0.2^{-6}	-	0.1^{-6}	-
16,000	4.5^{-6}	-	7.8^{-7}	-	0.1^{-6}	-	0.5^{-7}	-
50,000	1.3^{-6}	-	2.1^{-7}	-	0.2^{-7}	-	0.1^{-7}	-

Note:
1. DF is the dilution factor for the aerodynamic wake effect of the reactor building.
2. Orig DF is the X/Q originally shown in the Midland Plant PSAR, brought to 400 meters.
3. Zion DF is a new X/Q related to the Midland Plant analysis using DF's adopted from the Zion PSAR.
4. 2.1^{-4} means 2.1×10^{-4}.

2 INFORMATION TO BE OBTAINED

A meteorological monitoring program will be conducted at the Midland Plant site. The program will provide data with which to evaluate and, if necessary, upgrade the meteorological diffusion estimates presented in Section 2.3 and Appendix 2A.

Meteorological data will be obtained from three meteorological towers (one 300-foot tower and two ten-meter towers) located on or adjacent to the plant site (reference Figures 2A12, 2A13, 2A14 and 2A15). The sensitivity of the detection instrumentation and the instrument location on the towers are in compliance with Regulatory Guide 1.23. At least one year's data will be collected and evaluated prior to issuance of the Midland Plant final safety analysis report.

TOWER LOCATION, SENSOR SPECIFICATION, DATA RECORDING AND ACCURACY

The specific location of each tower and the data to be obtained together with the measuring systems and overall accuracies are discussed below.

300-Foot Tower

27 The 300-foot tower will be located in the nonmanual parking lot, north of the lay-down area, about 1,150 feet west of the nearest reactor building (reference Figures 2A12 and 2A14). The distances from the tower to the pond dikes are about 1,200 feet to the south and 1,050 feet to the southeast. The elevation of the top of the dike is 632 feet and the elevation of the base of the tower is 614 feet. The grade level at the reactor building is at 634 feet. The top of the building is 787 feet.

Bullock Creek diversion flows from southwest to northeast in the area west of the tower location. The diversion is 150 feet wide at its banks. The bed of the diversion gradually slopes down from its banks toward the central bottom (15 feet wide) at elevation 592 feet. The distance from the tower to the eastern bank of the diversion is about 50 feet. The tops of its western and eastern banks are, respectively, 616.5-foot and 614-foot elevations. Two ponds owned by Dow Chemical Company (one existing and one to be filled in 1974) are located in the area west of the diversion (reference Figure 2A13). The two ponds cover about 350 acres. The temporary construction offices stand east of the tower location on an elevated area of 634 feet elevation. The distance from the tower to the elevated area is about 450 feet. The road which runs to the northeast from Miller Road between the nonmanual parking and the lay-down area is 300 feet south of the tower. The north-south road directly east of the nonmanual parking area is 275 feet east of the tower location.

Since space is limited at the Midland Plant site, the tower will be located in the nonmanual parking lot. However, no automobiles will park within the area which will be fenced out from the parking lot (reference Figure 2A15). The distance from the tower base to the nearest cars parked just outside the fence is 130 feet. Besides, no cars will park in the area west and north of the tower where the Bullock Creek diversion flows.

The meteorological variables to be measured on the 300-foot tower are:

10-Meter Level - U, $T\mu$, E, θ, σ
40-Meter Level - U, $T\mu$, E
60-Meter Level - U, $T\mu$, E, θ, σ
300-Foot Level - U, $T\mu$, E

where:
U = Wind Speed
$T\mu$ = Ambient Air Temperature
E = Dew Point
θ = Wind Direction
σ = Wind Direction Fluctuation (Standard Deviation)

Table 2A19 shows the quantity, manufacturer, model number and the specifications of the sensors used on the tower. All wind direction and speed sensors will be mounted at least two tower widths from the tower and each sensor will be six feet or more from any other sensor. Temperature and dew point sensors will be at least one tower width from the tower.

27 An EG&G digital system is planned to convert the sensor outputs to 15-minute average data reports, in engineering units, for the above-mentioned variables. In addition, the temperature differences $(\Delta T)_{40m - 10m}$, $(\Delta T)_{60m - 10m}$ and $(\Delta T)_{300 ft - 10m}$ are computed from the measured temperatures and included in the data reports. The data reports are automatically listed on an ASR-33 teletype printer and recorded on an IBM compatible, 9-track, 800 BPI, magnetic tape. The digital system includes an Interdata Model 7/16 processor of 32K byte memory module and 16 general registers. The processor polls the sensors approximately four times per minute. Following each poll, a 15-minute average is computed. This feature allows a rapid assessment of the measured meteorological variables because a data report is immediately available upon request.

Eight dual-channel strip chart recorders (Esterline Angus Model 1102S) will be utilized to produce the analog records of the measured variables as a backup to the digital system. Instead of recording the ambient air temperatures measured at the 300-foot, 60-meter and 40-meter levels, the temperature differences $(\Delta T)_{40m - 10m}$, $(\Delta T)_{60m - 10m}$ and $(\Delta T)_{300\text{-}ft - 10m}$ are recorded on the strip charts, along with the temperature at the 10-meter level. The full scale of ΔT is $10^{\circ}C$. Each analog recorder has a 10-inch wide chart paper running at a speed of 4 inches per hour. The direct recording of temperature difference will provide an accuracy of within $\pm 0.1^{\circ}C$.

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All data receiving and recording equipment for the 300-foot tower is located in an environmentally controlled structure at the base of the tower. The accuracy of a measured variable depends upon the sensor, the electronics and the recording equipment used. The overall accuracies of the measured variables on the 300-foot tower are estimated as follows:

Wind Speed - Better than ± 0.5 mph up to 48 mph wind speed for both automatic and backup recordings.

Wind Direction - ± 3.2° over range from 0° to 356° for both automatic and backup recordings.

Temperature - ± 0.04°C on temperature measurement over range from -50°C to 50°C, and ± 0.06°C on temperature difference for automatic recording, ± 0.07°C on temperature difference for backup recording.

Dew Point - ± 0.4°C over range from -50°C to 50°C for automatic recording and ± 0.5°C for backup
27 recording.

<u>10-Meter Towers</u>

Data from the two 10-meter towers will be used to supplement the data from the 300-foot tower. Each 10-meter tower station will have instrumentation to measure wind speed, wind direction, ambient air temperature and relative humidity.

<u>10-Meter Tower No 1</u>

This tower is located about 800 feet northeast of the reactor building on the bank of the Tittabawassee River. The specific purpose of this tower is to provide meteorological data for winds from the northeast quadrant after they have traversed the Dow Chemical Co plant site and the Tittabawassee River. The base of the tower is 600-foot elevation. The water level in the Tittabawassee River is estimated to be about 590 feet about 50% of the year.

<u>10-Meter Tower No 2</u>

This tower is located about 6,600 feet south of the reactor building and about 400 feet south of the cooling and storage pond dike. It will provide information concerning winds with southerly components before they are possibly affected by the cooling pond. The elevation of the base of the tower is 628 feet. The elevation of the top of the dike, 400 feet to the north, is 632 feet.

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Table 2A20 shows the quantity, the manufacturer, the model number and the specifications of the sensors used at each of the 10-meter tower stations. The wind speed (Climet WS-011-1) and direction (Climet WD-012-30) sensors will be located on top of the 10-meter tower six feet apart. A Climet Model 025-9 weatherproof portable (battery powered) translator will be used in the wind measurements. An Esterline Angus Model No A601C recorder will provide the analog records of the wind speed and direction measured at each 10-meter tower. The recorder uses a 6-inch wide chart paper running at a speed of four inches per hour. The translator and the analog recorder will be housed in an environmentally sealed enclosure (36" x 30" x 16").

The ambient air temperature and relative humidity at each 10-meter tower station will be measured and recorded by Science Associates Inc, No 255 hygrothermograph. The recorder drive is spring-driven and can last for a period of eight days. The hygrothermograph will be housed in a Weather Measure ISI instrument shelter which will be located in the vicinity of the 10-meter tower.

No automatic digital data acquisition equipment is planned to record data for the two 10-meter tower stations.

27 The overall accuracies of the wind speed, wind direction, air temperature and relative humidity measured at each of the 10-meter tower stations are estimated as follows:

Wind Speed	- Better than ± 0.5 mph up to 33 mph wind speed.
Wind Direction	- ± 4.9° over range from 0° to 356°.
Temperature	- ± 1°F.
Relative Humidity	- ± 3%.

MAINTENANCE AND CALIBRATION

In order to assure the accuracy of the measured variables and to minimize the loss of data, instrument maintenance services will be made at least twice weekly and calibrations made semiannually for the 300-foot tower and the two 10-meter tower stations. It is planned that a full-time technologist will be on site during the tower operation to perform the maintenance services.

During the maintenance services, inkwells and pens are filled, chart paper changed and recorder drives wound, if necessary. A visual inspection of the sensors, signal conditioning equipment and recorders is made. Any necessary adjustments are made on site. Any malfunctions are either corrected on site or removed for repair. An inventory of spare parts, including wind speed and direction sensors, various signal conditioning cards, analog recorder, and so forth, will be stored on or adjacent to the site for immediate replacement. After adjustments or repairs, a calibration is performed if required. Routine cross-checks between the strip chart records and the digital system printouts are also made to minimize any potential period of invalid sampling. Routine maintenance on individual instruments is performed in accordance with manufacturer's operation and maintenance procedures.

Every six months, all sensors, electronics and recording equipment for both the 300-foot tower and the two 10-meter tower stations are calibrated. Hygrothermographs are compared and adjusted to an Assman psychrometer. The temperature sensor is calibrated by immersing the sensor in a laboratory temperature bath and reading the resistance of the sensor. The calibration data are plotted and checked for linearity and drift. The dew point sensor is calibrated using precision analog test equipment. The dew point temperature resistance output is measured, converted to temperature, and compared to dew point temperature as calculated from relative humidity measurements taken with an Assman psychrometer.

The wind speed transmitter with cup is calibrated at several given speeds
starting from the sensor threshold. The pulse output of the sensor is
27 counted for each given speed. The calibration data are plotted and
checked for linearity and drift, and the bearings are replaced.

The wind direction transmitter with vane is placed in the center of a polar coordinate jig and resistance readings are taken every 10°. The data are plotted and checked for linearity, and the bearings are replaced. The total resistance of the sensor is measured and compared to the previous measurement to detect wear of the potentiometer. If necessary, the potentiometer is replaced. After obtaining satisfactory results from linearity and torque tests, the balance of the vane is checked.

The electronics and recording systems are calibrated in accordance with manufacturer's procedures using precision test equipment, laboratory potentiometer or other measurement devices.

DATA ANALYSIS PLAN

The meteorological data obtained from the 300-foot tower with the supplemental data measured from the two 10-meter towers will be used primarily to develop the diffusion models applicable to the site. Monthly and annual frequencies of wind speed and direction by atmospheric stability as well as the long-term (annual) X/Q estimates as a function of wind direction and downwind distance will be obtained using hourly data for each of the following stations:

i) 300-Foot Tower

ii) Each 10-Meter Tower

The hourly data are composed of at least one 15-minute average per hour. The frequencies and the long-term X/Q for the 300-foot tower will be obtained with atmospheric stabilities determined separately by vertical temperature gradient and by standard deviation of the horizontal wind direction fluctuations. Wind speed and direction measured at the 10-meter level, and temperature difference data between the 60- and 10-meter levels will be used. The temperature difference data are converted to vertical temperature gradient and used in determining atmospheric stability. The classification of atmospheric stability in terms of vertical temperature gradient will be in accordance with Regulatory Guide 1.23.

The frequencies and the long-term X/Q for each 10-meter tower will be obtained with atmospheric stability determined by standard deviation. Wind speed and direction measured from the 10-meter tower will be used. The standard deviations used in determining atmospheric stability for the 300-foot tower and for the 10-meter towers are, respectively, obtained by dividing the corresponding wind direction range by a constant of 6.0. The ranges will be extracted from wind direction traces recorded on the strip charts. The atmospheric stability will be classified in terms of standard deviation (σ) as follows:

27

Pasquill Category	Range of Standard Deviation, Degrees
A	$\sigma \geq 22.5$
B	$22.5 > \sigma \geq 17.5$
C	$17.5 > \sigma \geq 12.5$
D	$12.5 > \sigma \geq 7.5$
E	$7.5 > \sigma \geq 3.8$
F	$3.8 > \sigma \geq 2.1$
G	$\sigma < 2.1$

Air arriving at the 300-foot tower from northeast through east to southwest will have traveled over buildings, dikes and construction facilities. The long-term X/Q obtained from the 300-foot tower data with stability determined by vertical temperature gradient and by standard deviation of the 10-meter wind direction fluctuations will be compared to the long-term X/Q obtained from the No 1 10-meter tower data for each of the wind direction sectors lying from northeast to east; and compared to the long-term X/Q obtained from the No 2 10-meter tower data for each of the sectors lying from east southeast to southwest. The highest X/Q found through the comparison for a given sector will be used as the long-term X/Q applicable to the site for that sector. For any wind direction sector outside the range from northeast through east to southwest, the long-term X/Q obtained from the 300-foot tower data with stability determined by vertical temperature gradient will be considered as applicable to the site.

Cumulative frequency distributions of X/Q will be calculated for the 0-8
hour time period assuming invarient winds and for 16-hour, 3-day and
26-day time periods assuming variant winds. These distributions will
be obtained separately for the 300-foot tower and for the two 10-meter
towers. Hourly data of wind speed, wind direction and stability will
be used in this calculation. Again for the 300-foot tower, the calcu-
lation will be performed with stability determined by vertical tempera-
ture gradient and by standard deviation. The 5% and 50% probability
level X/Q will be calculated for each time period and for each of the
three tower stations. The meteorological conditions for the short-term
27 (accident) diffusion estimates for the site will be the conditions which
yield the highest (conservative) value of the 5% probability level X/Q
calculated for the three tower stations.

In addition, monthly and annual frequencies of wind speed and direction by atmospheric stability with stability determined by vertical temperature gradient will be obtained using the 60-meter wind speed and direction, and the temperature difference between the 60- and 10-meter levels. Data from the 300-foot tower and from the 10-meter towers will be used for the analysis of cooling pond fog potential.

TABLE 2A-19
Sensors Used on 300-Foot Meteorological Tower

Sensor	Quantity	Manufacturer	Model Number	Specifications	
Wind Speed	4	Climet	Model WS-011-1	Threshold Level:	0.6 MPH
				Calibrated Range:	0.6 to 90 MPH
				Accuracy:	± 1% or 0.15 MPH, Whichever Is Greater
				Distance Constant:	5 Ft
Wind Direction	2	Climet	Model WD-012-30	Threshold:	0.75 MPH
				Range:	Electrical, 0-356° Mechanical, 360° Continuous
				Accuracy:	± 3°
				Linearity:	± 0.5% of Full Scale
				Delay Distance:	< 1 Meter
				Damping Ratio:	0.4 Standard
Temperature	4	Rosemount Eng Co	Model 171 Series Platinum Resistance Temperature Sensor	Stability:	Better Than 0.01° C for One Year
				Accuracy:	± 0.02°C Including the RSS Errors of Calibration, Repeatability, Stability and Pressure

27

TABLE 2A-19

Sensors Used on 300-Foot Meteorological Tower (Contd)

Sensor	Quantity	Manufacturer	Model Number	Specifications	
Temperature (Contd)		R. M. Young Co	Model 43404 Gill Aspirated Temperature Radiation Shield	Accuracy:	Better Than ± 0.05°C
				Aspirated Rate:	10-30 FPS Air-Wash Over Sensor, Air Drawn From not More Than 3 in From Shield Intake in 1 MPH Wind
Dew Point	4	EG&G, Inc	Model 110S-M	Range:	-80°F to 120°F
				Accuracy:	± 0.5°F (0.28°C)

TABLE 2A-20
Sensors Used on Each 10-Meter Tower Station

Sensor	Quantity	Manufacturer	Model Number	Specifications	
Wind Speed	1	Climet	Model WS-011-1	Threshold Level:	0.6 MPH
				Calibrated Range:	0.6 to 90 MPH
				Accuracy:	± 1% or 0.15 MPH, Whichever Is Greater
				Distance Constant:	5 Feet
Wind Direction	1	Climet	Model WD-012-30	Threshold:	0.75 MPH
				Range:	Electrical, 0-356° Mechanical, 360° Continuous
				Accuracy:	± 3°
				Linearity:	± 0.5% of Full Scale
				Delay Distance:	1 Meter
				Damping Ratio:	0.4 Standard
Air Temperature and Relative Humidity	1	Science Associates Inc	Model No 255 Hygrothermograph	Accuracy:	± 1°F on Temperature ± 3% on Relative Humidity

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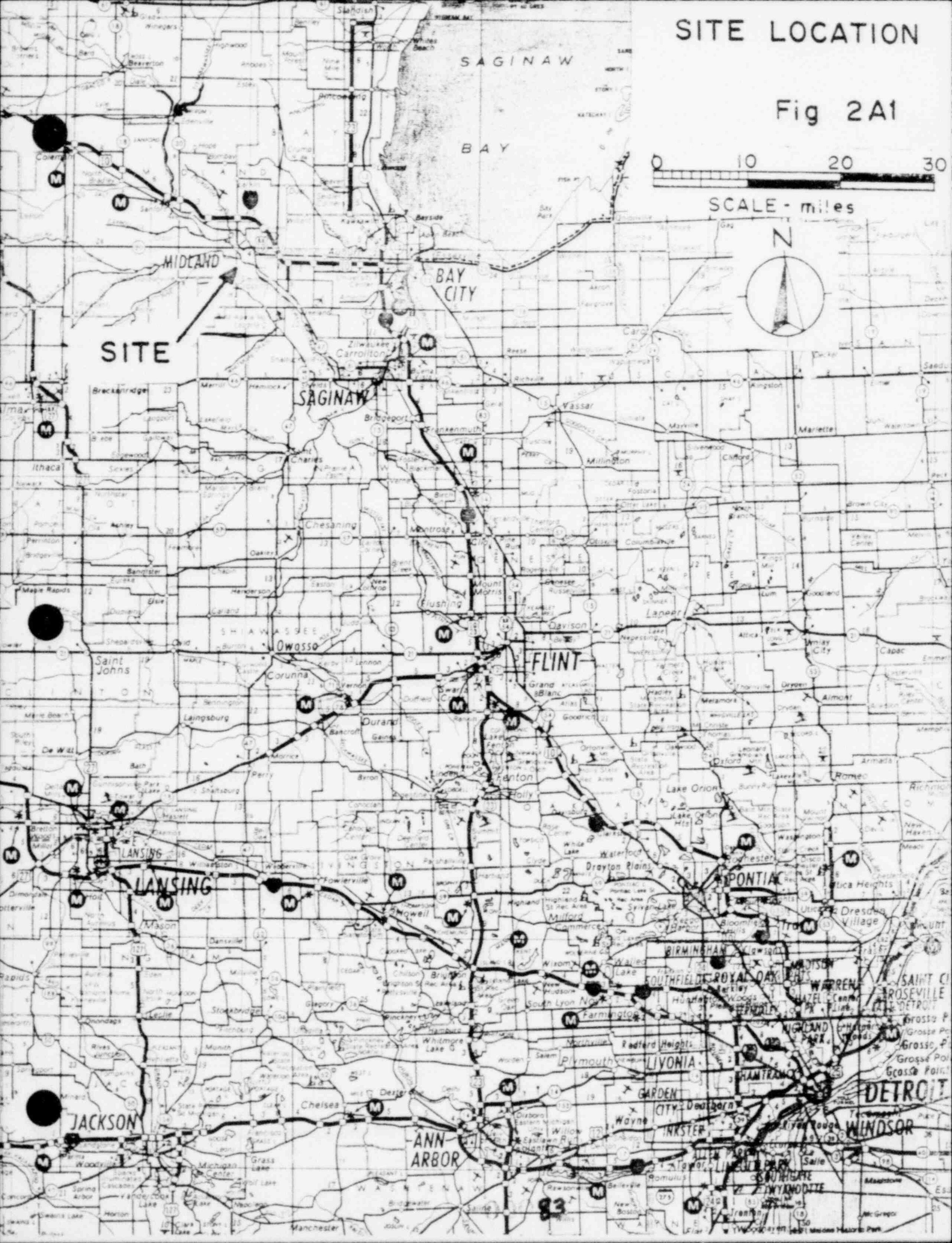
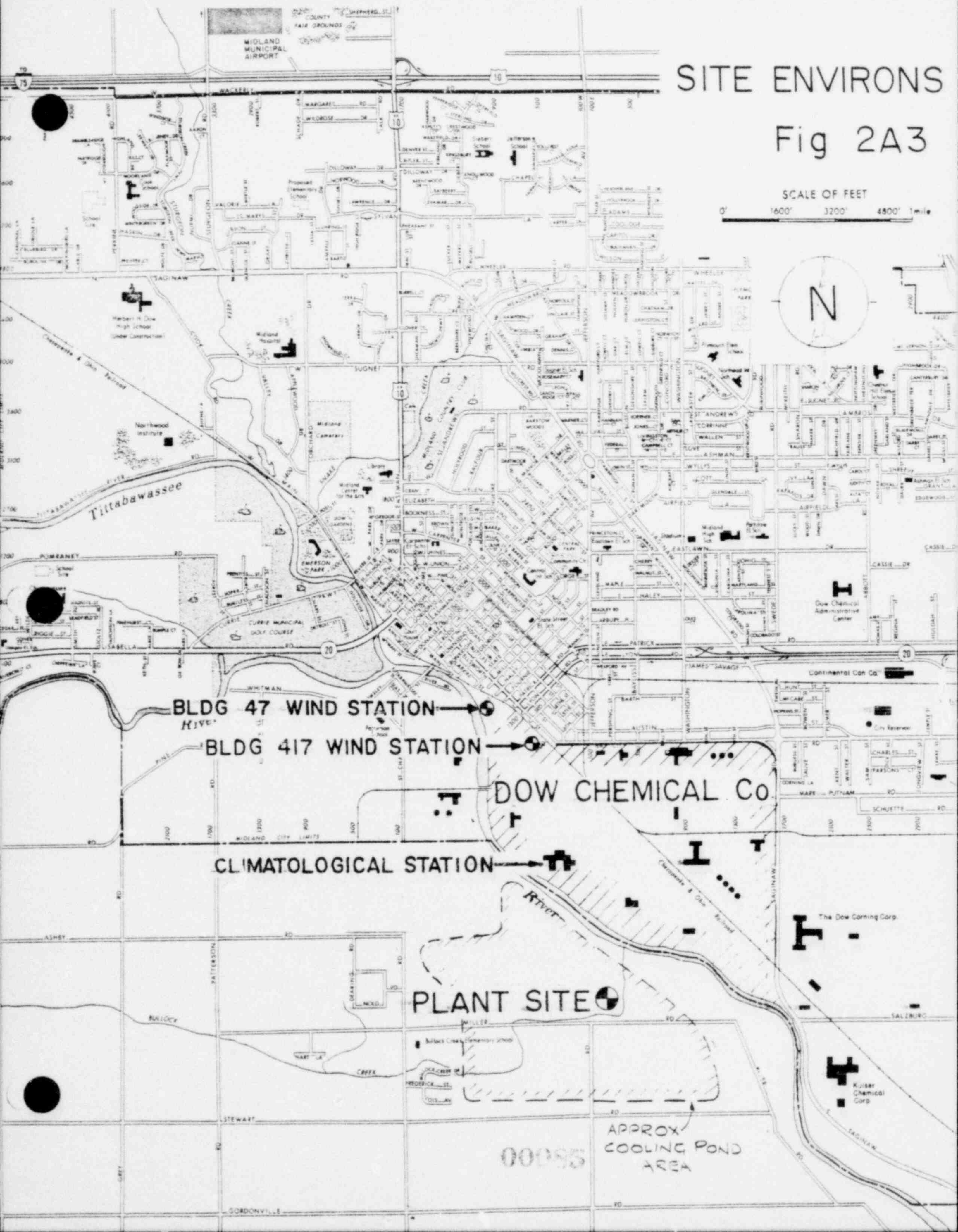


SITE LOCATION

Fig 2A1

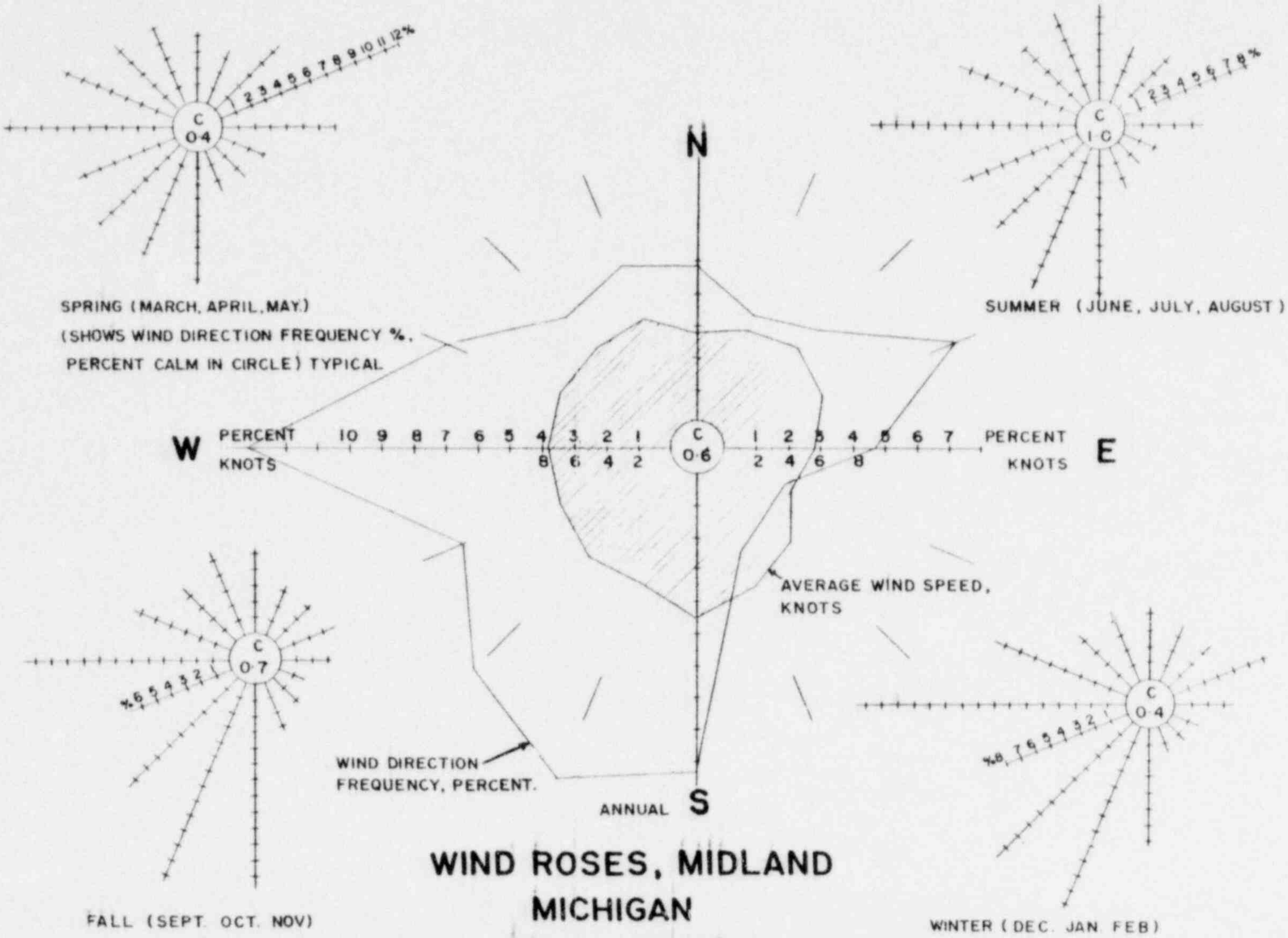
SITE LOCALITY

Fig 2A2

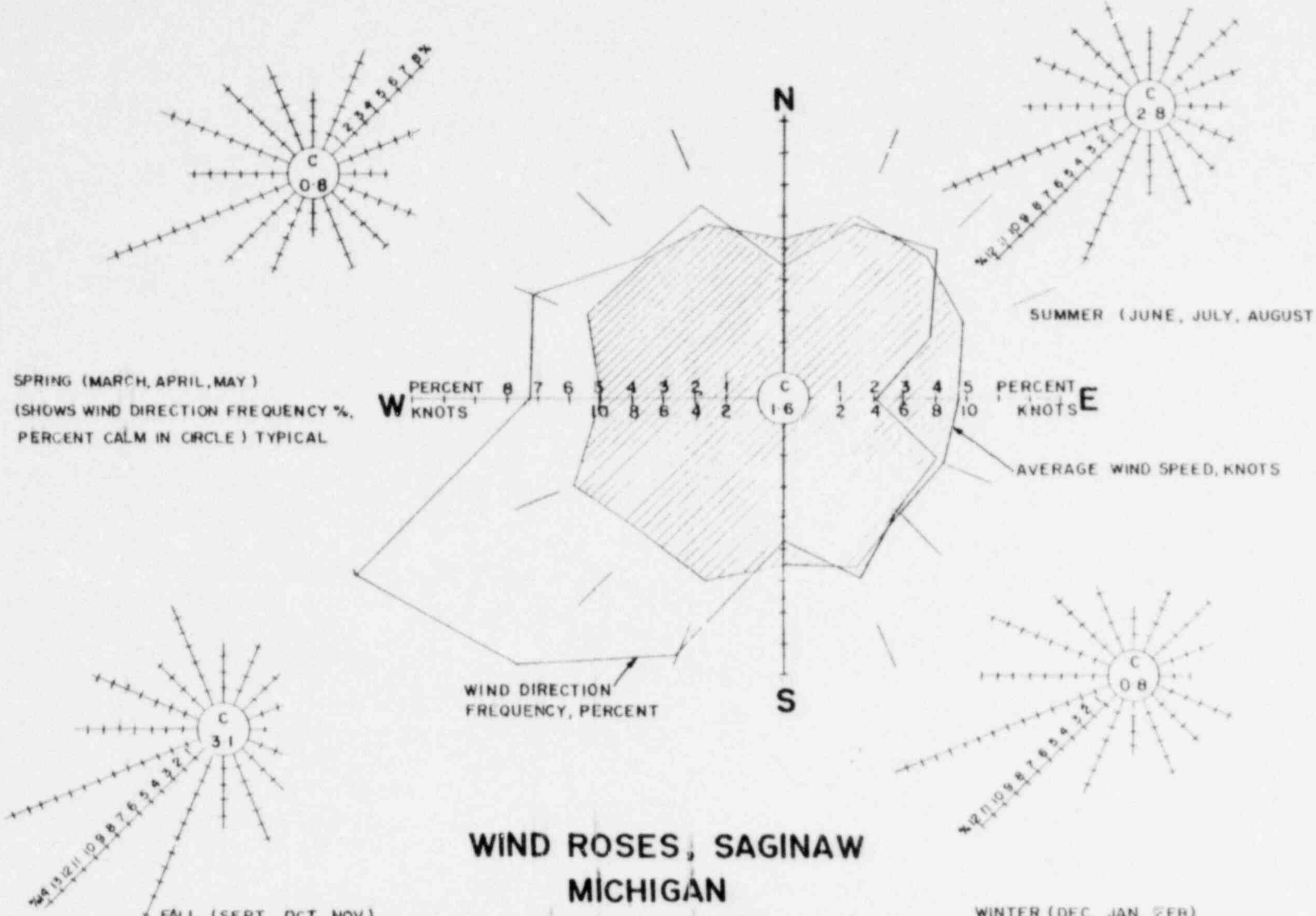


SITE ENVIRONS
Fig 2A3
SCALE OF FEET
0' 1600' 3200' 4800' 1 mile
N
MIDLAND MUNICIPAL AIRPORT
COUNTY FAIR GROUNDS
Tittabawassee
River
BLDG 47 WIND STATION
BLDG 417 WIND STATION
DOW CHEMICAL Co
CLIMATOLOGICAL STATION
PLANT SITE
APPROX COOLING POND AREA
The Dow Corning Corp.
Kaiser Chemical Corp
Continental Can Co.
Dow Chemical Administrative Center
Midland High Sch
Currie Municipal Golf Course
Northwood Institute
Midland Hospital
Herbert H. Dow High School (Under Construction)
Bullock Creek Elementary School

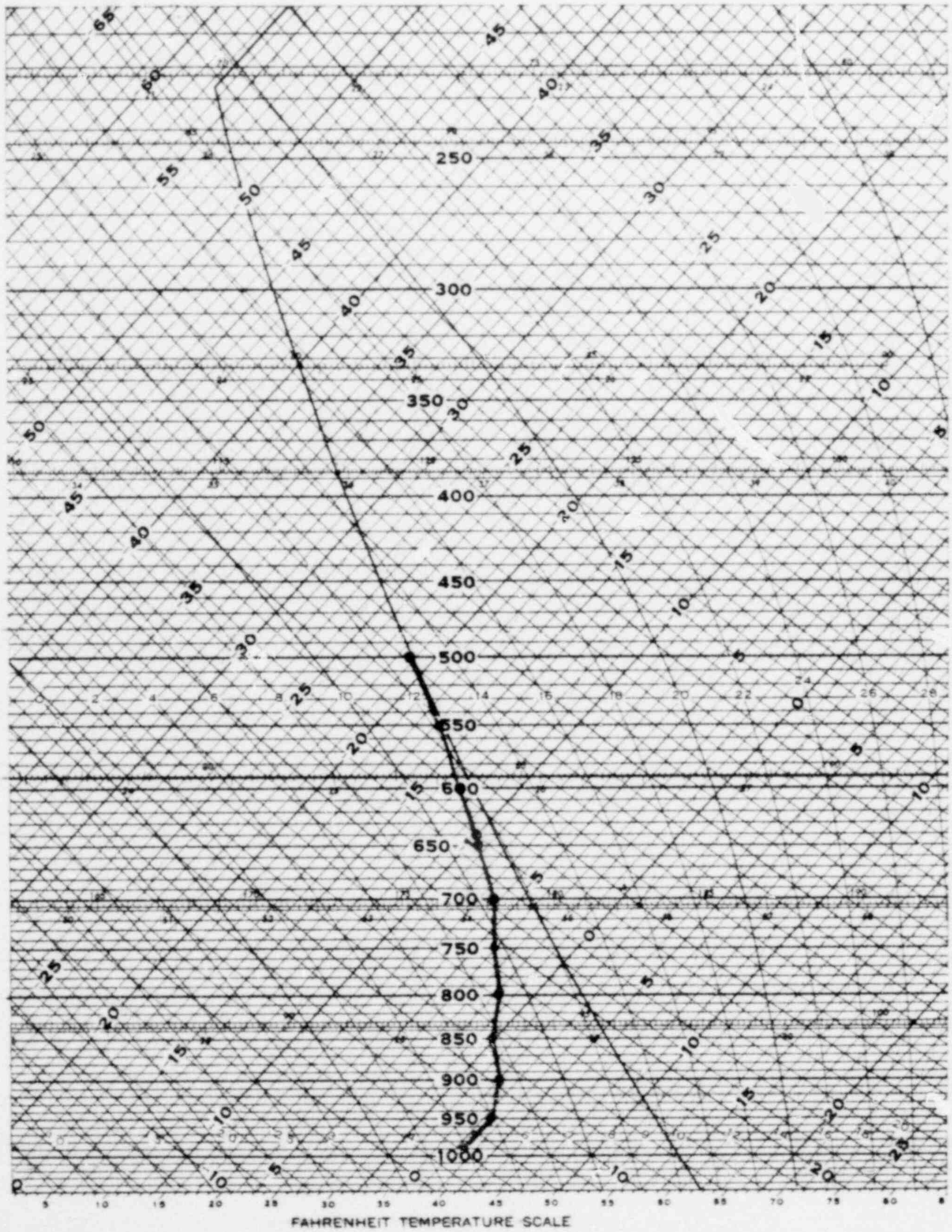
00085



WIND ROSES, MIDLAND
MICHIGAN
Figure 2A4



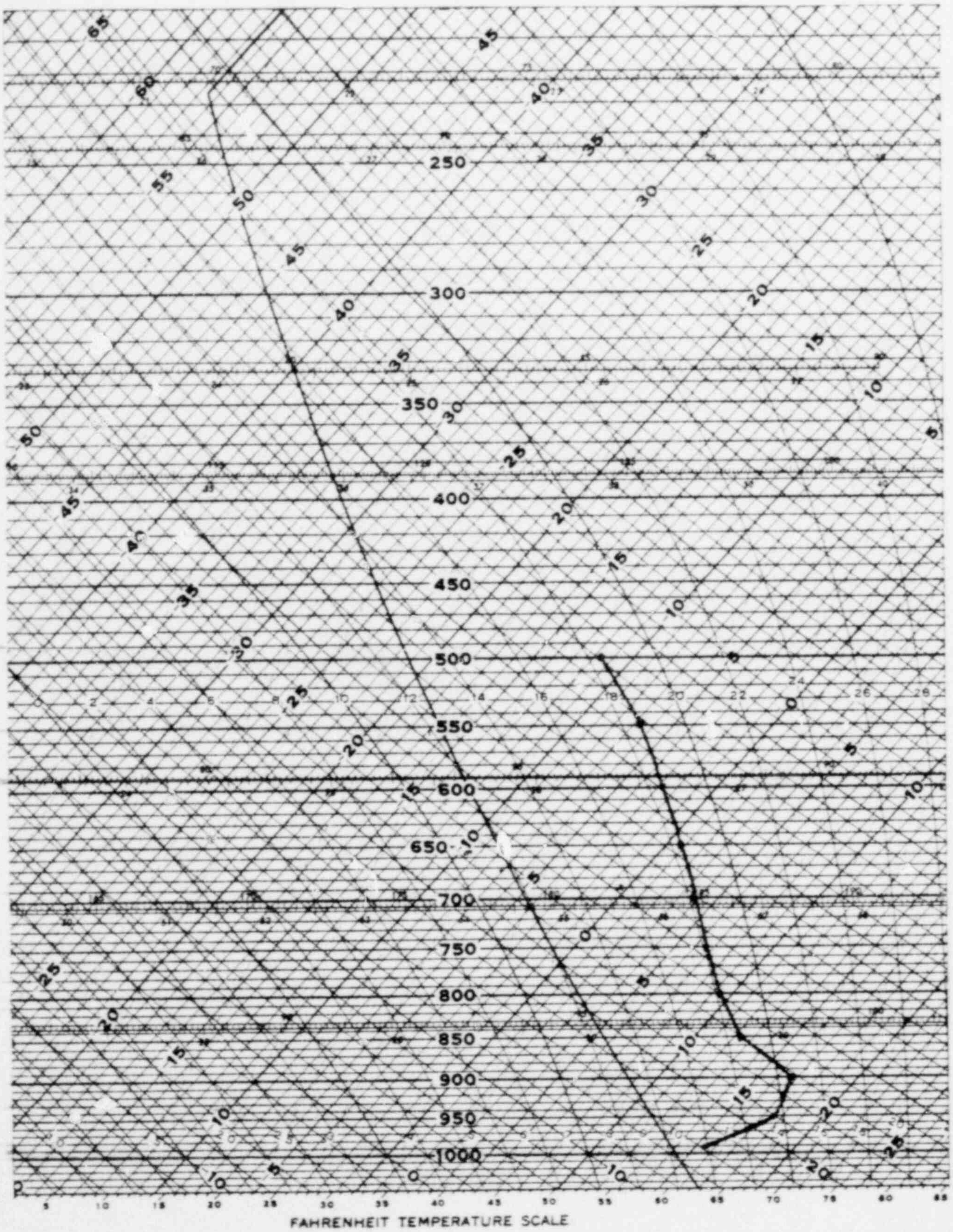
WIND ROSES, SAGINAW
MICHIGAN
Figure 2A5



FLINT MICHIGAN
1200 GCT SPRING
FIG 2A.6

MEAN SOUNDING

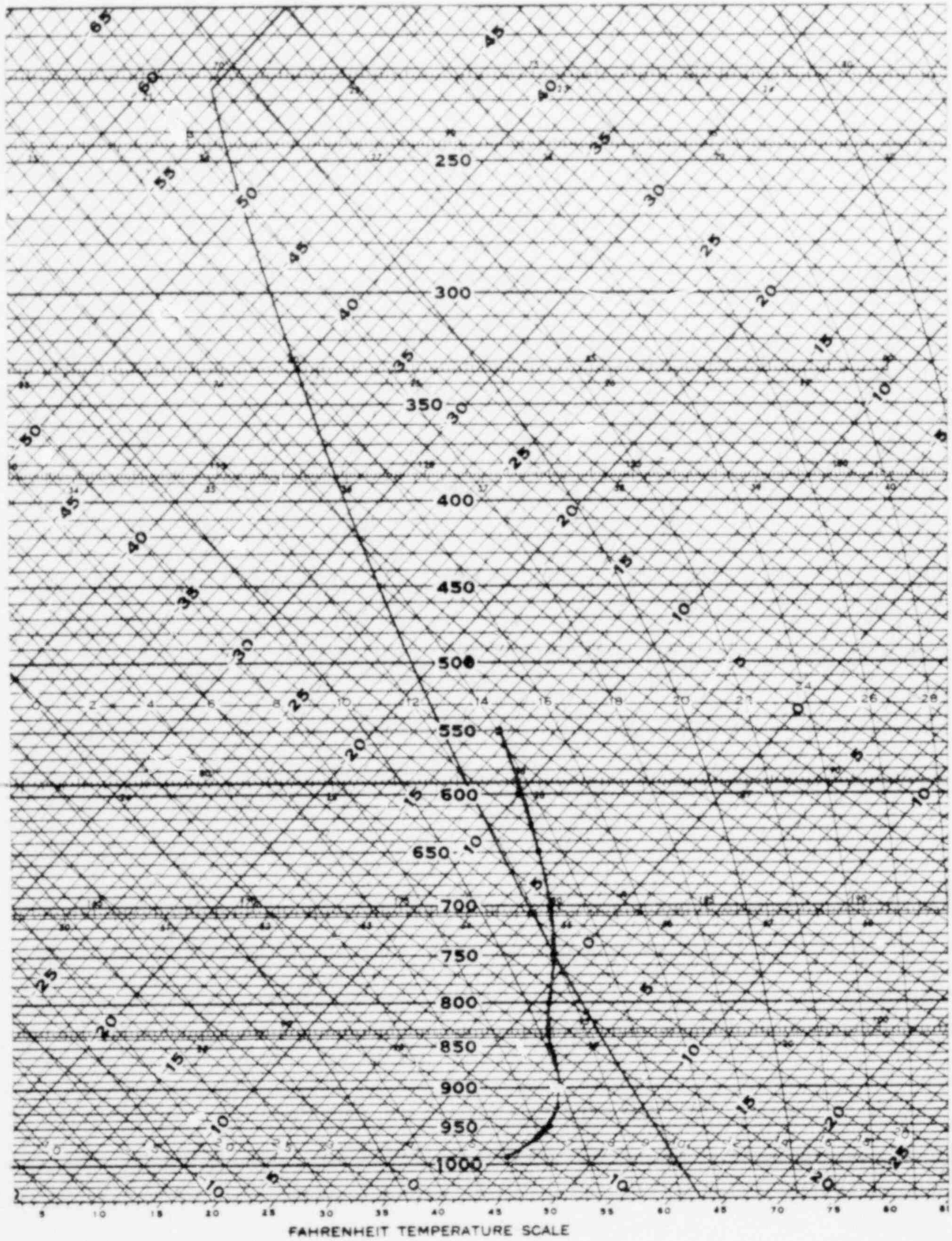
00058



FLINT MICHIGAN
1200 GCT SUMMER
FIG 2A.7

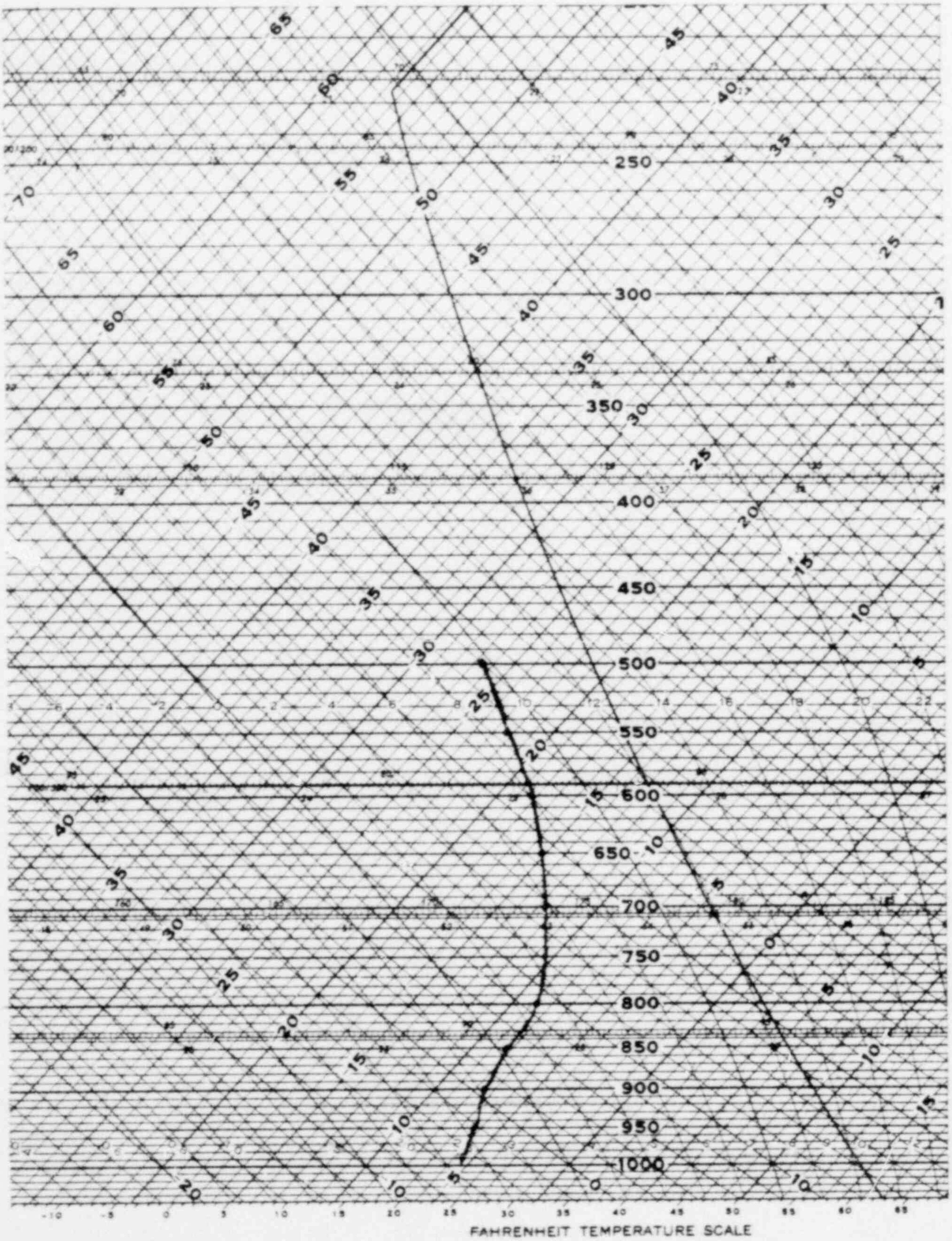
MEAN SOUNDING

00059



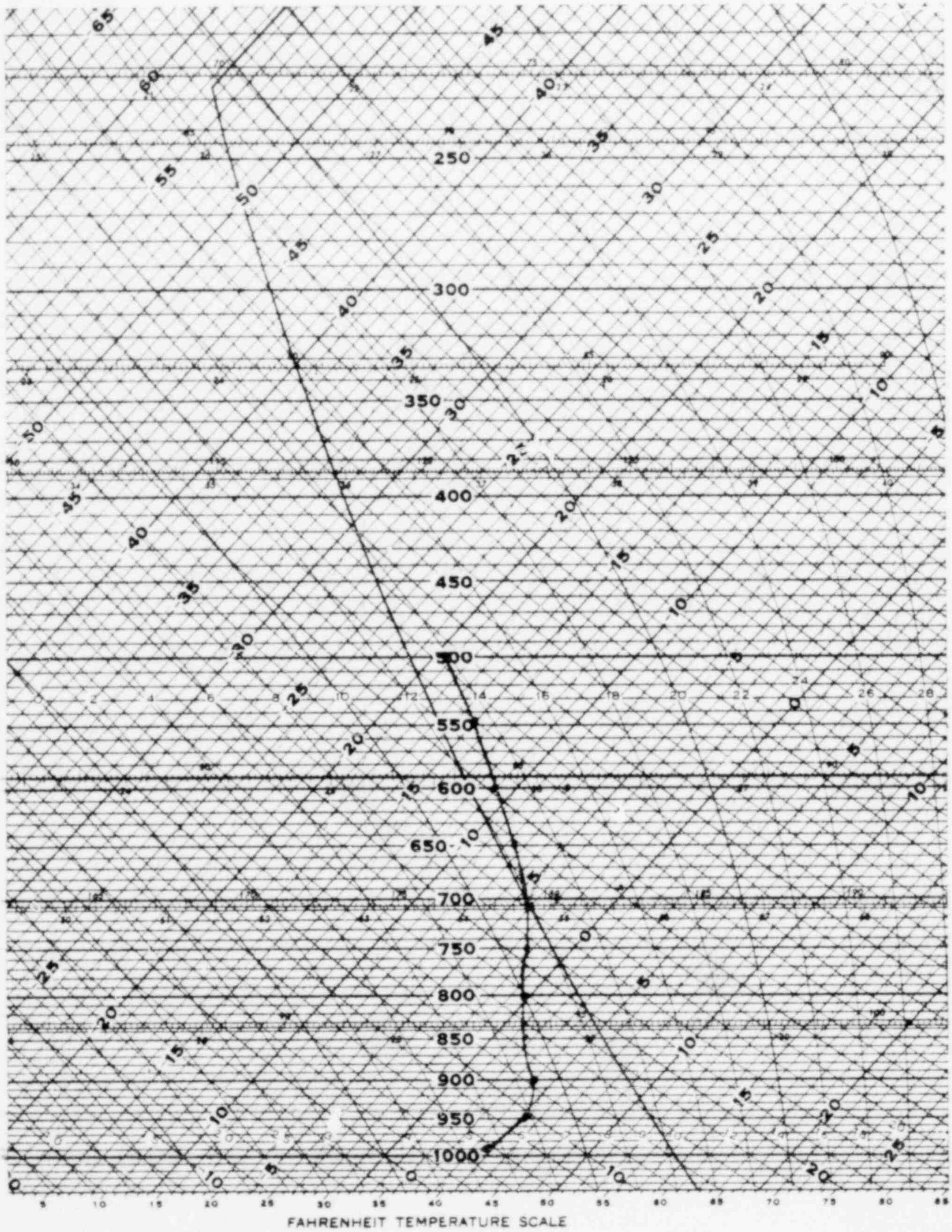
FLINT MICHIGAN
1200 GCT FALL
FIG. 2A.8

MEAN SOUNDING



FLINT MICHIGAN
1200 GCT WINTER
FIG 2A.9

MEAN SOUNDING



FLINT MICHIGAN
1200 GCT ANNUAL
FIG 2A.10

MEAN SOUNDING

00092

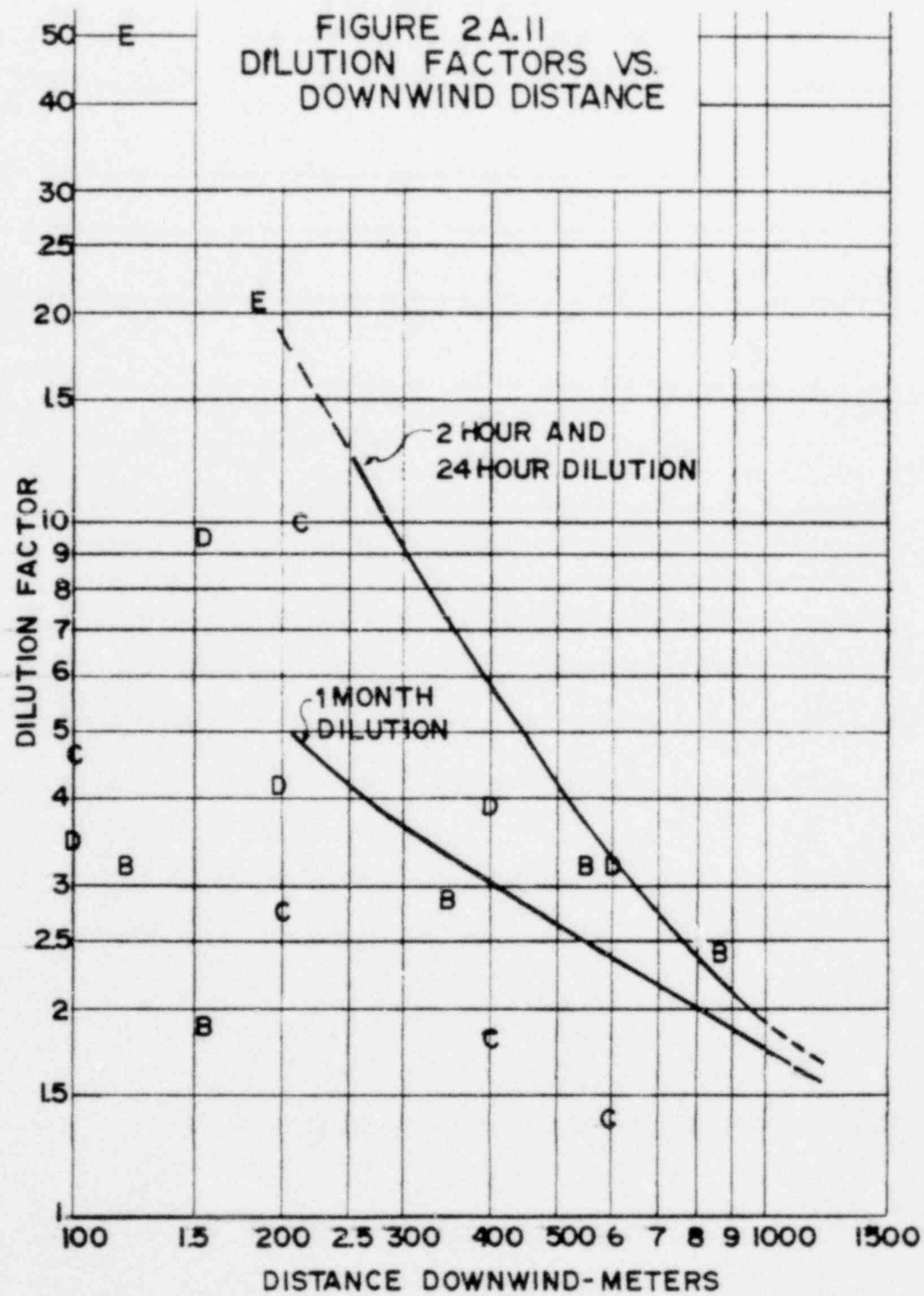
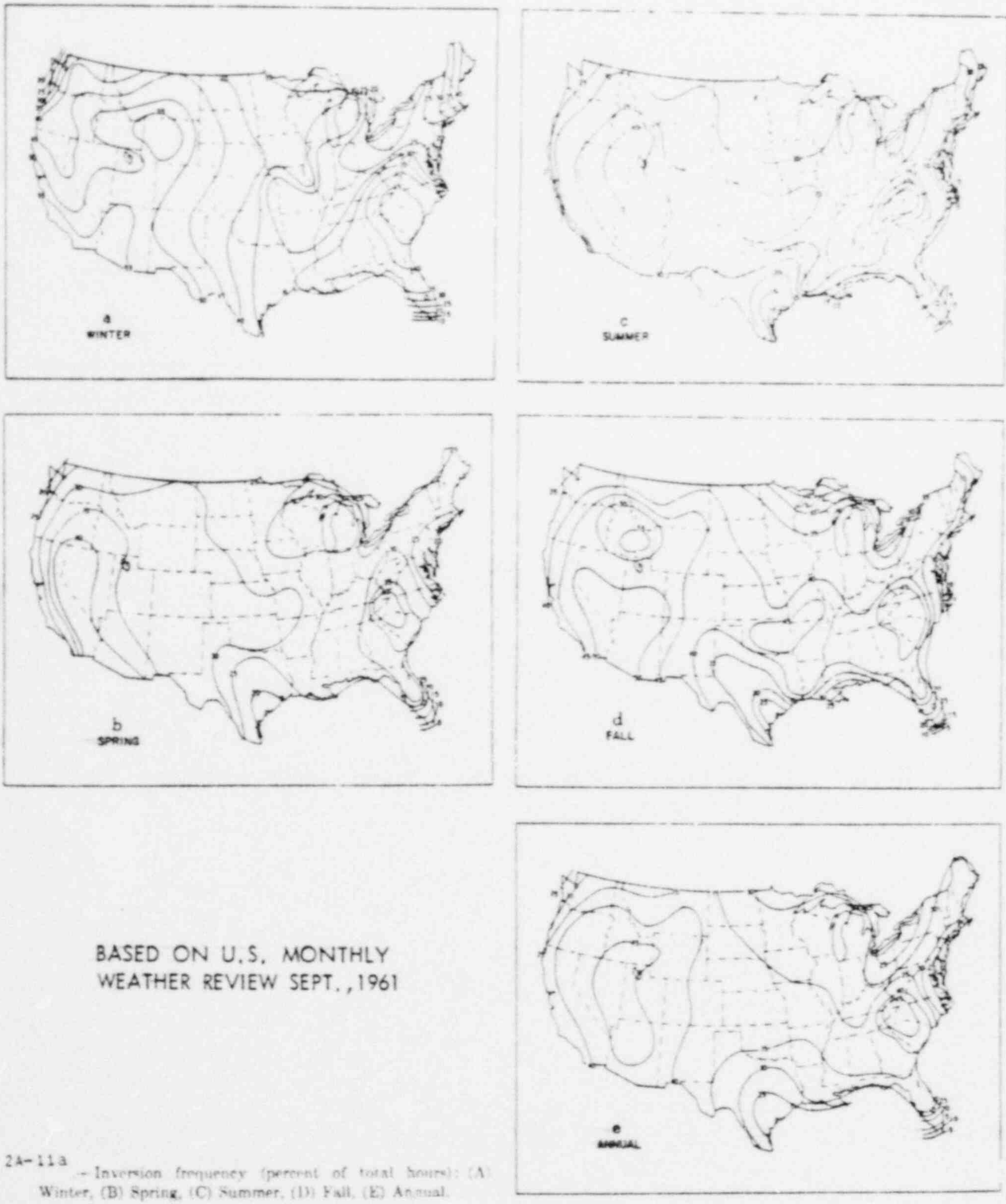


FIGURE 2A.11
DILUTION FACTORS VS.
DOWNWIND DISTANCE



BASED ON U.S. MONTHLY WEATHER REVIEW SEPT., 1961

FIGURE 2A-11a — Inversion frequency (percent of total hours): (A) Winter, (B) Spring, (C) Summer, (D) Fall, (E) Annual.

FIGURE 2A-11D —Isopleths of nighttime [(percent cloud cover ≤ 3/10) + (percent wind speed ≤ 7 m.p.h.)]/2: (A) Winter, (B) Spring, (C) Summer, (D) Fall, (E) Annual.

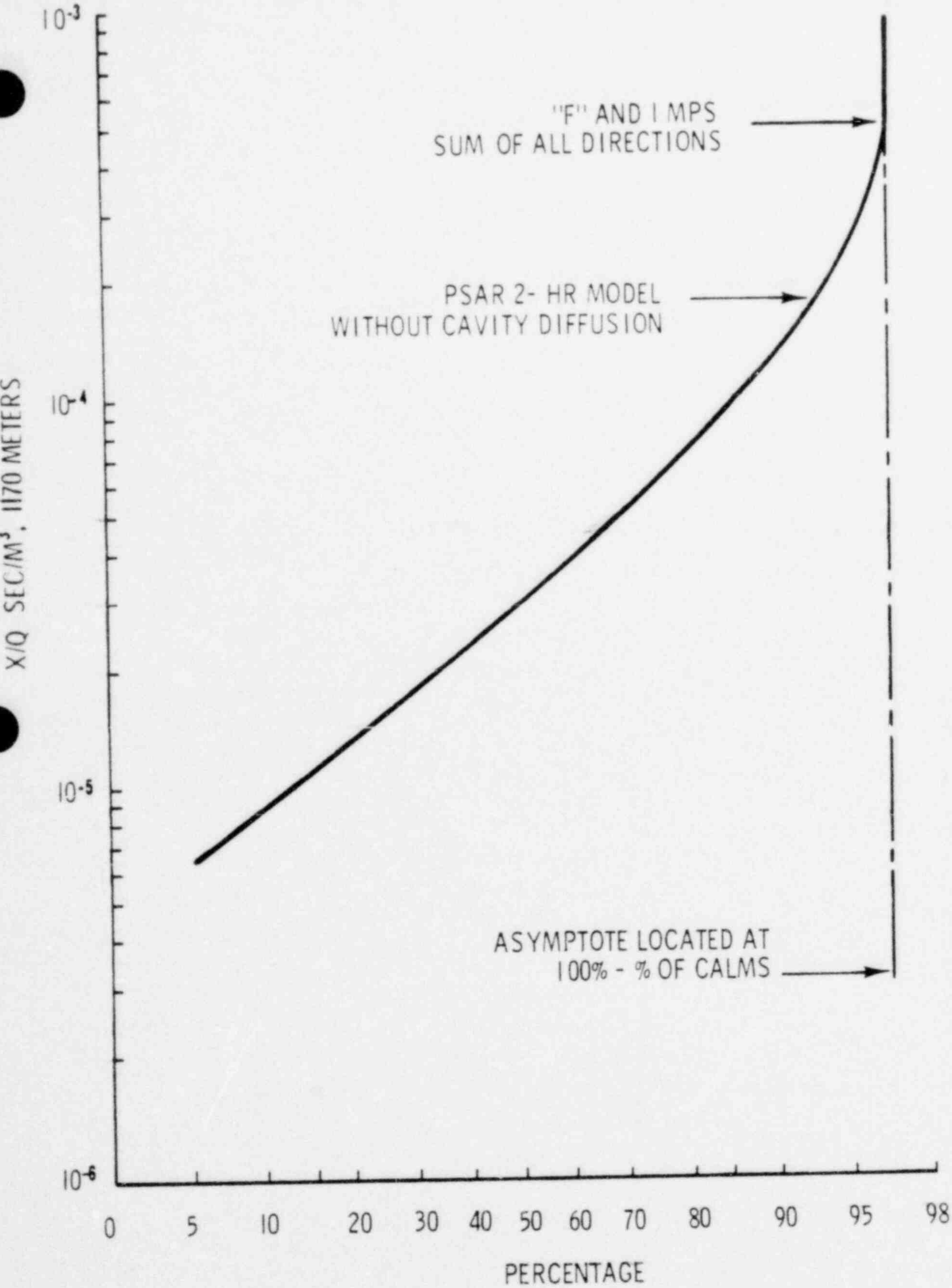


FIGURE 2A-11c CUMULATIVE PERCENTAGE PROBABILITY OF THE RELATIVE DIFFUSION, X/Q, BEING LESS THAN A SPECIFIED VALUE.

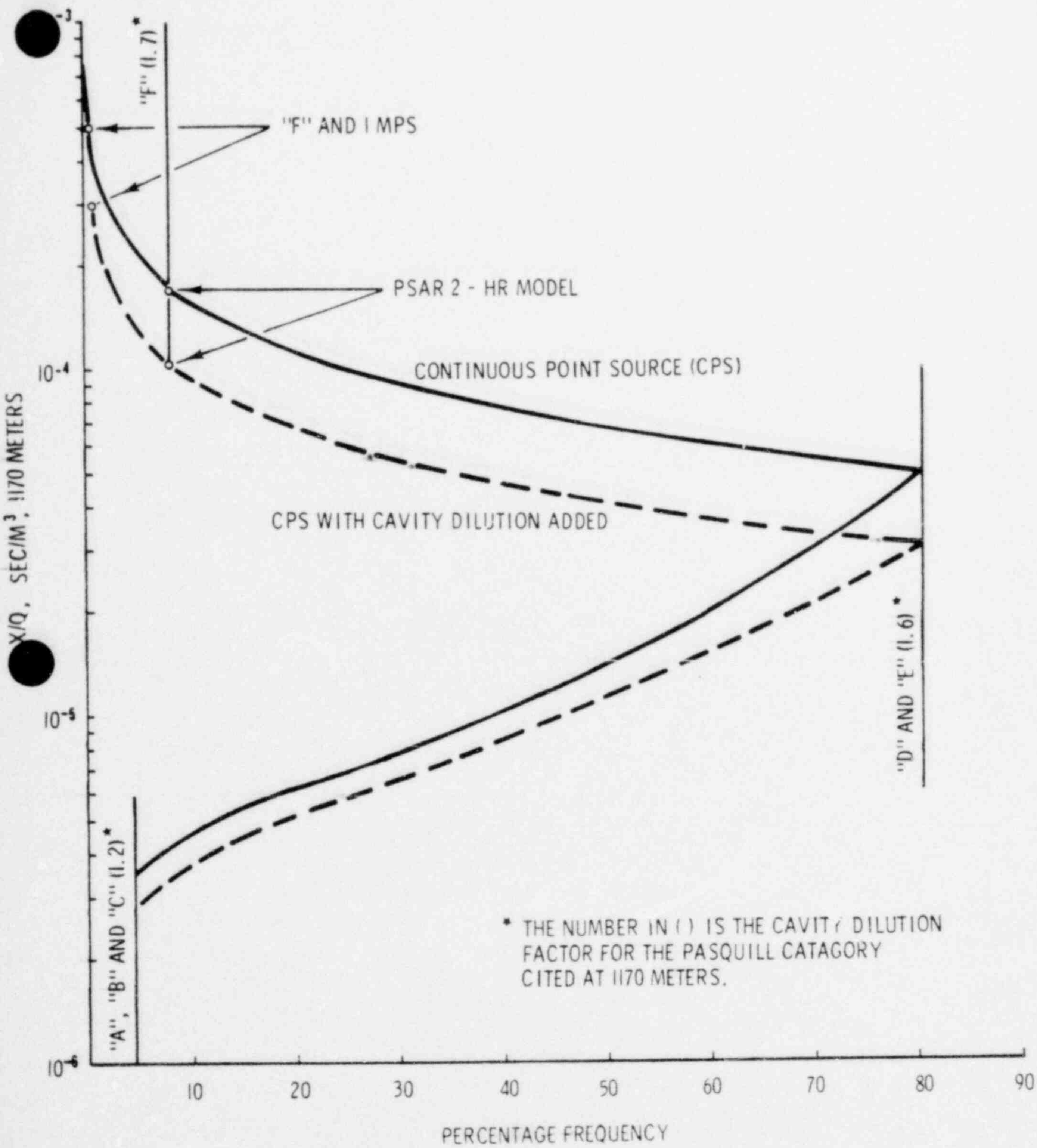
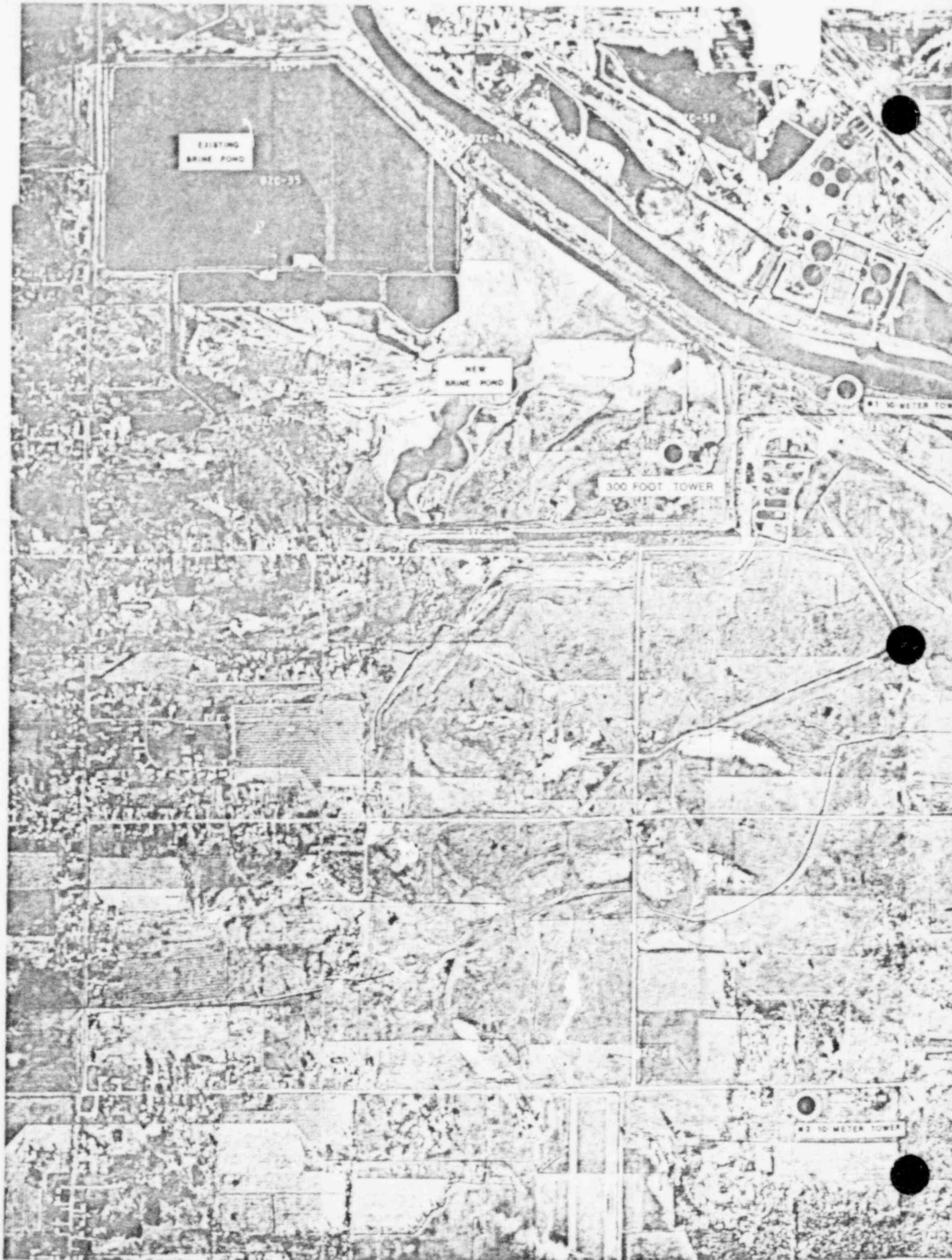


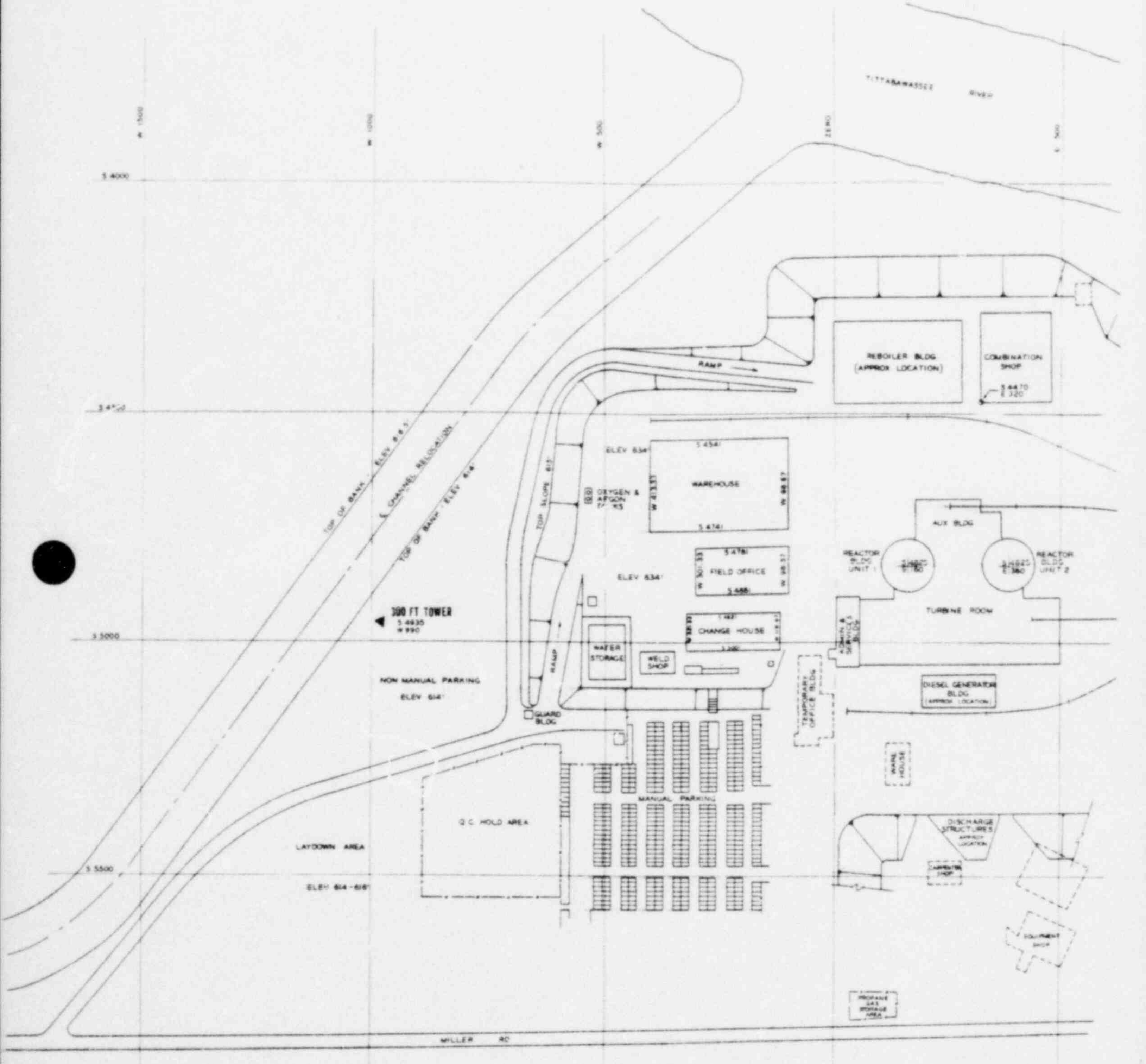
FIGURE 2A-11d PERCENTAGE FREQUENCY OF X/Q AND THE RELATED PASQUILL CATEGORY, WITH AND WITHOUT THE EFFECT OF CAVITY DIFFUSION.


EXISTING
BRINE POND
NEW
BRINE POND
300 FOOT TOWER
#2 10 METER TOWER

AMENDMENT NO 27
AUGUST 1974

BECHTEL ANN ARBOR, MICHIGAN		
MIDLAND PLANT UNITS 1 & 2 CONSUMERS POWER COMPANY		
AERIAL PHOTO - NOV. 1972 METEOROLOGY TOWER LOCATION		
JOB No.	DRAWING No.	REV
7220	FIGURE 2A13	A

00039



00100

Figure 2A14

300 FT TOWER LOCATION

MIDLAND PLANT UNITS 1 & 2

Amendment 27

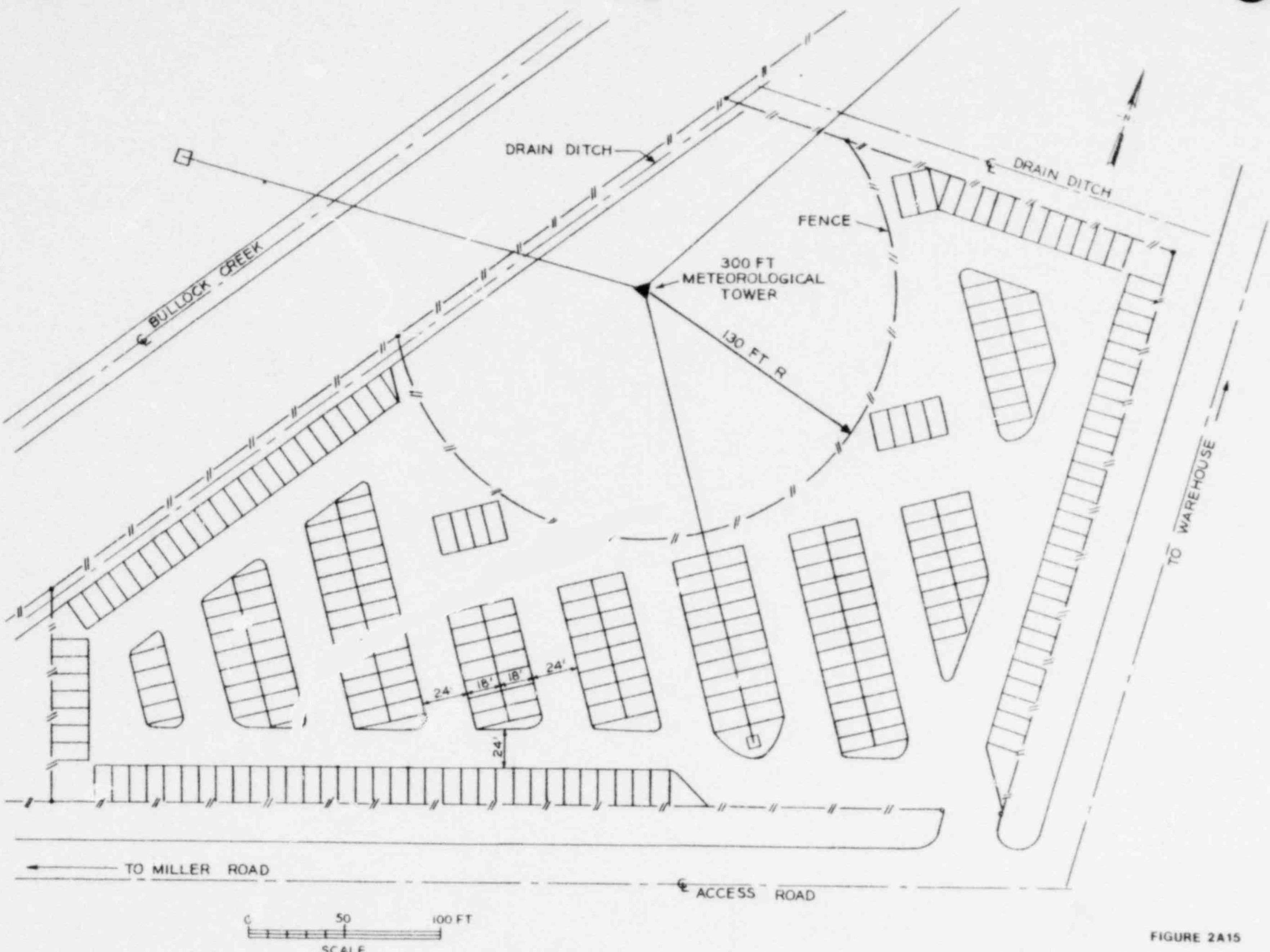


FIGURE 2A15

MIDLAND PLANT UNITS 1&2
CONSUMERS POWER COMPANY

NON-MANUAL PARKING

300 FT METEOROLOGICAL TOWER

Amendment 27
8/74