

**ASSESSMENT OF EROSION WIND FREQUENCY
FOR PORTAGE COUNTY, WISCONSIN**

by

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A Thesis

**submitted in partial fulfillment of the
requirements for the degree**

MASTER OF SCIENCE

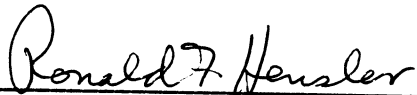
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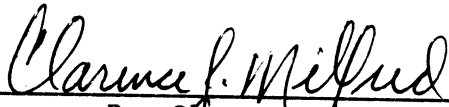
Stevens Point, Wisconsin

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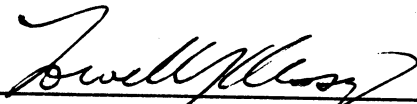
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ABSTRACT

To estimate soil loss by wind and determine proper orientation of wind barriers, local soil conservationists have been relying on erosive wind data from Eau Claire and Madison, locations outside Portage County. Analysis of 18 years of wind velocity and direction data for Stevens Point, WI, provided more reliable and accurate assessment of erosive wind information for use in Portage County.

Erosive winds are those ≥ 18 mph (8 msec^{-1}) measured at 33 feet (10 m). March accounted for 15.4% of the annual erosive wind energy (EWE) for Portage County, 10.6% more than observed in Eau Claire, WI. April accounted for 18.1% of the annual EWE in Portage County, nearly the same as that for Eau Claire (18.4%). The average maximum erosive wind duration in April was 8.8 hours and the average maximum average wind velocity (1-hour duration) was 28.5 mph (13 msec^{-1}). Climatic erosivity, C, was calculated to be only 4%, compared to the 6% value presently used. Soil erosion estimates calculated by the wind erosion equation with $C=4$ will generally be one-third less than those calculated with $C=6$.

Analysis of monthly and weekly erosive wind frequencies (March 15 through December 15) identified critical erosion periods and those most likely to result in abrasive flux damage to susceptible crops. In late May and June the soil surface is susceptible to erosion because vegetative cover is not yet fully established. This erosion can cause significant crop damage to susceptible crop seedlings.

Prevailing wind erosion direction (PWED) was either west or southwest throughout the year. During the erosive period (March 15 through December 15) in Portage County, all preponderance values were less than 2.0, which indicates highly variable erosive wind direction. Reliance upon only PWED and preponderance values to orient wind barriers is unwarranted; other factors, such as frequency and direction data of erosive winds during the critical erosive period, need to be considered. Circular and curvilinear wind barriers are analyzed as alternatives to traditional linear designs.

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TABLE OF CONTENTS

	PAGE
ABSTRACT	iii
ACKNOWLEDGEMENTS	v
TABLE OF CONTENTS	vi
LIST OF APPENDICES	viii
LIST OF FIGURES	xi
LIST OF TABLES	xiv
INTRODUCTION	1
Past Research	1
Justification for Present Research	1
Significance of Wind Erosion in Portage County	3
Objectives	5
WIND AS A SOIL-DISPLACING MEDIUM	7
Initiation of Soil Movement	7
Soil Transport Processes	12
Saltation	14
Surface Creep	16
Suspension	16
Sorting of Soil Particles	18
Wind Erosion Equation	19
Relevance to Conservation Planning	22
Soil Erosion Control	23
Crop Damage Abatement	25
RESEARCH METHODS	28
Source of Wind Data	28
Data Processing	28
Erosive Wind Frequency	29
Erosive Wind Energy	30
Prevailing Wind Erosion Direction and Preponderance	30
Extreme Wind Event Analysis	33
Climatic Erosivity	34
RESULTS AND DISCUSSION	36
Erosive Wind Assessment	36
Erosive Wind Frequency	36
Erosive Wind Energy	71
Prevailing Wind Erosion Direction and Preponderance	77
Extreme Wind Event Analysis	79
Climatic Erosivity	80
Cyclic Recurrence of Severe Erosion Potential	82
Conservation Planning Applications	84
Soil Erosion Control	84
Crop Damage Abatement	89
RESEARCH NEEDS	96
Prediction of Erosive Winds	96
Assessment of Cycle of Wind Erosion Occurrence	97
In-field Measurement of Erosion Rates	97
In-field Measurement of Crop Damage and Pest Distribution	98
REFERENCES	99
APPENDIX A: EXTREME WIND EVENT ANALYSIS	104
APPENDIX B: COMPUTER-PROGRAMMED METHODOLOGIES	125

TABLE OF CONTENTS
(Continued)

APPENDIX C: WIND MOVEMENT	153
Source of Wind	153
Local Climatology	157
Association and Prediction of Winds with Certain Weather Patterns	159
Dust Storms	164
Selected References	168

LIST OF APPENDICES

	PAGE
APPENDIX A: EXTREME WIND EVENT ANALYSIS	104
<u>FIGURE</u>	
19.1: Return Period (T_R) of Maximum Average 1-Hour Wind Velocity: April	105
19.2: T_R of Maximum Average 3-Hour Wind Velocity: April	105
19.3: T_R of Maximum Average 6-Hour Wind Velocity: April	106
19.4: T_R of Maximum Average 9-Hour Wind Velocity: April	106
19.5: T_R of Maximum Average 12-Hour Wind Velocity: April	107
19.1: T_R of Maximum Average 1-Hour Wind Velocity: Mar 29-Apr 4	107
20.2: T_R of Maximum Average 3-Hour Wind Velocity: Mar 29-Apr 4	108
20.3: T_R of Maximum Average 6-Hour Wind Velocity: Mar 29-Apr 4	108
20.4: T_R of Maximum Average 9-Hour Wind Velocity: Mar 29-Apr 4	109
20.5: T_R of Maximum Average 12-Hour Wind Velocity: Mar 29-Apr 4	109
21.1: T_R of Maximum Average 1-Hour Wind Velocity: April 5-11	110
21.2: T_R of Maximum Average 3-Hour Wind Velocity: April 5-11	110
21.3: T_R of Maximum Average 6-Hour Wind Velocity: April 5-11	111
21.4: T_R of Maximum Average 9-Hour Wind Velocity: April 5-11	111
21.5: T_R of Maximum Average 12-Hour Wind Velocity: April 5-11	112
22.1: T_R of Maximum Average 1-Hour Wind Velocity: April 12-18	112
22.2: T_R of Maximum Average 3-Hour Wind Velocity: April 12-18	113
22.3: T_R of Maximum Average 6-Hour Wind Velocity: April 12-18	113
22.4: T_R of Maximum Average 9-Hour Wind Velocity: April 12-18	114
22.5: T_R of Maximum Average 12-Hour Wind Velocity: April 12-18	114
23.1: T_R of Maximum Average 1-Hour Wind Velocity: April 19-25	115
23.2: T_R of Maximum Average 3-Hour Wind Velocity: April 19-25	115

LIST OF APPENDICES
(Continued)

	PAGE
APPENDIX A (cont.)	
23.3: T_R of Maximum Average 6-Hour Wind Velocity: April 19-25 . . .	116
23.4: T_R of Maximum Average 9-Hour Wind Velocity: April 19-25 . . .	116
23.5: T_R of Maximum Average 12-Hour Wind Velocity: April 19-25 . . .	117
24.1: T_R of Maximum Average 1-Hour Wind Velocity: Apr 26-May 2 . . .	117
24.2: T_R of Maximum Average 3-Hour Wind Velocity: Apr 26-May 2 . . .	118
24.3: T_R of Maximum Average 6-Hour Wind Velocity: Apr 26-May 2 . . .	118
24.4: T_R of Maximum Average 9-Hour Wind Velocity: Apr 26-May 2 . . .	119
24.5: T_R of Maximum Average 12-Hour Wind Velocity: Apr 26-May 2 . . .	119
25: Return Period (T_R) of Extreme Erosive Wind Duration: March 15-31	120
26: T_R of Extreme Erosive Wind Duration: April	120
27: T_R of Extreme Erosive Wind Duration: May	121
28: T_R of Extreme Erosive Wind Duration: June	121
29: T_R of Extreme Erosive Wind Duration: July	122
30: T_R of Extreme Erosive Wind Duration: August	122
31: T_R of Extreme Erosive Wind Duration: September	123
32: T_R of Extreme Erosive Wind Duration: October	123
33: T_R of Extreme Erosive Wind Duration: November	124
34: T_R of Extreme Erosive Wind Duration: December 1-15	124
APPENDIX B: COMPUTER-PROGRAMMED METHODOLOGIES 125	
(All are FORTRAN programs)	
WINDANAL/DAY	126
Program for determining erosive wind frequencies for selected days, by velocity speedgroup and direction.	
WINDANAL/MONTH	128
Program for determining erosive wind frequencies for selected months, by velocity speedgroup and direction.	

LIST OF APPENDICES
(Continued)

	PAGE
APPENDIX B (cont.)	
WINDANAL	130
General program documentation.	
WEIBULL/DISTRIBUTION	133
Program to calculate erosive wind energy (EWE) and EWE distribution.	
WEIBULL/SPT	136
Data values for Stevens Point, WI, entered into above program.	
PROGRAM FOR ASSESSING WIND EROSION FORCES	137
Monthly prevailing wind erosion direction and preponderance determinations.	
ROLLINGAVERAGE	149
Program to analyze data values from selected time intervals (weeks or months) in database to identify maximum average wind velocities for selected hourly intervals.	
APPENDIX C: WIND MOVEMENT	153
Source of Wind	153
Local Climatology	157
Association and Prediction of Winds with Certain Weather Patterns	159
Dust Storms	164
Selected References	168

LIST OF FIGURES

FIGURE		PAGE
1:	Golden Sands Area	2
2:	Portage County Priority Area Wind Erosion Rates	4
3:	Spinning Sand Grain in Moving Air Stream	8
4:	Wind Velocity near a Soil Surface	11
5:	Surface Wind Velocity Variation with Height	11
6:	Surface Wind Velocity-Soil Flow Relationships	13
7:	Path of a Saltating Grain	14
8:	Mechanics of Saltating Particles	15
9:	Stability Relationships of Soil Surfaces	17
10:	Schematic Determination of Erosion Force Vectors	32
11:	Erosive Wind Energy Distribution, Stevens Point	73
12:	Erosive Wind Energy Distribution, Eau Claire and Madison	75
13:	Comparison of Erosive Wind Energy Distribution (Stevens Point vs. Eau Claire vs. Madison)	76
14:	Total Erosive Wind Movement (1950-1967), Stevens Point	83
15:	Erosion and Crop Damage Potential of Erosive Winds near Stevens Point	86
16:	Alternative Wind Strip Design Providing Maximum Soil Protection	88
17:	Golden Sands Area Vegetable Crop Calendar	91
18:	Crop Tolerances to Wind Erosion Soil Loss	92
19.1:	Return Period (T_R) of Maximum Average 1-Hour Wind Velocity: April	105
19.2:	T_R of Maximum Average 3-Hour Wind Velocity: April	105
19.3:	T_R of Maximum Average 6-Hour Wind Velocity: April	106
19.4:	T_R of Maximum Average 9-Hour Wind Velocity: April	106

LIST OF FIGURES
(Continued)

FIGURE	PAGE
19.5: T_R of Maximum Average 12-Hour Wind Velocity: April	107
19.1: T_R of Maximum Average 1-Hour Wind Velocity: Mar 29-Apr 4 . . .	107
20.2: T_R of Maximum Average 3-Hour Wind Velocity: Mar 29-Apr 4 . . .	108
20.3: T_R of Maximum Average 6-Hour Wind Velocity: Mar 29-Apr 4 . . .	108
20.4: T_R of Maximum Average 9-Hour Wind Velocity: Mar 29-Apr 4 . . .	109
20.5: T_R of Maximum Average 12-Hour Wind Velocity: Mar 29-Apr 4 . . .	109
21.1: T_R of Maximum Average 1-Hour Wind Velocity: April 5-11	110
21.2: T_R of Maximum Average 3-Hour Wind Velocity: April 5-11	110
21.3: T_R of Maximum Average 6-Hour Wind Velocity: April 5-11	111
21.4: T_R of Maximum Average 9-Hour Wind Velocity: April 5-11	111
21.5: T_R of Maximum Average 12-Hour Wind Velocity: April 5-11	112
22.1: T_R of Maximum Average 1-Hour Wind Velocity: April 12-18	112
22.2: T_R of Maximum Average 3-Hour Wind Velocity: April 12-18	113
22.3: T_R of Maximum Average 6-Hour Wind Velocity: April 12-18	113
22.4: T_R of Maximum Average 9-Hour Wind Velocity: April 12-18	114
22.5: T_R of Maximum Average 12-Hour Wind Velocity: April 12-18	114
23.1: T_R of Maximum Average 1-Hour Wind Velocity: April 19-25	115
23.2: T_R of Maximum Average 3-Hour Wind Velocity: April 19-25	115
23.3: T_R of Maximum Average 6-Hour Wind Velocity: April 19-25	116
23.4: T_R of Maximum Average 9-Hour Wind Velocity: April 19-25	116
23.5: T_R of Maximum Average 12-Hour Wind Velocity: April 19-25	117
24.1: T_R of Maximum Average 1-Hour Wind Velocity: Apr 26-May 2	117
24.2: T_R of Maximum Average 3-Hour Wind Velocity: Apr 26-May 2	118
24.3: T_R of Maximum Average 6-Hour Wind Velocity: Apr 26-May 2	118
24.4: T_R of Maximum Average 9-Hour Wind Velocity: Apr 26-May 2	119

LIST OF FIGURES
(Continued)

FIGURE	PAGE
24.5: T_R of Maximum Average 12-Hour Wind Velocity: Apr 26-May 2	119
25: Return Period (T_R) of Extreme Erosive Wind Duration: March 15-31	120
26: T_R of Extreme Erosive Wind Duration: April	120
27: T_R of Extreme Erosive Wind Duration: May	121
28: T_R of Extreme Erosive Wind Duration: June	121
29: T_R of Extreme Erosive Wind Duration: July	122
30: T_R of Extreme Erosive Wind Duration: August	122
31: T_R of Extreme Erosive Wind Duration: September	123
32: T_R of Extreme Erosive Wind Duration: October	123
33: T_R of Extreme Erosive Wind Duration: November	124
34: T_R of Extreme Erosive Wind Duration: December 1-15	124
35: Windspeed Determination by Barometric Gradient Analysis	155
36: Wind Velocity Variation with Height	155
37: Effects of Surface Features on Wind Direction	156
38: Continental Polar Air Mass	159
39: Vertical Cross Sections of Cold and Warm Fronts	161

LIST OF TABLES

TABLE	PAGE
1: Wind Climatology Data for Erosion Control Planning	24
2: Factors Affecting Extent of Sandblast Injury to Crops	26
3: Wind Climatology Data for Crop Damage Abatement Planning	27
4: Percent Frequency of Total Erosive Winds: January	37
5: Percent Frequency of Total Erosive Winds: February	38
6: Percent Frequency of Total Erosive Winds: March	39
7: Percent Frequency of Total Erosive Winds: April	40
8: Percent Frequency of Total Erosive Winds: May	41
9: Percent Frequency of Total Erosive Winds: June	42
10: Percent Frequency of Total Erosive Winds: July	43
11: Percent Frequency of Total Erosive Winds: August	44
12: Percent Frequency of Total Erosive Winds: September	45
13: Percent Frequency of Total Erosive Winds: October	46
14: Percent Frequency of Total Erosive Winds: November	47
15: Percent Frequency of Total Erosive Winds: December	48
16: Percent Frequency of Total Erosive Winds: March 15-21	49
17: Percent Frequency of Total Erosive Winds: March 22-28	50
18: Percent Frequency of Total Erosive Winds: Mar 29-Apr 4	51
19: Percent Frequency of Total Erosive Winds: April 5-11	52
20: Percent Frequency of Total Erosive Winds: April 12-18	53
21: Percent Frequency of Total Erosive Winds: April 19-25	54
22: Percent Frequency of Total Erosive Winds: April 26-May 2	55
23: Percent Frequency of Total Erosive Winds: May 3-9	56
24: Percent Frequency of Total Erosive Winds: May 10-16	57
25: Percent Frequency of Total Erosive Winds: May 17-23	58

LIST OF TABLES
(Continued)

		PAGE
26:	Percent Frequency of Total Erosive Winds: May 24-30	59
27:	Percent Frequency of Total Erosive Winds: May 31-June 6	60
28:	Percent Frequency of Total Erosive Winds: June 7-13	61
29:	Percent Frequency of Total Erosive Winds: June 14-20	62
30:	Percent Frequency of Total Erosive Winds: June 21-27	63
31:	Percent Frequency of Total Erosive Winds: June 28-July 4	64
32:	Percent Frequency of Total Erosive Winds: July 5-11	65
33:	Percent Frequency of Total Erosive Winds: July 12-18	66
34:	Percent Frequency of Total Erosive Winds: July 19-25	67
35:	Percent Frequency of Total Erosive Winds: July 26-August 1	68
36:	Percent Frequency of Total Erosive Winds: August 2-8	69
37:	Percent Frequency of Total Erosive Winds: August 9-15	70
38:	Erosive Wind Energy, Stevens Point	72
39:	Monthly Prevailing Wind Erosion Direction and Preponderance, Stevens Point and Madison	77
40:	Climatic Erosivity, Stevens Point	81
41:	Nematodes Parasitic on Central Sands Area Vegetable Crops	95
42:	Spatial Systems of Climate	158
43:	Forecasting with Wind-Barometric Pressure Relationships	163
44:	Dust Storms Observed Near Stevens Point, WI (1948-1967)	165
45:	Classification of Blowing Dust	167

INTRODUCTION

Past Research

The wind erosion problem of the Golden Sands Area of Wisconsin (Fig. 1) has received only cursory examination to date. The problem was first documented some 90 years ago by a University of Wisconsin soil physicist (King, 1894). Qualitative estimates of soil and crop damage were designated for areas in Portage and Waushara counties (Fig. 1) as a result of severe wind erosion episodes observed at that time. The recurrence of severe wind erosion events in 1968 again spurred University of Wisconsin researchers to assess the problem. Woodruff et al. (1969) conducted portable wind tunnel erodibility tests for several sandy and muck soils under a variety of soil/crop conditions. However, no detailed analysis of wind frequency data for the Golden Sands Area was completed.

Justification for Present Research

Presently, local soil conservationists must rely on erosive wind frequency and direction data from locations outside the Golden Sands Area for estimating soil loss by wind and determining proper orientation of wind barriers. Changery (1975) has stated that estimates of wind climatology data are within 25% of the actual value for flat areas at distances up to 30 miles (48 km) from the observation location. Eau Claire and Madison, Wisconsin, the two most commonly used locations in the Golden Sands Area are 95 and 93 miles (152 and 149 km) away (respectively) from Stevens Point, the site of this study (Fig. 1). Obviously, there is reason to suspect that wind data for these two locations may not be accurately portraying what is actually observed in Stevens Point. Because of concern over recent severe wind erosion

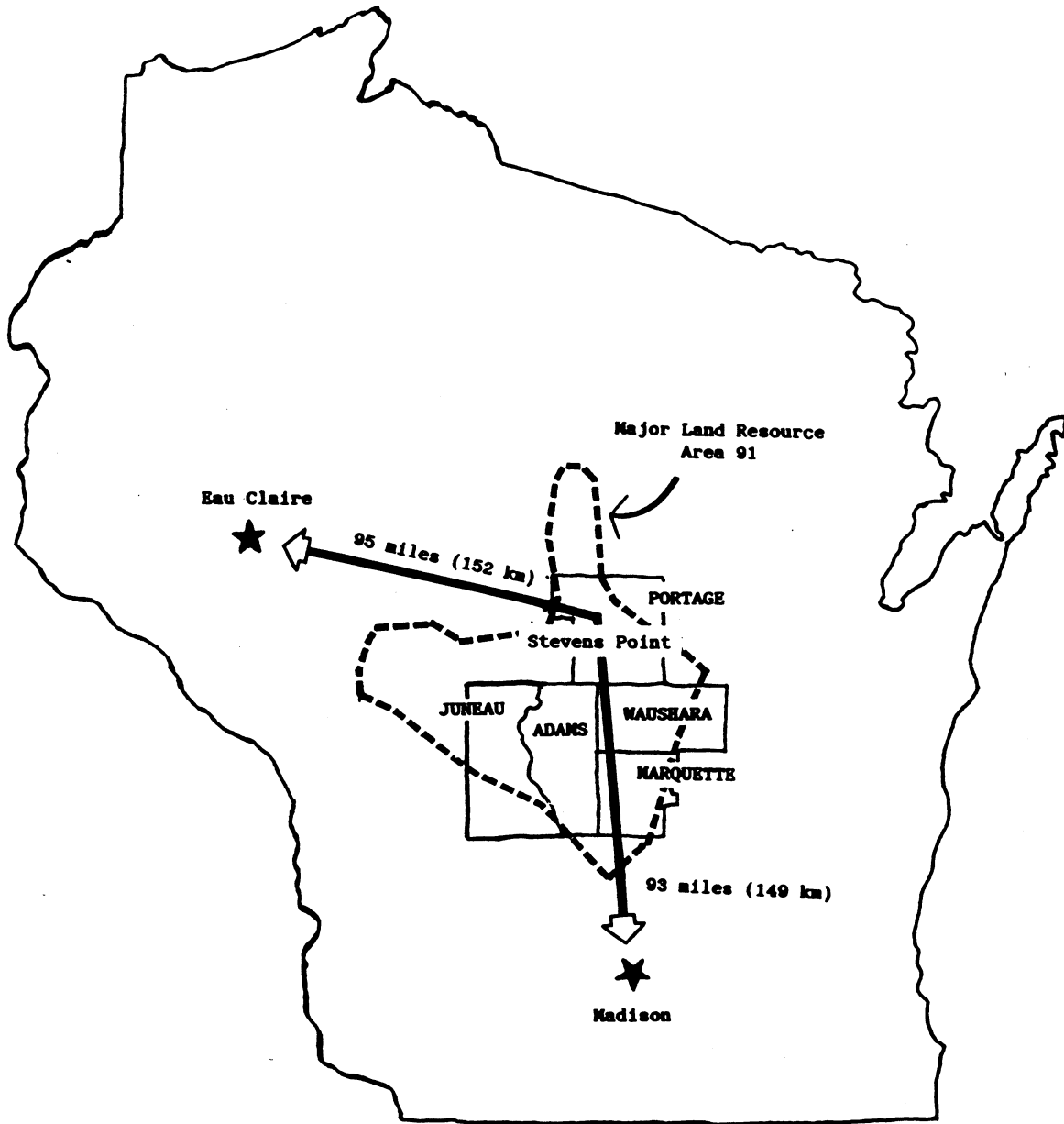


FIGURE 1: GOLDEN SANDS AREA

damages, a unique and timely opportunity presented itself for an analysis of long-term, potentially erosive wind frequencies for Stevens Point, Wisconsin to create a local database. This analysis is intended to serve as an alternative to the wind data currently being used in the Wisconsin Soil Conservation Service (SCS) Technical Guide for Portage County. Wind data for other locations in the Golden Sands Area should be analyzed and applied separately rather than extrapolating the results furnished herein to other locations.

Significance of Wind Erosion in Portage County

Recent National Resources Inventory (NRI) data compiled by SCS indicate that cropland in Major Land Resource Area (MLRA) 91 (Fig. 1) has an average annual soil loss of 6.6 tons per acre per year (T/A/Y) (15.2 mt/ha/y) with erosion due to wind accounting for 70% of that total (Arts, et al., 1984). Portage County average annual soil loss due to wind erosion is 7.3 T/A/Y (16.8 mt/ha/y) (Portage County Land Conservation Dept., 1986). Figure 2 indicates the soil loss due to wind erosion in areas of Portage County targeted for erosion control measures.

The Portage County personnel in the offices of SCS and Department of Land Conservation (1985) estimated countywide crop damages associated with the high winds observed during 1984. Based on interviews with 40 irrigation farmers (accounting for 44,717 acres (18100 ha) of cropland and 81% of all irrigated cropland), the countywide estimate was \$721,891. Adams County (Fig. 1) personnel in the offices of SCS and Department of Land Conservation (1985) also estimated countywide crop damages observed during 1984. There, \$857,371 of crop damages were reported with 91% of

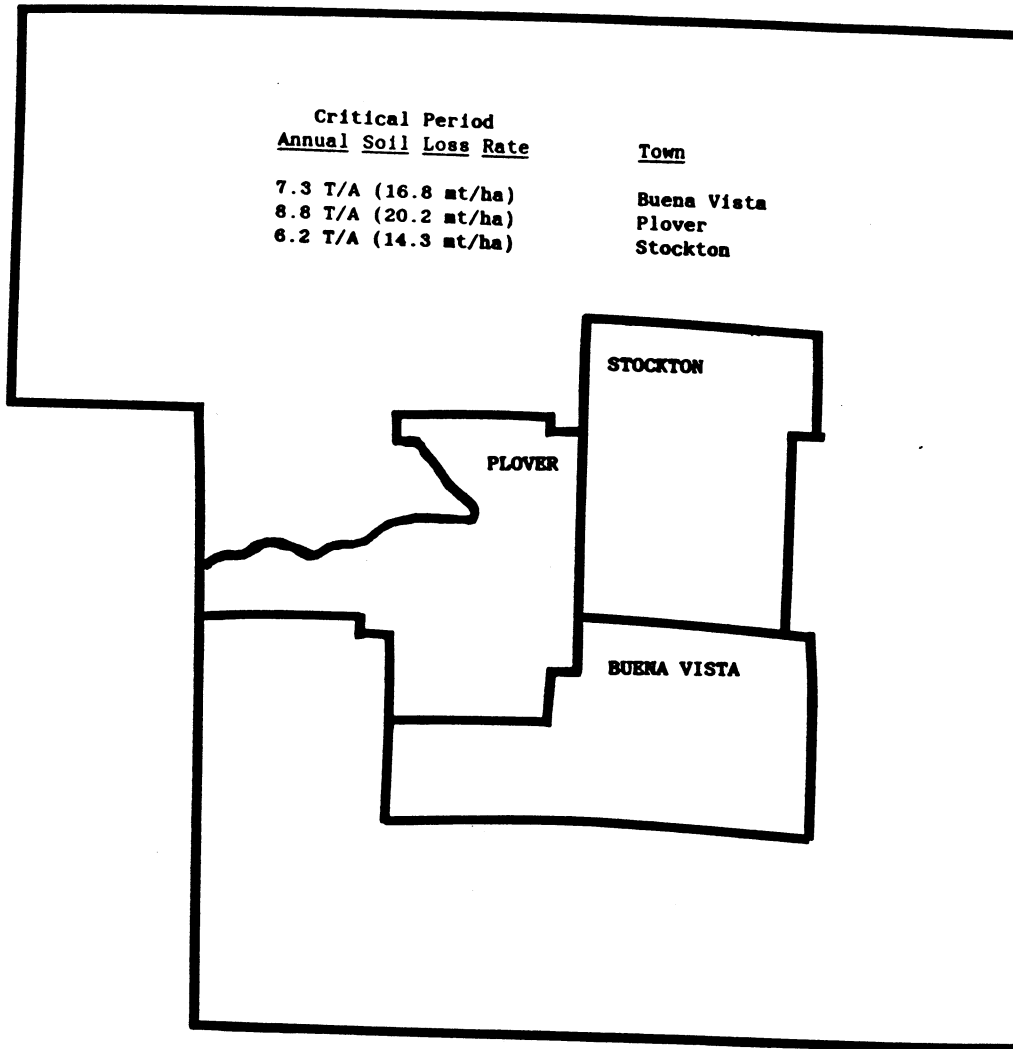


FIGURE 2:

WIND EROSION SOIL LOSS IN PRIORITY AREAS OF PORTAGE COUNTY

that total occurring on irrigated cropland. Damages of a similar magnitude probably occurred in 1985 as well.

Although undocumented quantitatively, there were numerous off-site damages occurring during these high wind periods as well. Recent attention has begun to focus on the potential human health impact of annual springtime dust storms which likely exceed ambient air quality particulate matter standards.

Over 90 years of observations of wind erosion and its effects have finally begun to motivate local, state, and federal government agencies to address this problem. Additional insight and knowledge of the extent and costs of wind erosion in the Golden Sands Area are necessary before the problem can be adequately treated and its effects abated.

Objectives

To these ends, this thesis has the following objectives:

(1) Summarize frequency and return periodicity of potentially erosive winds for Portage County, Wisconsin, according to monthly and critical crop-growth periods.

(2) Determine monthly prevailing wind direction, monthly wind preponderance, monthly and annual erosive wind energy distributions, and the annual climatic erosivity factor for Portage County.

(3) Assemble the data and results into formats useful for soil conservation and crop protection planning and management by Portage County conservationists and crop consultants.

(4) Analyze the erosive wind frequency data for potential identification of cyclic patterns over the period 1950-1967.

WIND AS A SOIL-DISPLACING MEDIUM

Wind erosion is the process of detachment, transportation and deposition of soil material by wind action. Not all winds have high velocities to cause soil movement. Soil grains are moved by wind when the moving airstreams have sufficient energy. Generally speaking, the higher the velocity of the wind, the higher the energy and the more erosive the wind.

In this chapter, the dynamics of initiation of soil movement and the transport of soil by wind action are reviewed. Special emphasis is given to wind as a soil-displacing medium rather than soil conditions susceptible to wind erosion. The latter is treated in sufficient detail elsewhere in the literature (Chepil, 1943; 1950; 1953; 1954; 1956; and 1958; Free, 1911; and Lyles et al., 1974).

The latter section of this chapter relates these processes to two conservation planning functions, (1) soil erosion control and (2) crop damage abatement.

Initiation of Soil Movement

Few researchers have attempted to describe exactly the initial motion of the first particles moved by the fluid force of wind. Most agree that the grain motion, once initiated, is maintained by a process called saltation. These researchers have been satisfied by Bagnold's (1941) statement:

A critical windspeed was reached when the surface grains, previously at rest, began to be rolled along the surface by the direct pressure of the wind. A foot or so downwind of the point at which the rolling began, the grains could be seen to have gathered sufficient speed to start bouncing off the ground.

Similar statements by others can be found in the literature (Chepil, 1945a; Chepil and Woodruff, 1963; Malina, 1941).

Bisal and Nielsen (1962), however, have challenged that description of movement of the first grains. Their study found that most erosive particles vibrated with increasing intensity as windspeed increased and then left the surface instantaneously (as if ejected), attributing the motion to "impulse forces caused by pressure fluctuations." Lyles and Krauss (1971) data supported this hypothesis and also their own hypothesis that the particle-vibration frequency is related to the spectral band containing the maximum energy of turbulent motion. Figure 3 illustrates Bernoulli's theorem that differences in velocity of fluid flow over the top and bottom surfaces of an object can set up pressure differences on these surfaces. Chepil (1945a) felt that the pressure fluctuations were sufficient to force the particles steeply upward into the air stream.

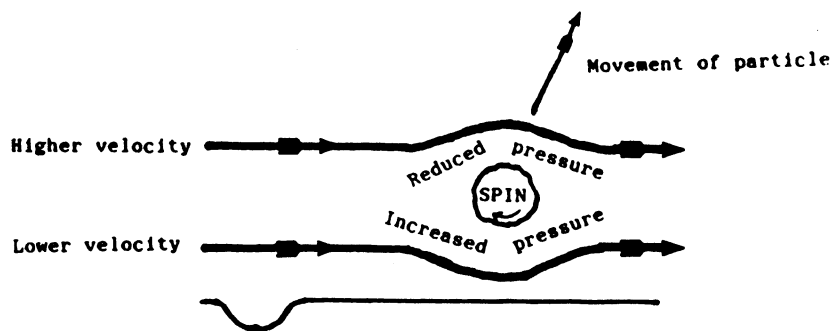


FIGURE 3: A spinning sand grain in a moving air stream is lifted by increased air pressure below and reduced pressure above (After Troeh et al., 1980).

There is generally much better agreement regarding the concept of "threshold velocity" which is the velocity of wind necessary for the majority of certain-sized grains to begin moving. There is a range of threshold velocities for any soil, depending on the previous history of its management. This range varies from 13 to 30 mph (6 to 13 m/sec) at a height of one foot (30 cm) above smooth ground surfaces (Chepil, 1945b and Stallings, 1951). A number of terms have evolved in describing these various velocities.

Bagnold (1941) used the term "initial fluid threshold" for the velocity of wind required to initiate the movement of the predominant diameter of dune sand present. Chepil (1945b), contrastingly, termed the "minimal fluid threshold" as the lowest velocity required to produce a definite movement of the most erosive grains. He also defined a more practical term known as the "minimal impact threshold." This is the minimal velocity required to initiate soil movement by the impact force of the descending grains carried in saltation (a transport process described later), rather than by the direct pressure of the wind against the most erosive grains resting on the soil surface. As stated earlier, there is widespread agreement among researchers that once erosion is initiated, it is maintained by the impacts of particles moving in saltation. Therefore, measuring and estimating minimal impact thresholds for several soil textures of varying characteristics can provide a basis for application of wind erosion control practices to site-specific conditions.

Chepil (1945b) found that the ratio of fluid to impact threshold for soil grains 0.004 inch (0.1mm) in equivalent diameter was approximately 1:1.1, that for large grains of 0.08 to 0.12 inch (2 to 3mm) in diameter was 1:1.13, and that particles smaller than 0.004 inch (0.1mm) in diameter the ratio was 1:1. Thus, the greatest single factor influencing the threshold velocity is size of soil grains. Threshold velocity is least for soil grains 0.004 to 0.006 inch (0.1mm to 0.15mm) in equivalent diameter. These particles only require velocities of 8 to 9 mph (3.6 to 4 m/sec) at six inches (15 cm) above the ground surface. Above this size range the threshold velocity increases with an increase in grain size, whereas below that size it also increases with a decrease in particle size.

The forward velocity of a wind near the ground increases with height. Zero velocity is somewhere above the average roughness elements of the surface (Fig. 4). The taller the roughness elements of the ground, or the taller and less air-permeable the vegetative cover, the higher the level at which zero velocity is found. From this level upward, the velocity increases very rapidly at first, then less rapidly with increasing height (Fig. 5) (Chepil and Woodruff, 1963).

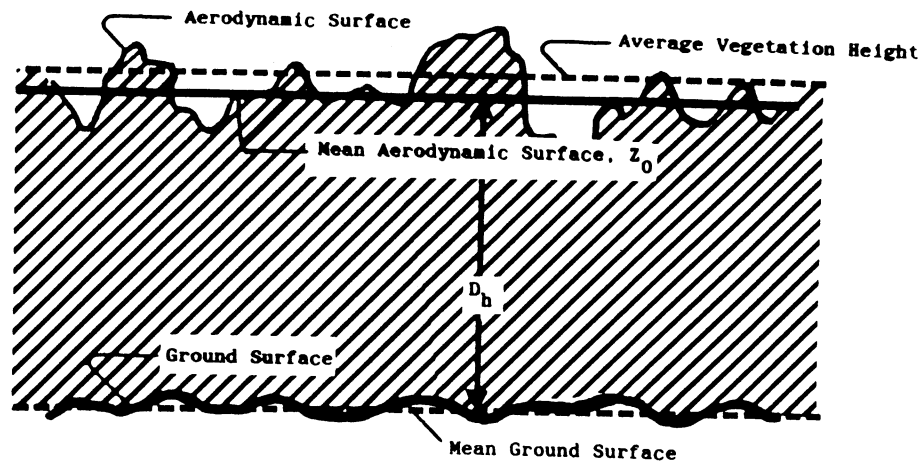


FIGURE 4: WIND VELOCITY NEAR A SOIL SURFACE. Zero wind velocity occurs at z_0 . D_b is the zero displacement height (After Chepil and Woodruff, 1963).

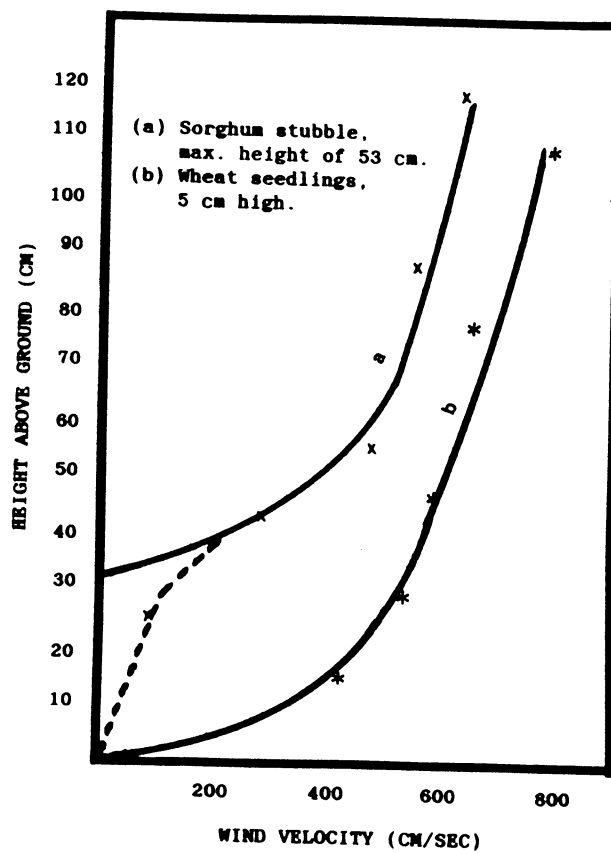


FIGURE 5: SURFACE WIND VELOCITY VARIATION WITH HEIGHT (After Chepil and Woodruff, 1963)

Another consideration of wind as a fluid to initiate soil movement is turbulence. A wind of sufficient velocity as to initiate erosion is characterized by eddies and irregularities of movement of extremely variable velocity. This movement is complex and, except for an extremely thin layer of air at the soil surface, there is a great deal of mixing of air molecules. The measured velocity of wind is the mean value of the forward velocity, although it is made up of momentary currents blowing in all directions. Because of this turbulence, the transporting power of wind is variable, and the threshold velocity depends on the maximum momentary velocities of turbulent flow rather than on the average forward velocity (Chepil, 1945b). Therefore, eddies are of greater importance in the lifting and transportation of soil materials than the average velocity of the wind. Even though these factors have been recognized to influence threshold velocities for initiating sand or soil movement, quantitative information remains limited (Lyles and Krauss, 1971).

Soil Transport Processes

The capacity of air currents for carrying soil material is dependent on the density, velocity, and viscosity of the air. The force of wind against a solid object varies directly with density and viscosity of air and as the square of its velocity. All other conditions remaining the same, the rate of soil movement varies as the cube of the drag velocity, V_* .

$$\text{Eq. [1]} \quad V_* = \frac{v_z}{5.75 \log z/k}$$

where v_z is the velocity at height z , and k is a constant equal to 1/30

of the height of surface irregularity, at which height the wind velocity is zero.

$$\text{Eq. [2]} \quad v_z = \sqrt{\frac{\gamma}{\rho}}$$

where γ is the surface drag in dynes per square centimeter and ρ the density of air (Chepil, 1945b).

Both density and viscosity of air are essentially insignificant factors in the detachment and transport of soil due to their relatively constant behavior in nature (Chepil, 1945b). Therefore, changes in the rate of soil movement must be attributed mainly to changes in the velocity (Fig. 6) and gustiness of the wind (Chepil, 1945c).

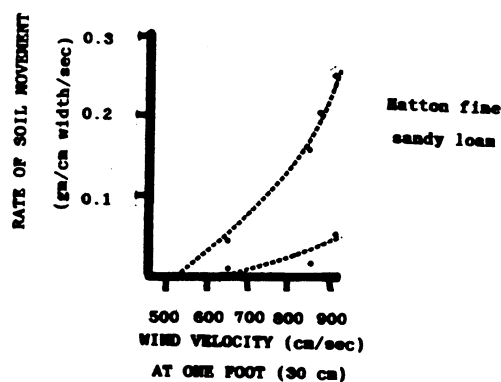


FIGURE 6: RELATION OF WIND VELOCITY IN OPEN FIELD TO (A) SOIL FLOW IN SALTATION AND (B) FLOW IN SURFACE CREEP (After Chepil, 1945c).

Wind erosion is characterized by three types of soil movement -- jumping (saltation), rolling and sliding (surface creep), and floating in the air (suspension). Impacts of grains in saltation cause movements by surface creep and suspension (Chepil and Woodruff, 1963).

The mode of transport of a particle depends primarily on the magnitude of the vertical air motions near the surface and the mass and size of the particle. The general limits of particle size (after Chepil, n.d. and Hilst and Nickola, 1959) for each of these modes of transport are:

Surface creep . . . 0.03 to 0.08 inch (1.00 to 2.00mm)
 Saltation 0.002 to 0.03 inch (0.05 to 1.00mm)
 Suspension < 0.002 inch (< 0.05mm).

Saltation

Chepil (1960b) defined saltation as a series of jumps "initiated when the forces of lift and drag of wind overcome the force of gravity on the individual soil grains." He also stated that the higher the particles rise into the air, the more energy they derive from the wind. The angle of ascent generally ranges between 75° and 90° (Fig. 7). Acceleration and the angle of descent, generally between 6° and 12° , is brought about by the forces of horizontal wind velocity and gravity. Over 90% of soil movement by saltation occurs below the height of one foot (30 cm), while the average vertical ascent of particles is only about 2 to 4 inches (5 to 10 cm), the equivalent of approximately $1/7$ to $1/10$ the length of the "jump." Also, saltating grains are ascending for only about $1/5$ to $1/4$ of the total length of the "jump."

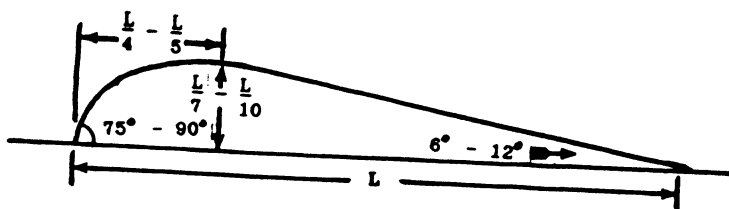


FIGURE 7: PATH OF A SALTATING GRAIN
 (After Troeh et al., 1980)

The impacts of saltation also cause clods and surface crust to

disintegrate to small fragments, which in turn are moved by the wind (Fig. 8). The longer erosion continues and the more the wind shifts from different directions, the greater is the quantity of erodible material formed by abrasion and the higher the rate of erosion (Chepil, n.d.). The proportion of soil particles moving via saltation generally varies between 55% and 72% of the total soil load, and the proportion (whether in saltation, suspension or creep) depends on the aggregate and particle size composition of the soil, not on the wind velocity (Chepil, 1945b).

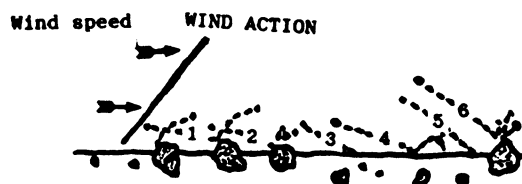


FIGURE 8: MECHANICS OF SALTATING PARTICLES

When these particles impinge upon the surface, 1) they may bounce back into the air stream by virtue of an elastic collision, 2) they may shatter as a result of collision, 3) they may slide along the surface, 4) they may dislodge other particles, 5) they may be absorbed in the surface with no further particle movement, or 6) they may chip off pieces of massive surface elements and the pieces in turn may continue in motion (After Hilst and Nickola, 1959, pg. 74).

On an unprotected eroding field, the rate of erosion is zero along the windward edge and increases with distance toward the leeward side. If the field is unprotected and wide enough, soil movement becomes the maximum that a wind of a given velocity can sustain. The acceleration of soil flow with distance downwind over an unprotected field is known as soil avalanching (Chepil, 1960b). Maximum rate of soil movement is approximately the same for all soils and is about equal to that of dune sand.

The presence of coarse grains and fine dust particles in the soil hinders the movement in saltation. Coarse grains hinder the movement by sheltering the finer, more erodible grains from the wind (Fig. 9). Dust hinders the movement by cohering to the grains and to other dust particles (Chepil and Woodruff, 1963). However, dust is readily moved into suspension by the grains moving in saltation, once the process is initiated.

Surface Creep

Soil particles of about 0.04 to 0.08 inch (1 to 2mm) in equivalent diameter are too heavy to be moved by saltation, hence they are considered nonerosive. However, these large particles are pushed along the surface by the impact of saltating particles. Therefore, they do participate in the erosion process. This sliding or rolling action is called surface creep. The amount of soil moved via surface creep varies between 7% and 25% of the total soil load (Chepil, 1945a).

Suspension

Soil particles smaller than 0.004 inch (0.1mm) in equivalent diameter are generally considered dust and can be carried in true suspension. Dust is highly resistant to erosion by the direct pressure of the wind, but it can readily be moved by the impacts of saltating particles. Once detached by saltation, dust particles will ascend to heights limited primarily by the vertical velocities ($> 3\text{mph}$ or 1.3 m/sec) of turbulent flow and can be carried hundreds or even thousands of miles from their origin (McLouth, 1902; Winchell and Miller, 1918; Watson, 1934; Martin, 1936 and Martin, 1937). Chepil (1945a) found that the amount of soil in

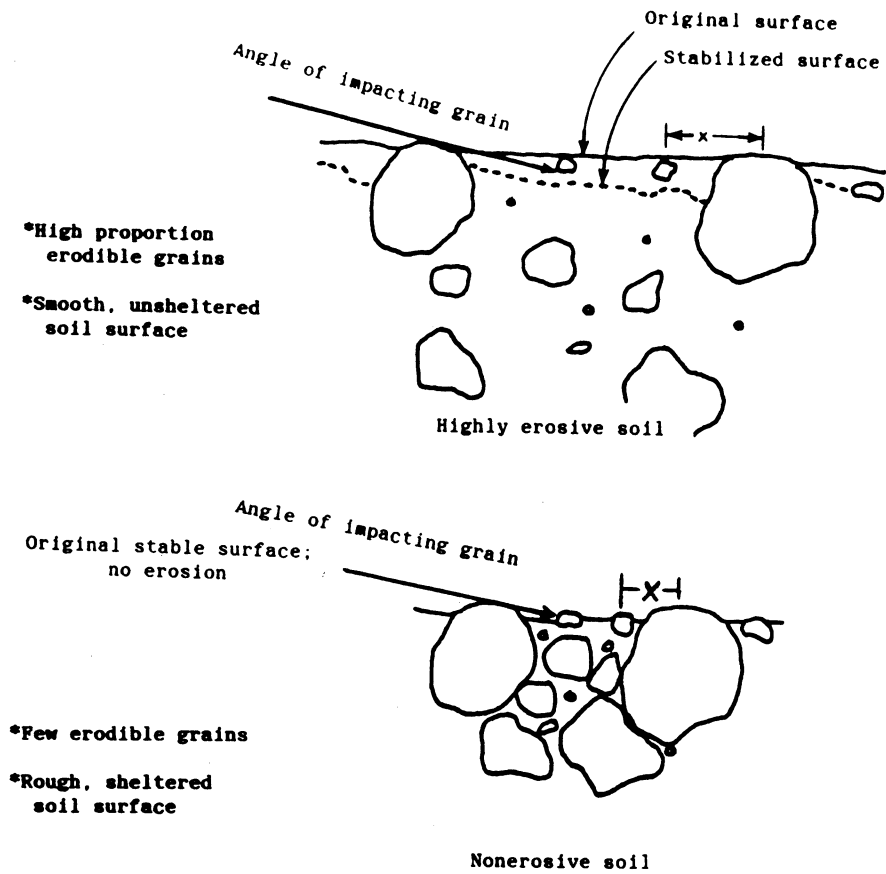


FIGURE 9: STABILITY RELATIONSHIPS OF SOIL SURFACES (After Chepil, 1950)

suspension ranges from 3% to 38% of the moving soil and generally less than 10%.

Sorting of Soil Particles

The wind acts as a fanning mill on the soil -- removing organic matter, fine silt and clay fractions, and leaving behind sand and gravel. The finer the eroded particles the greater is their speed, height and distance of travel. The finer particles have greater mobility despite the fact they are less erodible (Chepil and Woodruff, 1963).

Chepil (1946) aptly demonstrated this sorting action by comparing samples of newly drifted soil to that from which it originated. He found that the proportion of fractions smaller than 0.002 inch (0.05mm) in equivalent diameter was higher in cultivated soils than in the drifts, indicating that a great proportion of those particles had been sorted out from the drifts and removed (via suspension) beyond the vicinity of the eroding field.

The wind evidently tended to separate the soil into several distinct grades, as follows: (a) nonerosive clods and rock materials which remained in place; (b) coarse semierosive grains which were moved but slowly with the wind and most of which remained on the surface of the field after the storm; (c) highly erosive grains forming material that was piled into dunes, chiefly along the border of the eroded field; (d) highly erosive grains bordering on dust which tended to separate from the dune materials and became deposited in uniform layers beyond the position of the dunes; and (e) fine dust which, once lifted off the ground, was carried into the atmosphere.

Chepil (1946) also observed that the amount of grade (b) was in direct proportion to the amount of soil carried in surface creep, grade (c) to

Soil erodibility (I) is the potential annual soil loss (T/A/Y) from a wide, unsheltered field with a bare, smooth, non-crusted surface. Soil-erodibility values are based on wind-tunnel relative erodibilities (Chepil, 1960a) and on measured soil losses in the field in the vicinity of Garden City, Kansas, during 1954 to 1956. These values are modified for knolly terrain because wind is more erosive along the tops of knolls (Troeh et al., 1980).

Soil surface roughness (K) results from three distinct characteristics: (1) cloddiness of the surface soil (considered in I), (2) vegetative residues (considered in V), and (3) ridges on the soil surface resulting primarily from tillage operations. K is expressed in terms of height of standard ridges composed of nonerodible gravel 0.08 to 0.25 inch (2 to 6.4 mm) in diameter. K values indicate whether a soil surface, all else being equal, will resist wind as much as the standard ridges (Troeh et al., 1980).

Climate directly affects wind erosion through wind velocity and indirectly affects it through its influence on plant growth and surface soil moisture. The rate of soil movement by wind varies directly as the cube of wind velocity and inversely as approximately the square of average soil surface moisture, called effective moisture. Effective moisture varies directly with the amount of precipitation and inversely as the square of temperature (Chepil et al., 1962). These two factors are considered together as C, the local climatic factor in the WEE. C values influence a significant proportion of total estimated soil losses using the WEE. This significant influence is also largely unmanipulative

since little can be done to alter average monthly or annual wind velocity, precipitation or temperature patterns over extensive areas. For this reason, C is also the weakest factor in the equation and the one requiring significant research to address its inconsistencies. Several authors (Gillette, 1986; Woodruff, 1975; Skidmore, 1974; and Woodruff and Siddoway, 1965) have indicated some of these research needs regarding the C factor.

Equivalent length of field (L) is the unsheltered distance across or along a field parallel with the prevailing wind erosion direction, less the sheltered distance (that provided by 10x the height of a wind barrier) (Troeh et al., 1980). Calculation of the effect of L on soil loss is complex because it depends on the amount of soil being carried in the wind. On an unprotected, eroding field the rate of erosion increases with distance to the leeward until, if the field is wide enough, the flow reaches a maximum that a wind of a particular velocity can sustain.

Vegetative cover (V) effectiveness standards are for flattened wheat straw. Crop residues other than wheat straw must be converted to equivalent quantities of flattened wheat straw. The amount of erosion control provided by vegetative cover depends on (1) the amount of dry matter, (2) its texture, (3) whether it is living or dead, (4) whether it is standing or flattened, (5) its height if standing, and (6) how the cover is oriented to prevailing erosive winds (Troeh et al., 1980).

Relevance to Conservation Planning

Wind erosion is usually considered a major problem in dryland regions, but reports over the years show that sandy soils even in humid areas suffer severely from wind erosion (King, 1894; Drullinger and Schmidt, 1968). It is also serious on muck soils in humid areas. Wind erosion can also be a serious problem on irrigated land (Mech and Woodruff, 1967). All of these characteristics can be found in the Golden Sands Area (Fig. 1) of Wisconsin. Since the 1950s, the rapid conversion of pasture, scrub oak and jack pine woodlots and pine plantations to intensively-cropped, irrigated agriculture has resulted in more total soil exposure in this region which has heightened the opportunity for increasing occurrences of wind erosion. The effects of wind erosion will probably become more pronounced and cause damage to more extensive areas in the years ahead unless proper and adequate measures are adopted by landowners to reduce or abate soil erosion due to wind.

The intent of this thesis is to provide wind climatology data to local soil conservationists and crop consultants so that they may share this information with area growers to reduce damages to soil and crops due to wind erosion. To do so, conservationists and crop consultants must first understand the mechanics of wind erosion (discussed earlier in this chapter), and then use local wind climatology data to "prescribe" the necessary level of soil/crop protection for an individual grower. For simplicity, these two conservation planning functions are discussed separately, yet the reader is expected to know the obvious interrelationships and similarities each shares with the other.

Soil Erosion Control

Wind erosion can cause a great deal of damage to a soil. This damage takes a variety of forms including loss of soil, textural changes, and nutrient and productivity losses. Chepil (1949) reported that a Canadian loamy sand under virgin conditions lost all its silt and clay in less than 60 years. He also noted that sandy loams, which had gained about 15 percent sand in the top four inches (10 cm) during the same time, would become sand dunes within 150 years of cultivation (assuming no changes in cultural practices). Lyles (1975) proposed a procedure for estimating the effects of wind erosion soil loss on crop yields. He utilized research data from several Great Plains states on several soil types and for three crops (corn, wheat and grain sorghum). Despite the years of research directed toward wind erosion and its control, no widely accepted procedure exists to measure or otherwise quantify the effects of damage to the soil resource as a result of wind erosion.

Soil conservationists continue to rely upon soil loss estimates calculated by the wind erosion equation (WEE) (Woodruff and Siddoway, 1965) and their relationship to soil loss tolerance (T) values as their "yardstick" by which to evaluate soil productivity losses from soils susceptible to wind erosion. Therefore, local wind climatology data for Portage County, Wisconsin, were analyzed and presented herein as tabular and graphical aids to assist conservationists in WEE calculations.

Table 1 lists the types of wind climatology information presented herein and how each can be applied to erosion control planning purposes.

TABLE 1: WIND CLIMATOLOGY DATA FOR EROSION CONTROL PLANNING

DATA TYPE	REFERENCE PAGES	EROSION CONTROL PLANNING FUNCTION
Erosive Wind Frequency		Identification of timeframe when erosive winds occur
Monthly summaries	37-48	
Weekly summaries (March 15 to August 15)	49-70	
Erosive Wind Energy	72,73	Quantitative evaluation of when erosive winds occur
Monthly summaries		Assist computation of annual soil loss with WEE using crop stage periods
Cumulative annual summary		
Prevailing Wind Erosion Direction and Preponderance		Proper orientation of field cultivation practices and wind barriers
Monthly summaries	77	
Extreme Wind Event Analysis		Identification of recurrence of extreme velocity and duration of wind events
Monthly summary (April)	105-107	
Weekly summaries (March 29 through May 2)	107-124	Selection of erosion control measures necessary to prevent excessive soil loss
Climatic Erosivity	81	Assist computation of annual soil loss with WEE

Crop Damage Abatement

Abrasion by impacts of particles transported along the surface by wind is an important phase of the wind erosion process on all soils (Chepil, 1945d). Abrasion caused by wind-blown soil grains is also extremely injurious to plants. Skidmore (1966) reported only slight damage to green bean seedlings at wind speeds up to 40 mph (18 m/sec); however, introduction of even small quantities of sand into the wind greatly increased plant damage. Bubenzer and Weis (1974) observed snap bean and pea yield reductions of 8 to 14% and 16%, respectively, for plants subjected to an abrasive flux in winds of 35 mph (15 m/sec).

Sandblast injury to vegetable crops is a serious problem in many areas where large acreages of vegetables are grown on sandy soils. For example, an estimated total of \$1.6 million of crop damage was sustained in just two counties of the Golden Sands Area of Wisconsin in 1984 alone (Adams County SCS and LCD, 1985; Portage County SCS and LCD, 1985). Vegetable crops are most susceptible to sandblast damage in the seedling growth stage. This is also the time when much of the soil surface is unprotected and exposed to the sun's radiation. The soil surface dries quickly and becomes more susceptible to blowing. Even a small amount of erosion can make establishment difficult, damage early growth, and seriously reduce the marketability of certain crops. Table 2 lists the various factors which govern the extent of injury to a particular crop.

TABLE 2: FACTORS AFFECTING EXTENT OF SANDBLAST INJURY TO CROPS
(After Skidmore, 1966)

Wind velocity
Gustiness of wind
Abrasive flux (amount of airborne or saltating soil grains)
Duration of exposure to airborne flux
Size, shape and density of abrasive
Growth stage and vitality of plant
Temperature and humidity of plant root and aerial environment
(susceptibility to dessication)

Fryrear and Downes (1975) developed an expression to estimate crop survival or production when wind velocity, sand flux rate, plant age and exposure time are measured simultaneously. This relationship will be discussed in more detail in Chapter 4.

Wind and abrasive action of sand particles also provide opportunity for plant contamination by pathogens and nematodes. Thaung and Walker (1957) reported an epidemic of bacterial blight of lima beans shortly after and directly along the path of a severe cyclonic storm. The disease was most pronounced in crops growing on light sandy soils. They suggested that wind borne infested soil particles were the major means of spread of the bacterial blight. Claflin et al. (1973) concluded that wind-blown soil was important in the epidemiology of common blight of bean and that the wind disseminated the pathogens as well as serving as its inoculating agent. Carroll and Viglierchio (1981), Krnjaic and Krnjaic (1972-73), and Orr and Newton (1971) all observed distribution of plant parasitic nematodes by wind and wind erosion. All studies were conducted on light sandy soils known to undergo frequent wind erosion episodes.

Table 3 lists the types of wind climatology information presented herein and how each can be applied to crop damage abatement planning purposes.

TABLE 3: WIND CLIMATOLOGY DATA FOR CROP DAMAGE ABATEMENT PLANNING

DATA TYPE	REFERENCE PAGES	CROP DAMAGE ABATEMENT FUNCTION
Erosive Wind Frequency		
Monthly summaries	37-48	Identification of timeframe when various crop growth stages might be susceptible to sandblast effect or likelihood of pathogen/nematode distribution
Weekly summaries (March 15 to August 15)	49-70	
Erosive Wind Energy	72,73	Assist computation of annual soil loss with WEE using crop stage periods; relate soil loss to susceptibility of crop to sustain sandblast damage
Monthly summaries		
Cumulative annual summary		
Prevailing Wind Erosion		Proper orientation of crop rows and wind barriers
Direction and Preponderance Monthly summaries	77	
Extreme Wind Event Analysis		Identification of recurrence of extreme velocity and duration of wind events and relationship to probable recurrence of sandblast damage or the epidemiology of plant pathogens and nematodes Selection of appropriate erosion/wind control measures to prevent excessive soil movement and/or wind velocities
Monthly summaries	105-107	
Weekly summaries	107-124	

RESEARCH METHODS

Source of Wind Data

The National Oceanic and Atmospheric Administration National Climatic Data Center (NOAA-NCDC) maintains files of Weather Bureau-Army-Navy (WBAN) surface weather records for all such observation locations in the United States. WBAN Forms 10A and 1030A were assembled for Stevens Point, Wisconsin for the period of January 1, 1950 through December 31, 1967. The entire record averaged 17 to 18 observations per day, usually between the hours of 05:50 and 22:50. Other years of record were also available, but were not used here because of lack of sufficient observations, ranging from eight per day to a low of only five per month.

The location of the observation site for the period of record was approximately two miles (3.2 km) northeast of Stevens Point at the present day site of the Municipal Airport. Wind recording equipment were located south of a hangar building. The instruments had good exposure and were mounted 35 feet (10.6 m) above the ground surface.

Data Processing

Quality of the WBAN forms, especially for the early years of the period of record, were poor enough to warrant restraint in use of all data recorded. For example, the original sheets were often very yellow and brittle because of age which made the reading of the numbers difficult at times. Also, wind direction was expressed graphically by an arrow (e.g., ↗ = a wind blowing from the southwest) rather than an azimuth reading. Due to poorly drawn arrows, assignment of wind direction was, at times, a subjective decision by the author. For this reason, and for simplicity

in data entry, wind direction was expressed in only eight principal directions (45-degree segments), rather than the typical 16 directions.

Data were entered into a CANDE file for analysis utilizing the Burroughs B6700 digital computer of the University of Wisconsin-Stevens Point Academic Computing Services. Wind data were entered by date (year, month and day) as a function of repeating direction-velocity values. For example, wind direction was a single digit (e.g., 1 through 8 indicating the eight principal compass points and "0" designating "calm") code value followed by a two-digit velocity value; these three values were repeated corresponding to the number of observations made for each date in the file.

Erosive Wind Frequency

Although no "universal" threshold velocity exists for the initiation of wind erosion, due to site specific conditions and variability (i.e., soil texture and moisture, vegetative cover and/or residue, gustiness and vorticity parameters of wind, etc.), a velocity of 12 mph (5.3 m/s) at approximately one foot (30 cm) above the soil surface is used herein as the minimal erosive velocity (Chepil, 1945b and Stallings, 1951). This velocity roughly corresponds to 18 mph (8 m/s) at a height of 20 to 26 feet (6 to 8 m) (Bondy, Lyles and Hayes, 1980). All wind velocities observed in the data which were ≥ 18 mph (8 m/sec) were assumed to be potentially erosive winds.

For a selected time interval (i.e., weekly critical crop-growth periods, monthly, annual, etc.), the number of hourly observations of wind

velocities ≥ 18 mph (8 m/sec) were divided by the total number of hourly observations to derive a frequency of occurrence of "erosive winds."

Erosive Wind Energy

Erosion rates are commonly related to the cube of windspeed, \bar{u}_z^3 or $(\bar{u}_z - u_t)^3$, where \bar{u}_z is mean windspeed at height z above some reference plane and u_t is the threshold windspeed, the minimum needed to initiate erosion (Chepil and Woodruff, 1963). The cube of windspeed characterizes its energy and represents a logical choice for determining distributions of wind energy over time.

Monthly windspeed distributions were described by the two-parameter, Weibull distribution function [Eq. 4] using windspeed frequency summaries according to Bondy et al. (1980).

$$\text{Eq. [4]} \quad f(V) = (K/C) (V/C)^{k-1} \exp[-(V/C)^k]$$

Windspeed is indicated by V and C and k are the scale and shape parameters, respectively (Justus and Mikhail, 1976; Justus et al., 1978). C is expressed in units of velocity while k is dimensionless. Average monthly wind energy was determined for an interval of 18 to 45 mph (8 to 20 m/s) at increments of 2 mph (1 m/sec) using the Weibull parameters.

Prevailing Wind Erosion Direction and Preponderance

Determination of monthly prevailing wind direction and preponderance values followed the procedures provided in Skidmore (1965). The magnitude of a wind erosion force vector, r_j , is obtained by summing, for all speed groups with windspeeds greater than 18 mph (8 m/sec), the

product of mean windspeed cubed and a duration factor for a specified direction as expressed by Eq. [5].

$$\text{Eq. [5]} \quad r_j = \sum_{i=1}^n \bar{u}_i^3 f_i$$

where \bar{u}_i^3 is the mean windspeed within the i th speed group. f_i is a duration factor which is expressed as the decimal percentage of the total observations that occur in the i th direction within the i th speed group. The sub j 's indicate direction and take on values from 0 through 7, inclusive, representing the eight principal compass directions. They are numbered counterclockwise, starting with east, which is arbitrarily taken as the initial side of the coordinate system. Therefore, $r_j = 0$ and $r_j = 1$ are wind erosion force vectors pointing east and northeast, respectively.

The magnitude of erosion forces parallel to a particular direction can be obtained from the wind erosion force vectors. If p is an imaginary straight line intersecting at the origin of a polar coordinate system and θ_j is the angle between r_j and the imaginary line p (Fig. 10) the amount of erosion forces caused by r_j that occur parallel to p is $r_j \cos \theta_j$ (Skidmore, 1965). A useful parameter is the ratio of the wind erosion forces parallel to line p to those perpendicular to line p . The ratio is computed by:

$$\text{Eq. [6]} \quad R = \frac{\sum_{j=0}^7 r_j | \cos (j \times 45 - \theta) |}{\sum_{j=0}^7 r_j | \cos (j \times 45 - \theta) |}$$

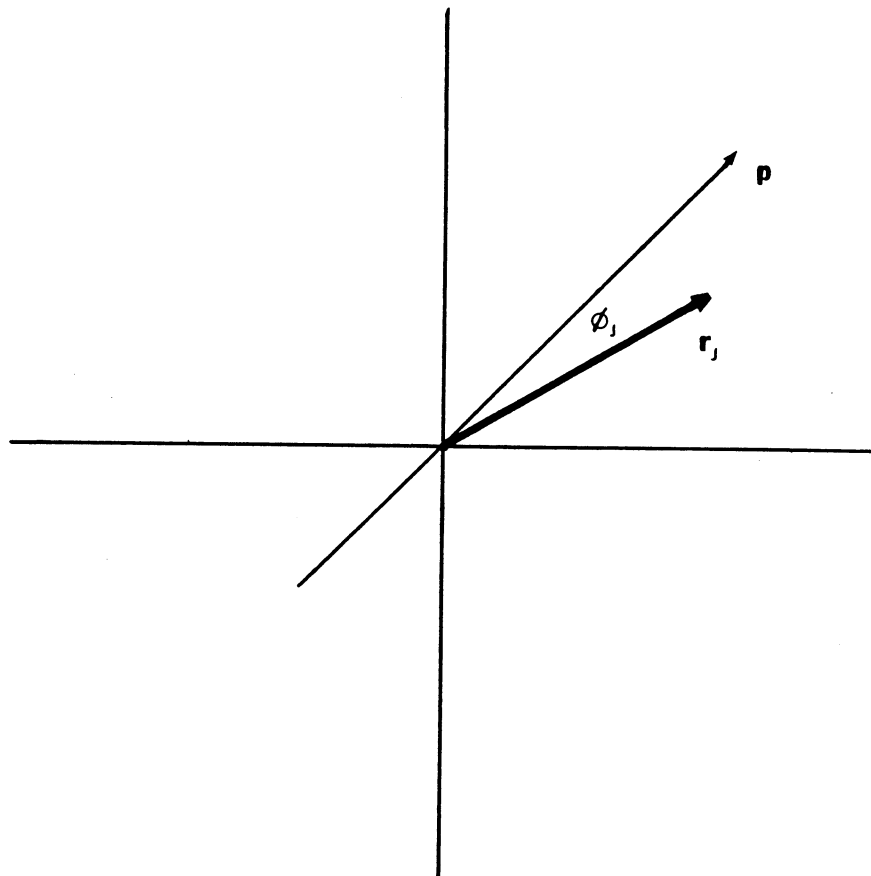


FIGURE 10: SCHEMATIC DETERMINATION OF EROSION FORCE VECTORS

Obtaining an orientation of line p so that this ratio is maximum, tends to maximize wind erosion forces parallel to p and also minimize wind forces perpendicular to p . The greatest value for R , symbolized R_m , is found in the same manner as is direction of maximum wind erosion forces. The orientation of p when R is maximum is called direction of parallel-maximum perpendicular-minimum and is symbolized θ_R . θ_R may also be considered as being the prevailing wind erosion direction. R_m indicates the preponderance of wind erosion forces in the prevailing wind erosion direction (Skidmore, 1965).

Extreme Wind Event Analysis

Estimates of the recurrence of given climatological phenomenon have been made by various methods. The recurrence of erosive winds may not be unlike varying return periods of rain events. Therefore, Zingg (1950) adopted a simplified Gumbel (1941) method described by Powell (1943) to assess the recurrence of specified levels or durations of winds observed in Kansas. A similar method is used here utilizing the MINITAB statistical package on a Burroughs B6700 digital computer.

Initially, the data were screened to identify "extreme events" or maximum velocities observed for a specified time interval set over the entire period of record. For example, the maximum average 1-, 3-, 6-, 9- and 12-hour wind velocities for the month of April of each year (1950 through 1967) were identified. These velocities were then assigned a ranking (m) from highest to lowest values. Probability of exceedance was calculated by Eq. [7].

$$\text{Eq. [7]} \quad P = \frac{m}{N+1}$$

where P is probability, m is rank order, and N is total number of observations (N=18 years of data). Recurrence interval (T_R) or return period was then calculated by Eq. [8]:

$$\text{Eq. [8]} \quad T_R = \frac{1}{P}$$

Return periods of the maximum average velocity for each time interval (1- or 3-hour durations, etc.) were then plotted on Gumbel probability paper for a straight-line curve. Since this method is graphical in nature, no mathematical equation expressing the "line of best fit" is provided.

Climatic Erosivity

The rate of soil movement varies directly as the cube of wind velocity (Chepil, 1945c) and inversely as approximately the square of effective moisture, i.e., moisture held by the soil particles against a given tension exerted by forces of evaporation acting on the soil particles (Chepil, 1956). The effective moisture varies directly with the amount of precipitation and inversely as the square of temperature.

Chepil et al. (1962) assumed that the effective moisture of surface soil particles varied as the Thornthwaite (1948) precipitation effectiveness (P-E) index. P-E Index is calculated by Eq. [9]:

$$\text{Eq. [9]} \quad \begin{array}{l} \mathbf{I} - \mathbf{P-E\ Index} \\ \mathbf{I} = \sum_{n=1}^{12} 115 \times \left[\frac{P}{T-10} \right]_n^{10/9} \end{array}$$

where P is precipitation in inches (≥ 0.5 inch or 13 mm), T is temperature in degrees Fahrenheit ($\geq 28.4^\circ\text{F.}$) and n is the number of the month of year. Once the P-E Index is calculated, the annual climatic erosivity factor, C, is calculated by Eq. [10]:

$$\text{Eq. [10] } C = 100 \left[\frac{v^3}{(P-E)^2} / 2.9 \right]$$

where V is mean annual windspeed (mph) for a standard height of 30 feet (9 m), 2.9 is a constant for the approximate average value for Garden City, Kansas (the location to which all reference locations are standardized), and 100 is a factor to express C in per cent (Chepil et al., 1962).

RESULTS AND DISCUSSION

Erosive Wind Assessment

On an average annual basis, neither the frequency (5%) nor the duration (2 hours) of winds ≥ 18 mph (8 m/sec) observed in Portage County are cause for great concern regarding wind erosion. However, average annual values describing wind erosiveness are not very accurate or revealing regarding the potential frequencies and durations of erosive winds during critical time intervals associated with short-term periods when soils and crops may be highly susceptible to damage. Therefore, analysis of wind data for Portage County focussed primarily on monthly and weekly time intervals. Weekly time intervals can be associated with soil conditions and crop growth stages to determine their susceptibility to wind erosion damage.

Erosive Wind Frequency

Tables 4 through 37 express percent frequency of erosive winds in a manner to facilitate their understanding by their users. Values listed in the tables represent the frequency of a given wind of known velocity and direction expressed as a percent of only the erosive winds observed for the given time interval (monthly or weekly).

Tables 4 through 15 summarize each monthly frequency of total erosive winds, by direction. The observed extreme wind velocity and its direction are also noted as are monthly prevailing wind erosion direction (PWED) and preponderance values.

TABLE 4:
 PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:
 JANUARY²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 + [>23.6]
N	9.7	1.1	0	0	0
NE	5.1	0.9	0	0	0
E	16.1	2.3	0	0	0
SE	3.5	0.2	0	0	0
S	9.2	0.5	0	0	0
SW	4.4	0.2	0.2	0	0
W	31.6	5.8	1.6	2.5	0
NW	5.1	0	0	0	0

Prevailing Wind Erosion Direction = W Preponderance = 3.1

Extreme Wind Velocity = 50 mph (22.2 m/sec) Direction = W

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (monthly).

²N = 9786 hourly observations (1950 - 1967) including 2933 observations of calm periods ("zero velocity") and 484 erosive wind observations.

TABLE 5:
 PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:
 FEBRUARY²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	5.8	1.5	0	0	0
NE	8.3	2.5	0.2	0	0
E	27.3	1.5	0	0	0
SE	2.3	0	0	0	0
S	8.5	0	0	0	0
SW	4.5	0	0	0	0
W	26.1	4.3	0	0	0
NW	6.8	0.4	0	0	0

Prevailing Wind Erosion Direction = W Preponderance = 2.3

Extreme Wind Velocity = 40 mph (17.8 m/sec) Direction = NE

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (monthly).

²N = 8897 hourly observations (1950 - 1967) including 2491 observations of calm periods ("zero velocity") and 483 erosive wind observations.

TABLE 6:
 PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:
 MARCH²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 + [>23.6]
N	18.7	2.1	0	0.2	0.1
NE	8.6	0.8	0.4	0	0
E	20.6	1.8	0.2	0	0
SE	1.6	0	0	0	0
S	6.4	0.4	0.1	0	0
SW	5.2	1.0	0	0	0
W	21.4	2.8	0	0	0
NW	7.2	0.4	0	0	0

Prevailing Wind Erosion Direction = W Preponderance = 1.4

Extreme Wind Velocity = 65 mph (28.9 m/sec) Direction = N

¹Observations of windspeeds ≥ 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (monthly).

²N = 9822 hourly observations (1950 - 1967) including 2420 observations of calm periods ("zero velocity") and 830 erosive wind observations.

TABLE 7:
 PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:
 APRIL²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	12.4	0.4	0	0	0
NE	7.8	1.1	0.1	0	0
E	21.6	0.9	0	0	0
SE	4.6	0	0	0	0
S	7.3	0	0	0	0
SW	4.9	0	0	0	0
W	28.3	2.2	0	0	0
NW	8.4	0	0	0	0

Prevailing Wind Erosion Direction = W Preponderance = 1.9

Extreme Wind Velocity = 40 mph (17.8 m/sec) Direction = NE

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (monthly).

²N = 9470 hourly observations (1950 - 1967) including 1687 observations of calm periods ("zero velocity") and 1117 erosive wind observations.

TABLE 8:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

MAY²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	7.4	0.1	0	0	0
NE	6.7	0.3	0	0	0
E	21.9	0.1	0	0	0
SE	5.6	0.1	0	0	0
S	13.6	0.5	0.4	0.8	0
SW	7.9	0.5	0	0	0
W	25.3	1.3	0.8	0.3	0
NW	6.3	0	0	0	0

Prevailing Wind Erosion Direction = W Preponderance = 1.5

Extreme Wind Velocity = 50 mph (22.2 m/sec) Direction = S

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (monthly).

²N = 9745 hourly observations (1950 - 1967) including 1697 observations of calm periods ("zero velocity") and 748 erosive wind observations.

TABLE 9:
 PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:
 JUNE²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 + [>23.6]
N	12.0	0	0	0	0
NE	2.8	0	0	0	0
E	7.6	0	0	0	0
SE	1.9	0	0	0	0
S	25.9	0.9	0	0	0
SW	10.6	0.2	0.5	0	0
W	30.8	1.9	0	0	0
NW	4.9	0	0	0	0

Prevailing Wind Erosion Direction = SW Preponderance = 1.2

Extreme Wind Velocity = 40 mph (17.8 m/sec) Direction = SW

¹Observations of windspeeds ≥ 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (monthly).

²N = 9513 hourly observations (1950 - 1967) including 2355 observations of calm periods ("zero velocity") and 432 erosive wind observations.

TABLE 10:
 PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:
 JULY²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	5.4	0.5	0	0	0
NE	5.4	0	0	0	0
E	11.3	0.5	0	0	0
SE	5.9	0	0	0	0
S	24.2	0	0	0	0
SW	11.8	0.5	0	0	0
W	23.6	1.0	0	0	0
NW	9.9	0	0	0	0

Prevailing Wind Erosion Direction = W Preponderance = 1.2

Extreme Wind Velocity = 35 mph (15.6 m/sec) Direction = W

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (monthly).

²N = 9797 hourly observations (1950 - 1967) including 3175 observations of calm periods ("zero velocity") and 203 erosive wind observations.

TABLE 11:
 PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:
 AUGUST²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	6.4	0.8	0	0	0
NE	14.4	0	0	0	0
E	7.2	0	0	0	0
SE	4.8	0	0	0	0
S	22.4	0.8	0	0	0
SW	18.4	0	0	0	0
W	11.2	0.8	0	0	0
NW	12.8	0	0	0	0

Prevailing Wind Erosion Direction = SW Preponderance = 1.3

Extreme Wind Velocity = 30 mph (13.3 m/sec) Direction = S and W

¹Observations of windspeeds ≥ 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (monthly).

²N = 9774 hourly observations (1950 - 1967) including 3375 observations of calm periods ("zero velocity") and 125 erosive wind observations.

TABLE 12:
 PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:
 SEPTEMBER²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	5.8	0	0	0	0
NE	2.0	0	0	0	0
E	10.5	0	0	0	0
SE	6.1	0.7	0	0	0
S	32.2	1.0	0	0	0
SW	8.8	0.7	0	0	0
W	23.7	3.1	0	0	0
NW	5.4	0	0	0	0

Prevailing Wind Erosion Direction = W Preponderance = 1.0

Extreme Wind Velocity = 35 mph (15.6 m/sec) Direction = W and SW

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (monthly).

²N = 9466 hourly observations (1950 - 1967) including 3017 observations of calm periods ("zero velocity") and 295 erosive wind observations.

TABLE 13:
 PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:
 OCTOBER²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	8.7	0	0	0	0
NE	6.4	0	0	0	0
E	10.4	0	0	0	0
SE	7.8	0	0	0	0
S	24.3	0	0	0	0
SW	10.3	0	0.6	0	0
W	22.3	0	0.3	0	0
NW	8.9	0	0	0	0

Prevailing Wind Erosion Direction = SW Preponderance = 1.1

Extreme Wind Velocity = 40 mph (17.8 m/sec) Direction = SW and W

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (monthly).

²N = 9807 hourly observations (1950 - 1967) including 2996 observations of calm periods ("zero velocity") and 358 erosive wind observations.

TABLE 14:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

NOVEMBER²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 + [>23.6]
N	11.3	1.5	0	0	0
NE	3.6	0	0	0	0
E	10.1	0	0	0	0
SE	7.4	0	0	0	0
S	13.9	0.4	0	0	0
SW	6.5	1.4	0	0	0
W	32.3	3.4	0	0	0
NW	7.8	0.4	0	0	0

Prevailing Wind Erosion Direction = W Preponderance = 1.4

Extreme Wind Velocity = 35 mph (15.6 m/sec) Direction = W, SW and N

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (monthly).

²N = 9477 hourly observations (1950 - 1967) including 2509 observations of calm periods ("zero velocity") and 524 erosive wind observations.

TABLE 15:
 PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:
 DECEMBER²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	10.8	0.3	0	0	0
NE	5.2	0.3	0	0	0
E	19.0	1.2	0	0	0
SE	4.2	0.3	0	0	0
S	10.8	0.9	0	0	0
SW	14.2	0	0	0	0
W	26.5	0.3	0	0	0
NW	6.0	0	0	0	0

Prevailing Wind Erosion Direction = W Preponderance = 1.5

Extreme Wind Velocity = 30 mph (13.3 m/sec) Direction = E and S

¹Observations of windspeeds ≥ 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (monthly).

²N = 9806 hourly observations (1950 - 1967) including 2908 observations of calm periods ("zero velocity") and 332 erosive wind observations.

TABLE 16:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

MARCH 15 - 21²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 + [>23.6]
N	20.8	0.9	0	0	0.4
NE	4.0	0	0	0	0
E	20.4	0.9	0	0	0
SE	0	0	0	0	0
S	7.4	0.4	0.4	0	0
SW	6.4	0.9	0	0	0
W	28.7	2.5	0	0	0
NW	5.9	0	0	0	0

Extreme Wind Velocity = 65 mph (28.9 m/sec) Direction = N

¹Observations of windspeeds ≥ 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2194 hourly observations (1950 - 1967) including 440 observations of calm periods ("zero velocity") and 202 erosive wind observations.

TABLE 17:
 PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:
 MARCH 22 - 28²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54+ [>23.6]
N	8.8	1.5	0	0	0
NE	9.8	3.6	2.0	0	0
E	22.7	6.2	1.0	0	0
SE	2.6	0	0	0	0
S	10.3	0.5	0	0	0
SW	5.7	2.0	0	0	0
W	9.3	5.2	0	0	0
NW	8.8	0	0	0	0

Extreme Wind Velocity = 40 mph (17.8 m/sec) Direction = NE and E

¹Observations of windspeeds ≥ 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2240 hourly observations (1950 - 1967) including 625 observations of calm periods ("zero velocity") and 194 erosive wind observations.

TABLE 18:
 PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:
 MARCH 29 - APRIL 4²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	7.2	0.6	0	0	0
NE	1.2	0	0	0	0
E	26.9	0	0	0	0
SE	7.2	0	0	0	0
S	15.6	0	0	0	0
SW	2.4	0	0	0	0
W	30.5	2.4	0	0	0
NW	6.0	0	0	0	0

Extreme Wind Velocity = 30 mph (13.3 m/sec) Direction = N and W

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2231 hourly observations (1950 - 1967) including 459 observations of calm periods ("zero velocity") and 167 erosive wind observations.

TABLE 19:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

APRIL 5 - 11²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	19.6	0	0	0	0
NE	8.9	0	0	0	0
E	20.5	2.7	0	0	0
SE	8.5	0	0	0	0
S	5.4	0	0	0	0
SW	0.9	0	0	0	0
W	21.4	0.9	0	0	0
NW	11.2	0	0	0	0

Extreme Wind Velocity = 30 mph (13.3 m/sec) Direction = W and E

¹Observations of windspeeds ≥ 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2218 hourly observations (1950 - 1967) including 449 observations of calm periods ("zero velocity") and 224 erosive wind observations.

TABLE 20:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

APRIL 12 - 18²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	16.1	1.4	0	0	0
NE	9.3	3.9	0.4	0	0
E	8.5	0	0	0	0
SE	2.9	0	0	0	0
S	5.7	0	0	0	0
SW	6.1	0	0	0	0
W	31.4	2.9	0	0	0
NW	11.4	0	0	0	0

Extreme Wind Velocity = 40 mph (17.8 m/sec) Direction = NE

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2186 hourly observations (1950 - 1967) including 399 observations of calm periods ("zero velocity") and 280 erosive wind observations.

TABLE 21:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

APRIL 19 - 25²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	9.2	0	0	0	0
NE	11.6	0.4	0	0	0
E	29.2	0.7	0	0	0
SE	1.8	0	0	0	0
S	7.7	0	0	0	0
SW	4.2	0	0	0	0
W	25.3	3.2	0	0	0
NW	6.7	0	0	0	0

Extreme Wind Velocity = 30 mph (13.3 m/sec) Direction = W

¹Observations of windspeeds ≥ 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2200 hourly observations (1950 - 1967) including 334 observations of calm periods ("zero velocity") and 284 erosive wind observations.

TABLE 22:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

APRIL 26 - MAY 2²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 + [>23.6]
N	7.4	0	0	0	0
NE	10.7	0	0	0	0
E	30.3	0.8	0	0	0
SE	3.7	0	0	0	0
S	7.8	0	0	0	0
SW	8.6	0	0	0	0
W	25.4	0.8	0	0	0
NW	4.5	0	0	0	0

Extreme Wind Velocity = 30 mph (13.3 m/sec) Direction = W and E

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2213 hourly observations (1950 - 1967) including 377 observations of calm periods ("zero velocity") and 244 erosive wind observations.

TABLE 23:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

MAY 3 - 9²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 + [>23.6]
N	9.6	0	0	0	0
NE	4.8	0	0	0	0
E	9.6	0	0	0	0
SE	9.0	0	0	0	0
S	7.8	1.2	1.8	3.6	0
SW	5.4	0	0	0	0
W	29.2	6.0	3.6	1.2	0
NW	7.2	0	0	0	0

Extreme Wind Velocity = 50 mph (22.2 m/sec) Direction = N

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2223 hourly observations (1950 - 1967) including 384 observations of calm periods ("zero velocity") and 167 erosive wind observations.

TABLE 24:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

MAY 10 - 16²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	5.0	0.5	0	0	0
NE	4.5	1.0	0	0	0
E	14.5	0	0	0	0
SE	3.5	0.5	0	0	0
S	18.0	0.5	0	0	0
SW	10.5	1.5	0	0	0
W	26.5	0	0	0	0
NW	13.5	0	0	0	0

Extreme Wind Velocity = 32 mph (14.2 m/sec) Direction = S

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2194 hourly observations (1950 - 1967) including 409 observations of calm periods ("zero velocity") and 200 erosive wind observations.

TABLE 25:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

MAY 17 - 23²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	3.2	0	0	0	0
NE	7.6	0	0	0	0
E	38.2	0.7	0	0	0
SE	8.9	0	0	0	0
S	10.8	0.7	0	0	0
SW	10.2	0	0	0	0
W	17.2	0	0	0	0
NW	2.5	0	0	0	0

Extreme Wind Velocity = 30 mph (13.3 m/sec) Direction = S

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2198 hourly observations (1950 - 1967) including 354 observations of calm periods ("zero velocity") and 157 erosive wind observations.

TABLE 26:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

MAY 24 - 30²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	13.4	0	0	0	0
NE	0.8	0	0	0	0
E	22.8	0	0	0	0
SE	3.9	0	0	0	0
S	18.9	0	0	0	0
SW	8.7	0	0	0	0
W	29.9	0	0	0	0
NW	1.6	0	0	0	0

Extreme Wind Velocity = 25 mph (11.1 m/sec) Direction = NW

¹Observations of windspeeds ≥ 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2192 hourly observations (1950 - 1967) including 393 observations of calm periods ("zero velocity") and 127 erosive wind observations.

TABLE 27:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

MAY 31 - JUNE 6²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	17.4	0	0	0	0
NE	1.7	0	0	0	0
E	5.2	0	0	0	0
SE	0.9	0	0	0	0
S	25.3	0	0	0	0
SW	9.6	1.7	0	0	0
W	33.9	0	0	0	0
NW	4.3	0	0	0	0

Extreme Wind Velocity = 35 mph (15.6 m/sec) Direction = SW

¹Observations of windspeeds ≥ 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2210 hourly observations (1950 - 1967) including 528 observations of calm periods ("zero velocity") and 115 erosive wind observations.

TABLE 28:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

JUNE 7 - 13²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	5.4	0	0	0	0
NE	6.3	0	0	0	0
E	10.8	0	0	0	0
SE	2.7	0	0	0	0
S	26.1	1.8	0	0	0
SW	11.8	0	0	0	0
W	30.6	0	0	0	0
NW	4.5	0	0	0	0

Extreme Wind Velocity = 30 mph (13.3 m/sec) Direction = S

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2240 hourly observations (1950 - 1967) including 566 observations of calm periods ("zero velocity") and 111 erosive wind observations.

TABLE 29:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

JUNE 14 - 20²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	14.9	0	0	0	0
NE	0	0	0	0	0
E	5.0	0	0	0	0
SE	2.0	0	0	0	0
S	18.8	1.0	0	0	0
SW	8.9	0	0	0	0
W	36.6	5.9	0	0	0
NW	6.9	0	0	0	0

Extreme Wind Velocity = 30 mph (13.3 m/sec) Direction = S and W

¹Observations of windspeeds ≥ 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2213 hourly observations (1950 - 1967) including 531 observations of calm periods ("zero velocity") and 101 erosive wind observations.

TABLE 30:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

JUNE 21 - 27²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	14.5	0	0	0	0
NE	2.7	0	0	0	0
E	5.4	0	0	0	0
SE	1.8	0	0	0	0
S	28.8	0.9	0	0	0
SW	7.2	0	1.8	0	0
W	30.6	1.8	0	0	0
NW	4.5	0	0	0	0

Extreme Wind Velocity = 40 mph (17.8 m/sec) Direction = SW

¹Observations of windspeeds ≥ 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2222 hourly observations (1950 - 1967) including 576 observations of calm periods ("zero velocity") and 111 erosive wind observations.

TABLE 31:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

JUNE 28 - JULY 4²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	1.3	0	0	0	0
NE	1.3	0	0	0	0
E	20.5	0	0	0	0
SE	5.1	0	0	0	0
S	7.6	0	0	0	0
SW	14.1	0	0	0	0
W	44.9	2.6	0	0	0
NW	2.6	0	0	0	0

Extreme Wind Velocity = 35 mph (15.6 m/sec) Direction = W

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2202 hourly observations (1950 - 1967) including 551 observations of calm periods ("zero velocity") and 78 erosive wind observations.

TABLE 32:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

JULY 5 - 11²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	10.3	0	0	0	0
NE	0	0	0	0	0
E	10.7	0	0	0	0
SE	7.2	0	0	0	0
S	28.5	0	0	0	0
SW	7.2	0	0	0	0
W	25.0	0	0	0	0
NW	10.7	0	0	0	0

Extreme Wind Velocity = 25 mph (11.1 m/sec) Direction = SW

¹Observations of windspeeds ≥ 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2197 hourly observations (1950 - 1967) including 669 observations of calm periods ("zero velocity") and 28 erosive wind observations.

TABLE 33:
PERCENT FREQUENCY OF TOTAL EROSIVE WINDS¹:

JULY 12 - 18²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	0	0	0	0	0
NE	2.6	0	0	0	0
E	2.6	2.6	0	0	0
SE	5.3	0	0	0	0
S	65.8	0	0	0	0
SW	7.9	0	0	0	0
W	5.3	0	0	0	0
NW	7.9	0	0	0	0

Extreme Wind Velocity = 30 mph (13.3 m/sec) Direction = E

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2221 hourly observations (1950 - 1967) including 745 observations of calm periods ("zero velocity") and 38 erosive wind observations.

TABLE 34:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

JULY 19 - 25²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	8.2	0	0	0	0
NE	14.8	0	0	0	0
E	8.2	0	0	0	0
SE	6.6	0	0	0	0
S	16.4	0	0	0	0
SW	19.7	1.6	0	0	0
W	19.7	0	0	0	0
NW	4.8	0	0	0	0

Extreme Wind Velocity = 30 mph (13.3 m/sec) Direction = SW

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2221 hourly observations (1950 - 1967) including 726 observations of calm periods ("zero velocity") and 61 erosive wind observations.

TABLE 35:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

JULY 26 - AUGUST 1²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54+ [>23.6]
N	8.3	4.2	0	0	0
NE	8.3	0	0	0	0
E	8.3	0	0	0	0
SE	4.2	0	0	0	0
S	16.7	0	0	0	0
SW	8.3	0	0	0	0
W	4.2	0	0	0	0
NW	37.5	0	0	0	0

Extreme Wind Velocity = 30 mph (13.3 m/sec) Direction = N

¹Observations of windspeeds ≥ 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2215 hourly observations (1950 - 1967) including 821 observations of calm periods ("zero velocity") and 24 erosive wind observations.

TABLE 36:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

AUGUST 2 - 8²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 + [>23.6]
N	17.6	0	0	0	0
NE	23.5	0	0	0	0
E	17.6	0	0	0	0
SE	0	0	0	0	0
S	5.9	0	0	0	0
SW	23.5	0	0	0	0
W	0	0	0	0	0
NW	11.9	0	0	0	0

Extreme Wind Velocity = 24 mph (10.7 m/sec) Direction = SW

¹Observations of windspeeds ≥ 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2190 hourly observations (1950 - 1967) including 778 observations of calm periods ("zero velocity") and 17 erosive wind observations.

TABLE 37:
PERCENT FREQUENCY OF TOTAL EROSIIVE WINDS¹:

AUGUST 9 - 15²

Direction	Windspeed Group in Miles per Hour [m/sec]				
	18 - 26 [8 - 11.6]	27 - 35 [12-15.6]	36 - 44 [16-19.6]	45 - 53 [20-23.6]	54 ⁺ [>23.6]
N	4.2	0	0	0	0
NE	12.5	0	0	0	0
E	12.5	0	0	0	0
SE	4.2	0	0	0	0
S	12.5	0	0	0	0
SW	20.9	0	0	0	0
W	4.2	4.2	0	0	0
NW	25.0	0	0	0	0

Extreme Wind Velocity = 30 mph (13.3 m/sec) Direction = W

¹Observations of windspeeds \geq 18 mph (8 m/sec), measured at a reference height of 35 feet (10.6 m), expressed as a percent of total erosive winds during selected time interval (weekly).

²N = 2203 hourly observations (1950 - 1967) including 801 observations of calm periods ("zero velocity") and 24 erosive wind observations.

Tables 16 through 37 summarize each weekly frequency of total erosive winds, by direction, for the 22-week period (March 15 through August 15) of critical soil-crop conditions most susceptible to damage. The observed extreme wind velocity and its direction are also noted.

Monthly erosive wind frequencies show how the prevailing direction changes throughout the year, yet it also suggests a westerly component during the critical months of March through June and October through November. This latter fact has been assumed to be true by soil conservationists and farmers alike, as evidenced by the orientation of windbreaks and crop rows generally perpendicular to west on most local farms having wind erosion control practices. However, as suggested by the relatively low monthly preponderance values, the constancy of the prevailing wind erosion direction may not be great enough to justify over-reliance on PWED values in prescribing permanent erosion control practices such as tree windbreaks. Results in tables 4 through 37 suggest a substantially variable nature of the directional component of a given "prevailing" erosive wind observed in Portage County. Therefore, reliance upon only monthly PWED in dictating orientation of erosion control practices is unwarranted and undesirable. Further discussion and classification of this point will be treated in a latter section of this chapter.

Erosive Wind Energy

Table 38 lists the erosive wind energy $[(m/sec)^3]$ and associated monthly and cumulative annual percent values. Figure 11 illustrates the

TABLE 38: EROSION WIND ENERGY, STEVENS POINT

MONTH	WIND ENERGY (m/sec) ³	PERCENT OF ANNUAL	CUMULATIVE PERCENT
January	67	8.5	8.5
February	74	9.3	17.8
March	122	15.4	33.2
April	144	18.1	51.3
May	87	11.0	62.3
June	54	6.8	69.1
July	17	2.1	71.2
August	16	2.0	73.2
September	39	4.9	78.1
October	47	5.9	84.0
November	84	10.6	94.6
December	43	5.4	100.0

ANNUAL TOTAL = 100.0

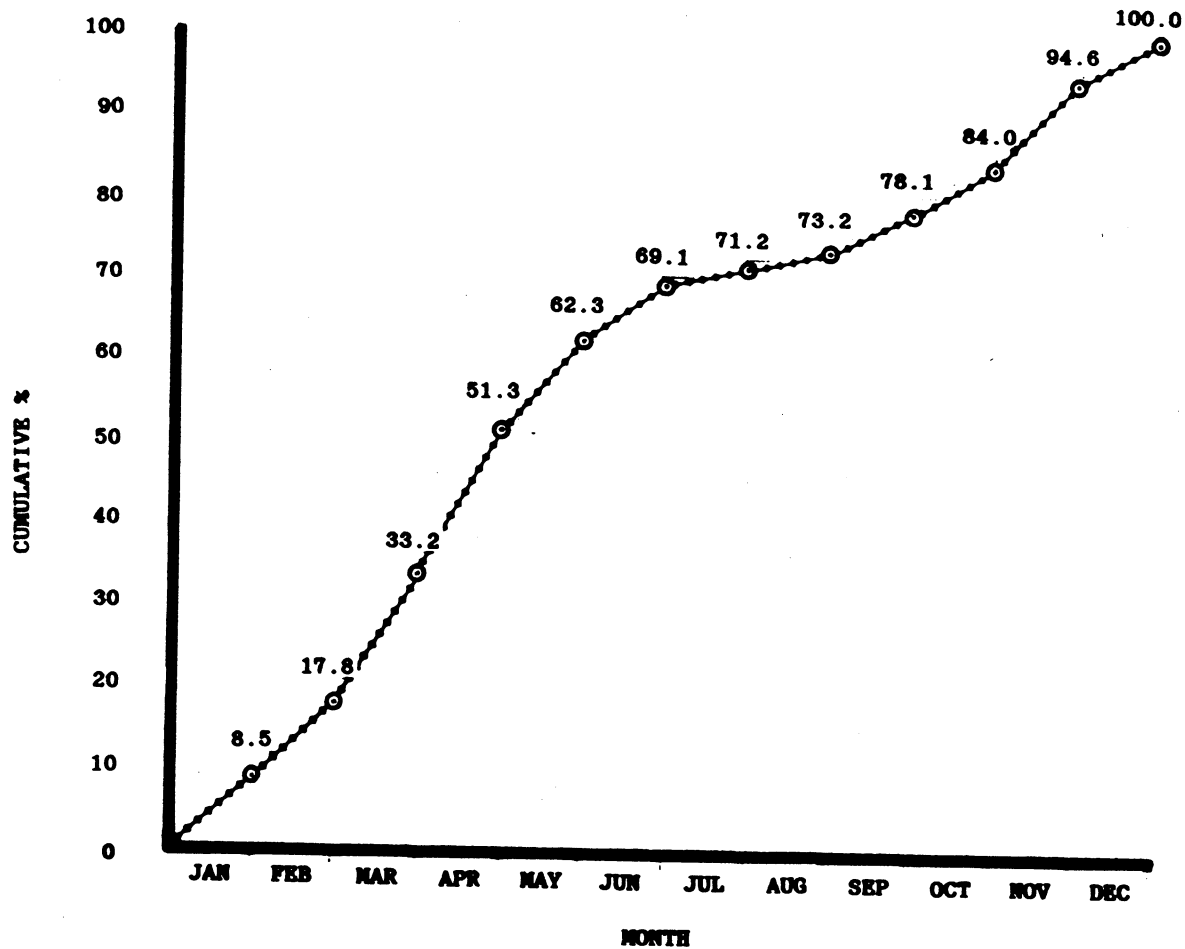


FIGURE 11: EROSIIVE WIND ENERGY DISTRIBUTION
(STEVENS POINT, WI)

graphical representation of erosive wind energy distribution. Figure 12 illustrates the erosive wind energy distributions for Madison and Eau Claire.

The erosive wind energy (EWE) distribution for Eau Claire (Fig. 12) has traditionally been extrapolated for use in Portage County in estimating average annual soil losses due to wind via calculation with the wind erosion equation (WEE). Figure 13 illustrates the significant differences between the distribution of erosive wind energy for Stevens Point and Eau Claire, especially during the month of March. The cumulative percent of annual erosive wind energy at Stevens Point is 10.6% greater than that at Eau Claire. March is a critical period for erosion in Portage County since 15.4% of the total annual erosive wind energy occurs during this month and cropping practices expose the soil to wind erosion at this same time. April is also a critical month for erosion in Portage County, accounting for 18.1% of the annual EWE.

It should be noted that prevailing wind erosion direction and preponderance data are not available for Eau Claire, therefore data for Madison are extrapolated to Stevens Point. However, the erosive wind energy distribution for Madison is very similar to that of Stevens Point. Despite knowledge of these differences now, Madison EWE distribution should have been used in the past anytime its PWED and preponderance values were used (and vice versa) to ensure consistency in use of this wind data. This is true due to the fact that all three types of data (EWE, PWED, and preponderance) share the same physical data collection characteristics and other inherent interrelationships (e.g., temporal,

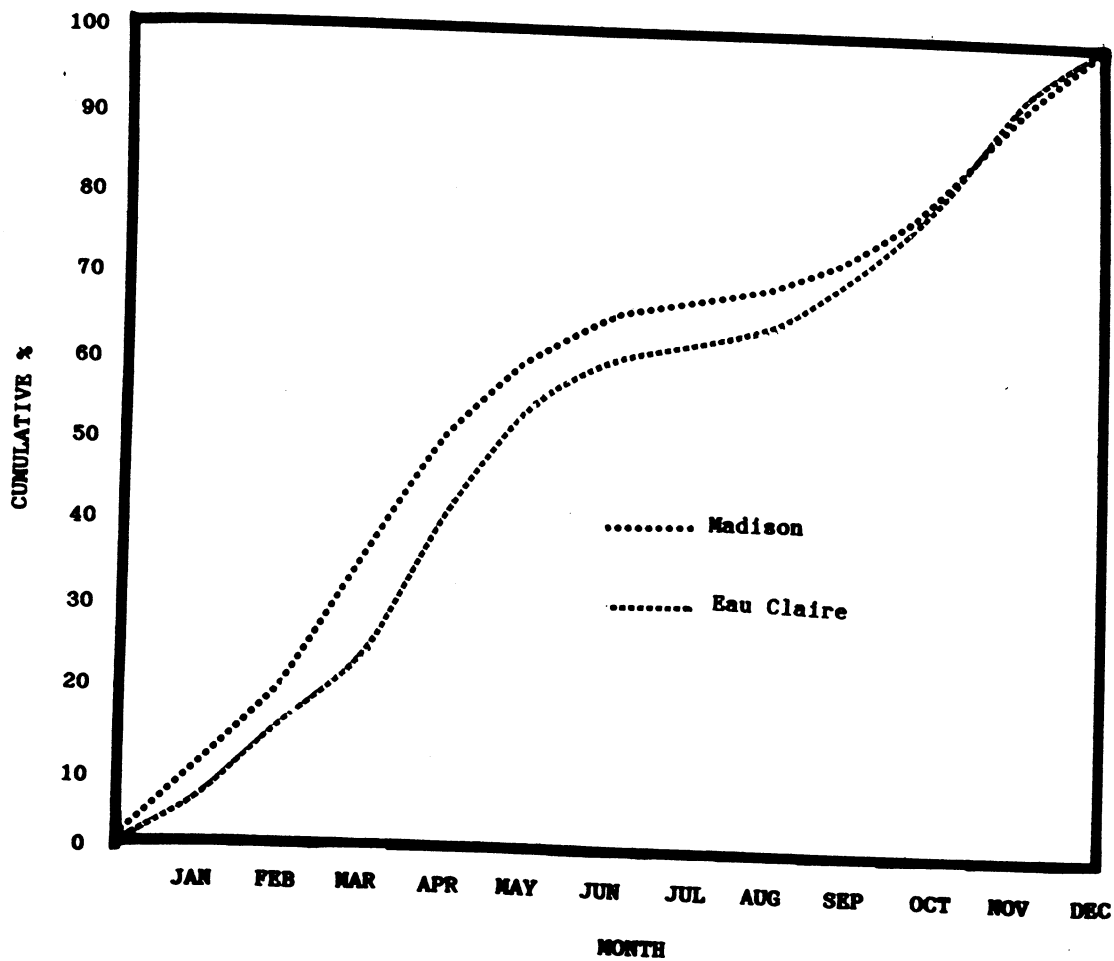


FIGURE 12: EROSION WIND ENERGY DISTRIBUTIONS (EAU CLAIRE AND MADISON)

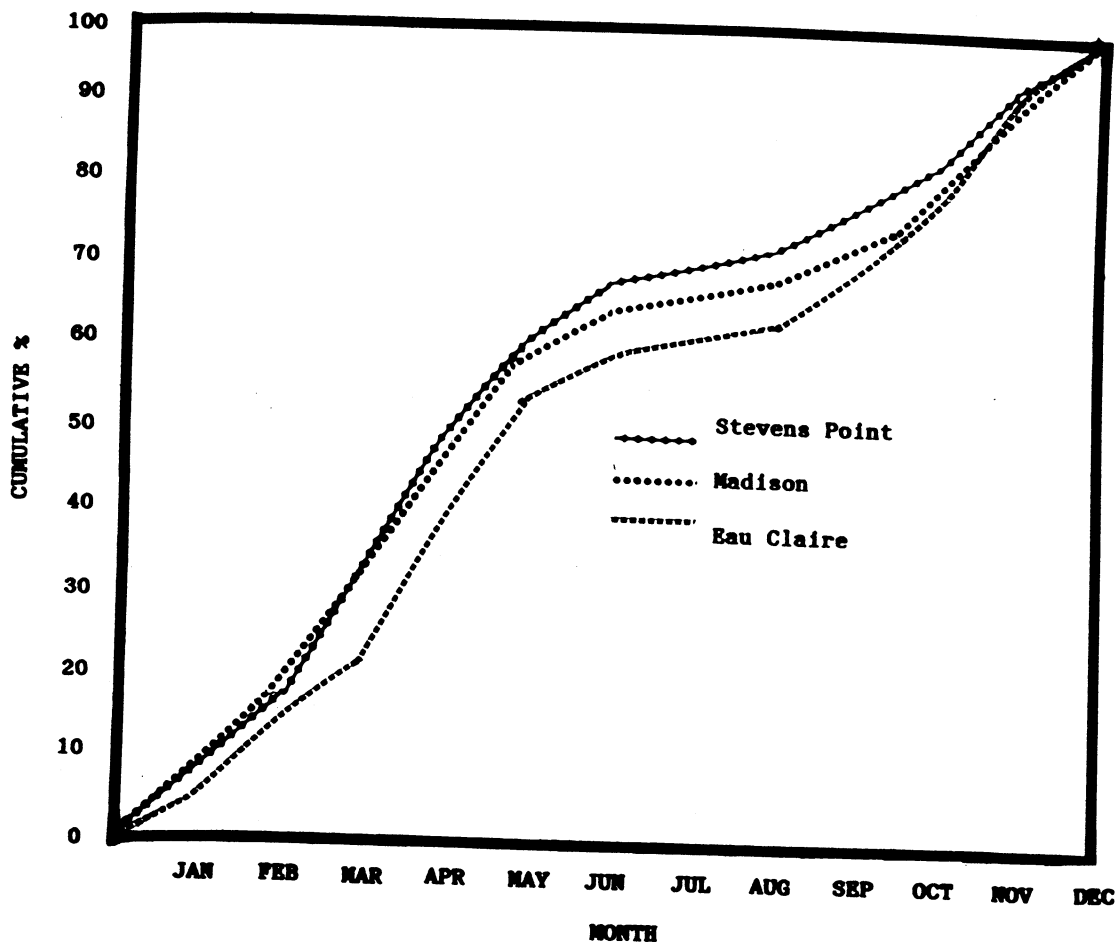


FIGURE 13: COMPARISON OF EROSIIVE WIND ENERGY DISTRIBUTIONS (Stevens Point vs. Madison vs. Eau Claire)

geographic, etc.). In addition to the more logical representation of Stevens Point for Portage County than either Madison or Eau Claire, Figure 11 and Table 38 are suggested as alternatives to similar data presently used by local conservationists from the SCS Technical Guide for the reasons just described.

Prevailing Wind Erosion Direction and Preponderance

Table 39 summarizes monthly prevailing wind erosion direction and preponderance values for both Stevens Point and Madison. The critical months of March through June and October through November show little significant difference in preponderance, except perhaps for the month of April.

TABLE 39:
PREVAILING WIND EROSION DIRECTION AND PREPONDERANCE,
STEVENS POINT AND MADISON

LOCATION-DATA		MONTH											
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Madison	PWED	315	270	250	270	248	247	248	225	247	247	270	248
	Preponderance	1.2	1.3	1.4	1.5	1.3	1.3	1.3	1.3	1.3	1.1	1.4	1.2
Stevens Point	PWED	270	270	270	270	270	225	270	225	270	225	270	270
	Preponderance	3.1	2.3	1.4	1.9	1.5	1.2	1.2	1.3	1.0	1.1	1.4	1.5

April preponderance in Stevens Point is 1.9 compared to 1.5 for Madison. A preponderance value of 2.0 would indicate a prevailing wind erosion direction with wind erosion forces twice as great parallel as

perpendicular to the prevailing wind erosion direction. Since all values are less than 2 for these months in both locations, reliance upon these values (in conjunction with PWED) to dictate the orientation of permanent wind erosion control practices may be unwarranted. Stated another way, fully one-third of the erosive winds observed could conceivably blow from a direction perpendicular to the identified PWED in which case such practices would be ineffective to reduce soil loss or to reduce crop damage due to abrasive flux. In fact, if such winds occurred, the existing practices would actually serve to increase the soil erosion rate through funneling of the wind between wind strips or adjacent to perimeter windbreaks, leading to enhanced soil avalanching. This would increase the probability of incurring substantially greater crop damage if the crops were present and in a stage of growth susceptible to abrasive flux damage.

Tables 6 through 9, 13 and 14 illustrate the percent frequency erosive winds blow from varying directions at different magnitudes for these critical months. During March (Table 6), for example, the PWED is west, accounting for 24% of all erosive winds. Preponderance is 1.4. The significance of this relatively low number and the implications for orienting practices perpendicular to west can be appreciated when noting that 21% of all erosive winds (including an extreme wind event of 65 mph (28.9 m/sec)) blew from the north, which is perpendicular to the PWED. It is also important to note that nearly 78% of all erosive winds \geq 36 mph (16 m/sec) blew from a direction nearly perpendicular to the PWED. These velocities are considerably greater than any of those of winds from the PWED. In other words, when an erosive wind perpendicular to the PWED

is observed, it may be a very severe wind event which could result in substantial soil loss if sufficient vegetation (cover crop), surface residues (from conservation tillage), or wind barriers (wind strips and perimeter windbreaks) are not in place to reduce or abate soil movement.

Winds near Madison and Stevens Point both exhibit a westerly direction. Variations of 20-22° between locations during some of the critical months is significant for proper orientation of any wind barrier to control potential soil loss and crop damage resulting from "average erosive wind events" on a specific field. Actual determination of significant difference in PWED would depend on the orientation of a specific field and suggested practice in question, the type and spacing of wind barriers and the month(s) for which greatest protection is desired.

Extreme Wind Event Analysis

Figures 19.1 through 24.5 (Appendix A) illustrate the recurrence intervals of maximum average erosive wind velocities of 1-, 3-, 6-, 9- and 12-hour durations for the month of April and individual weeks of April. April is the critical period of erosive winds and therefore is of greatest concern to soil conservation planning efforts. The average maximum average wind velocity (1-hour duration) was 28.5 mph (13 msec^{-1}). Figures 25 through 34 illustrate the recurrence intervals of extreme wind durations for selected months. The average maximum erosive wind duration during April was 8.8 hours. Use of these figures for soil conservation planning is discussed in a latter section of this chapter.

Figures 19.1 through 34 will, for the first time, categorize certain magnitudes of wind events to given recurrence intervals or return periods, similar to those of rain events. The intent of such categorization is to allow for the eventual "design standard" of wind erosion control practices once additional research, if completed, can "rate" the effectiveness of various practices to varying magnitudes of erosive winds. In other words, by furnishing this data, it is hoped that a given wind erosion control practice can be designed so as to provide the desired level of protection to soils and crops from the damaging effects of a "design" or pre-selected extreme duration or velocity of erosive wind event. This is presently done in a similar fashion when designing a flood control structure, for example, for a rain event of a given return period (ie., 5-, 25- or 100-year rainfall event).

Climatic Erosivity

Annual climatic erosivity factor, C, is a significant and unmanipulative factor in the overall calculation of soil loss due to wind in the wind erosion equation. Therefore, having a C factor value pertinent to the area under investigation is essential for more reliable estimates of wind erosion soil loss.

Table 40 shows the calculation of C for Portage County. It is important to note the significant difference between the calculated value of 4% and the present extrapolated value of 6% in the SCS Technical Guide. This difference is significant since use of the lower C factor may reduce average annual soil loss estimates by one-third from those calculated with the present C value, all other factors being equal. Lower average

TABLE 40: CLIMATIC EROSIVITY, PORTAGE COUNTY, WISCONSIN¹

$$C = 100 \left[\frac{V^3}{(P-E)^2} / 2.9 \right]$$

where V is the corrected mean annual wind velocity (mph)^a for a standard height of 30 feet (9.1 m), P-E is the Thornthwaite (1948) precipitation-effectiveness index, and 2.9 is the approximate average value of

$V^3 / (P-E)^2$ for Garden City, Kansas (Chepil et al., 1962).

^a For Stevens Point, WI, corrected mean annual wind velocity was 8.2 mph for the period 1950-1967.

MONTH	AVERAGE PRECIPITATION ² (inches)	AVERAGE TEMPERATURE ² (F)	P-E RATIO ³
January	0.81	< 28.4	3.58
February	1.08	< 28.4	4.93
March	1.93	< 28.4	9.39
April	2.86	44	7.35
May	3.30	56	6.16
June	3.68	66	5.58
July	3.57	70	5.00
August	3.91	68	5.75
September	3.52	59	6.17
October	2.31	49	4.98
November	1.82	34	6.55
December	1.14	< 28.4	5.23
			= 70.67

$$C = 100 \frac{(8.2)^3 / (70.67)^2}{2.9} = 4\%$$

¹ Based on temperature, precipitation, and wind velocity data collected at Stevens Point, Wisconsin during the period 1950-1967.

² Sources: U.S. Dept. of Commerce, Weather Bureau. 1965. Decennial census of United States Climate, Climatic Summary of the United States: Supplement for 1951 through 1960--Wisconsin. Climatography of the United States No. 86-41.

U.S. Dept. of Commerce, Weather Bureau. 1962-1968. Climatological Data--Wisconsin, Annual Summary 1961-1967. Vols. 66-72, No. 13.

³ P-E = $115 (P/T-10)^{10/9}$ where P is average monthly precipitation (>0.5 inch) and T is average monthly temperature (≥ 28.4 F) (Thornthwaite, 1948).

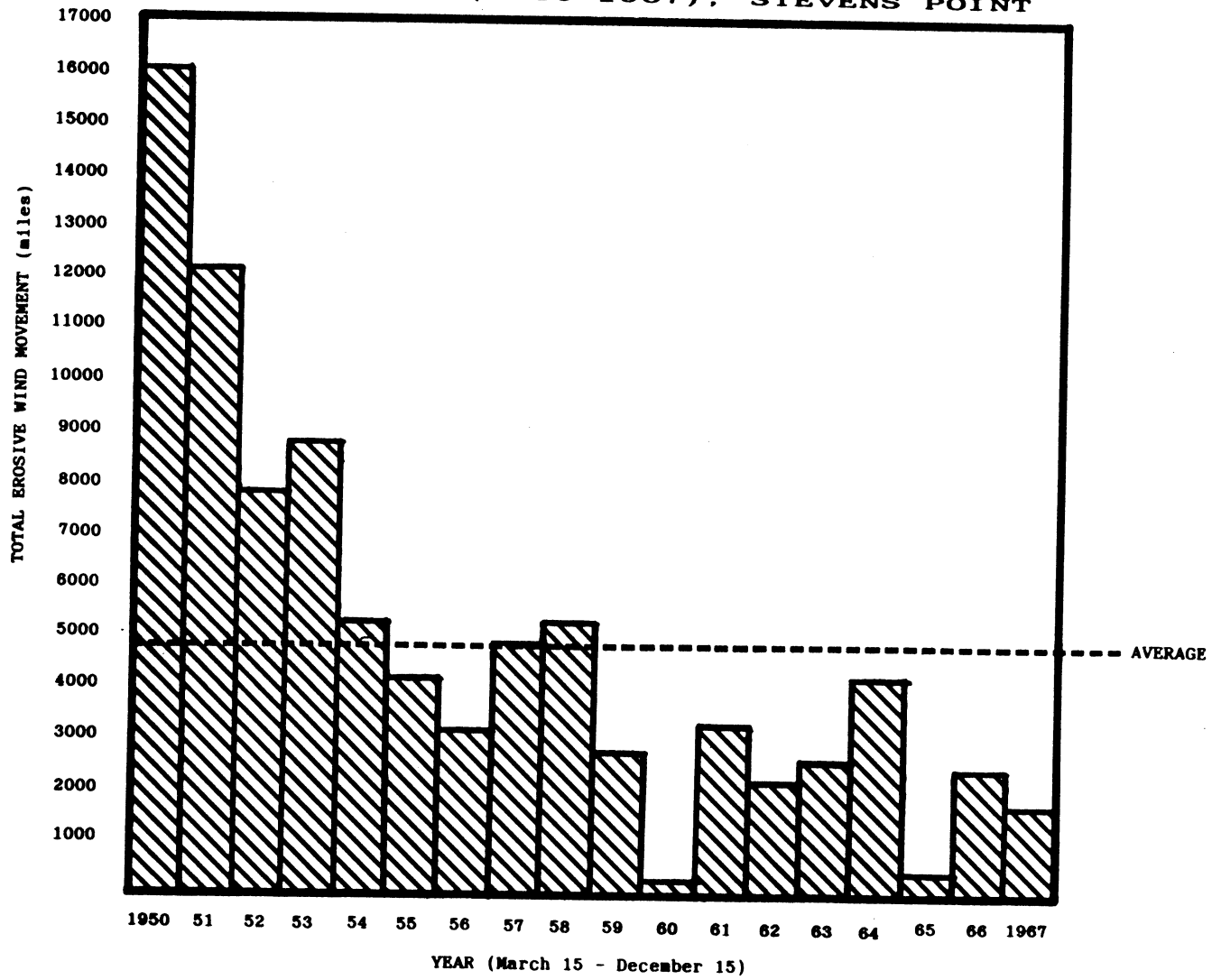
annual soil loss estimates for this county as a result of merely changing a single factor in the WEE could pose significant problems to local soil conservationists in that local landowners may lose confidence in their credibility as professionals and that county, state and federal soil conservation programs may have greater burden of proof of defining quantitatively the scope and extent of alleged soil erosion problems. While it is recommended that the lower-valued C factor be adopted by SCS and used locally, its use and effects on local average annual soil loss estimates must be given adequate justification and explanation to potential users and any landowners affected by significant changes in calculated soil loss estimates (ie., those presently eligible for local, state and/or federal cost-share or other assistance programs may lose their eligibility as a result of soil loss estimates dropping below soil loss "tolerance" values).

Cyclic Recurrence of Severe Erosion Potential

The identification of a possible cyclic recurrence of severe wind erosion potential was attempted on the 18-year database. All erosive winds (≥ 18 mph or 8 m/sec) were tabulated on a yearly basis as well as a notation of each erosive wind event's duration (hours). Multiplication of velocity (mph) times duration (hours) yielded a product of total erosive wind movement (miles).

The yearly sums for all 18 years of record were then plotted so as to compare total erosive wind movement in hopes of identifying certain "peak" years in the data. Unfortunately, the early 1950s were extremely windy and resulted in a very skewed bar graph (Fig. 14). Average total

FIGURE 14: TOTAL EROSIIVE WIND MOVEMENT (1950-1967), STEVENS POINT



erosive wind movement was indicated so as to aid in identification of a cyclic pattern, but again only the 1950s were significantly greater than that average value. As a result, no apparent recurrence cycle of extreme erosion potential can be determined from the 18-year database.

It is interesting to note, however, a few extreme values indicated in Figure 14. Years 1950 and 1951 had many extreme wind velocities and durations as well as significantly greater frequencies of erosive winds than all other years. Contrastingly, 1960 was unusually calm as there were five consecutive months (May through September) in which there were no erosive winds observed. Obviously, then, years 1950 through 1951 and 1960 represented extreme cases during the period of record but this does not necessarily suggest a potential 20-year cycle. Additional wind data collection and analysis is necessary to assist in identification of a cycle.

Conservation Planning Applications

Soil Erosion Control

Table 1 suggests several applications of wind climatology data for erosion control planning purposes. Assessment of erosive wind frequency, duration and prevailing direction can indicate what practices are needed, the proper orientation and placement of those practices and what level of management and maintenance are required to reduce or prevent wind erosion soil losses. This information can assist both the farmer and the soil conservationist in selecting the desired level of soil protection.

Monthly erosive wind frequencies are greatest during March through May and again in November. Both of these periods could be considered critical soil erosion intervals since unprotected and smooth soil surfaces may exist on area farms (Fig. 15). Therefore, concern over loss of soil productivity should focus on these critical periods. Harvest after October 1 may limit successful establishment of a cover crop due to limited heat units available for growth. If an adequate cover crop is not established, other methods of erosion control must be used. If an adequate cover crop is successfully established, it protects the soil from erosive winds during late autumn until seedbed preparation in late April or early May. At that time, the soil is laid bare, smooth and susceptible to the erosive action of winds which can result in significant erosion until a 50% crop canopy cover is established (usually no earlier than mid-June for snap beans). Therefore, it should be realized that several complementary wind erosion control practices may be necessary in order to curb soil loss on a given field. Surface vegetative residue management is an alternative to employing numerous practices for a given field. Depending on soil conditions and the desired crops, nearly any type of conservation tillage practice can accomplish this. If sufficient residues are maintained throughout these critical soil erosion periods, then a continuous and adequate level of protection is provided.

Wind erosion soil loss is presently estimated using the Wind Erosion Equation (WEE) and the "Wind Erosion by Crop Stage" worksheet in the Wisconsin SCS Technical Guide. Erosive wind energy (EWE) distribution aids soil conservationists in estimating potential annual soil loss per

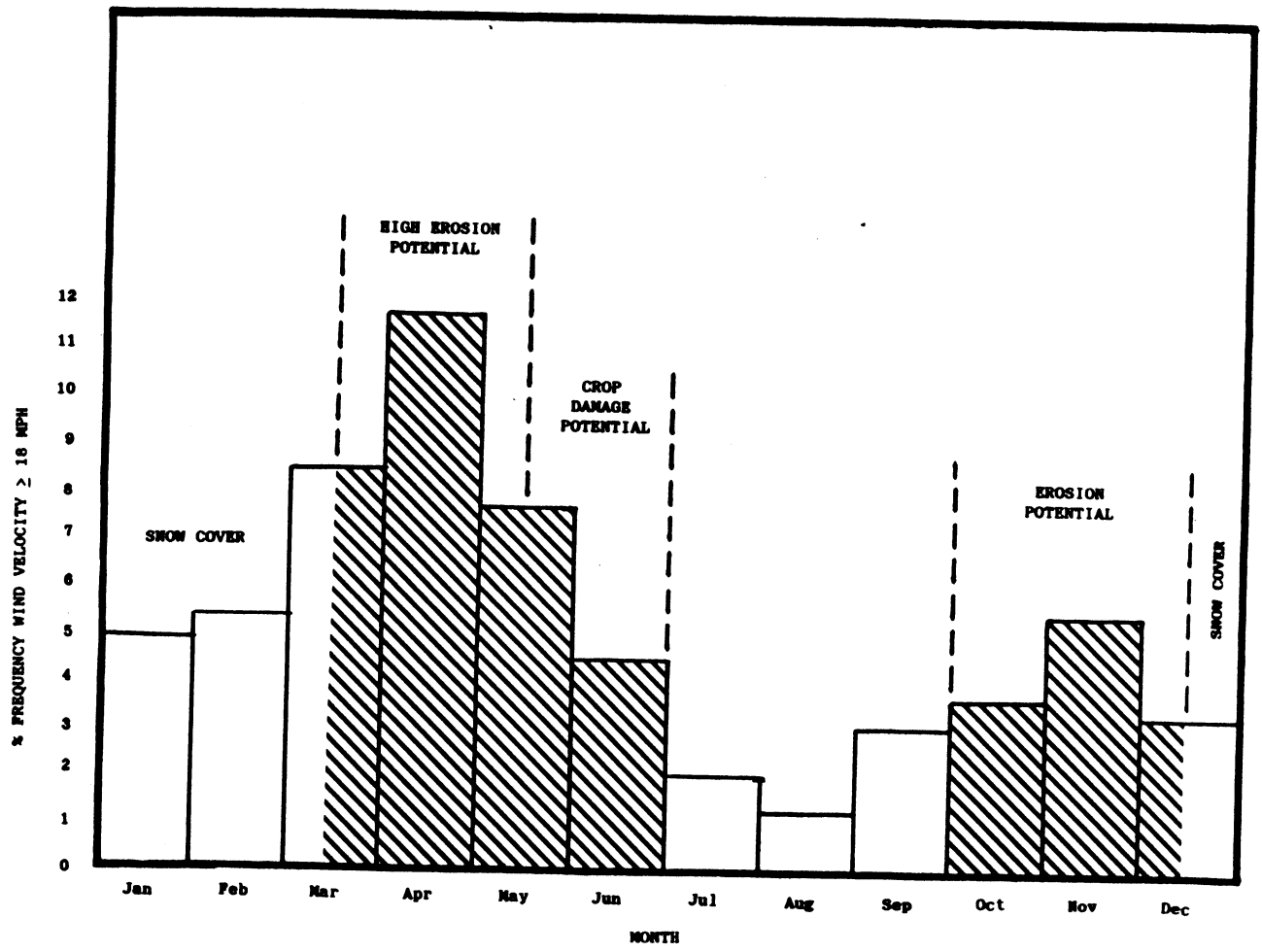
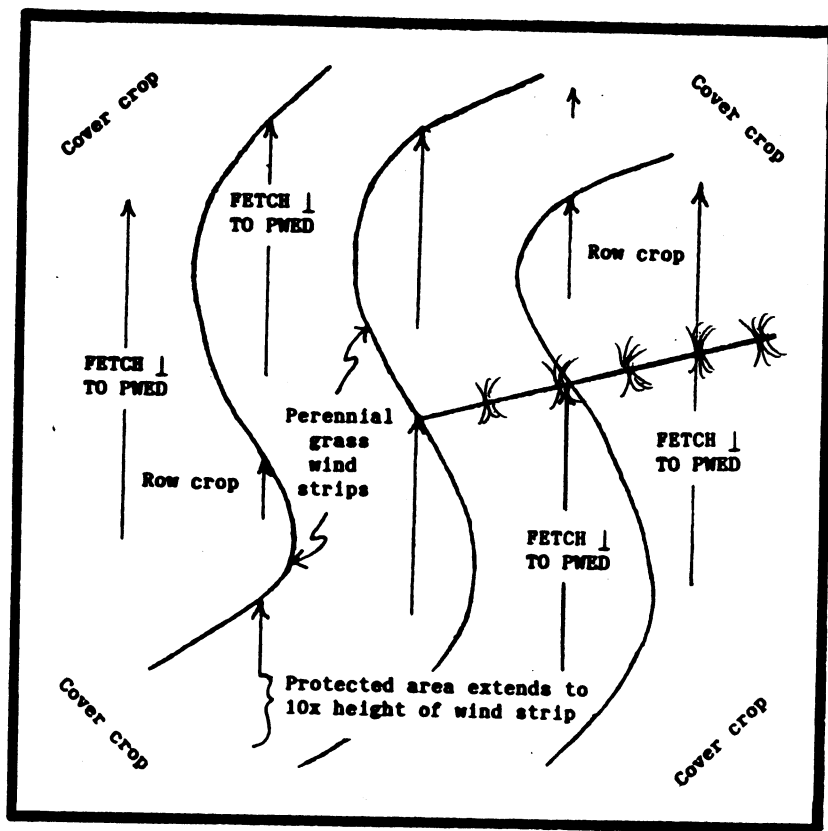


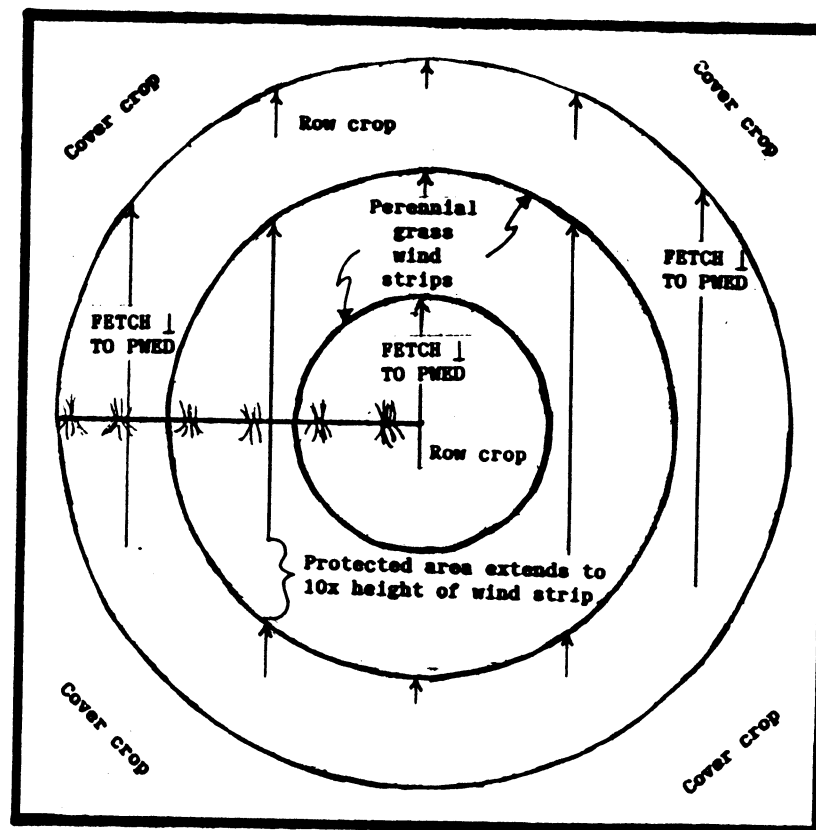
FIGURE 15: EROSION AND CROP DAMAGE POTENTIAL OF EROSIIVE WINDS NEAR STEVENS POINT

crop stage period. Calculation of soil loss per crop stage allows for better illustration of when most of the total annual soil erosion occurs. Figure 11 and Table 38 could assist in calculating wind erosion losses per crop stage period since it is more representative of Portage County than the previously used EWE curve (Fig. 12) for Eau Claire. Figure 11 and Table 38 clearly indicate that the greatest erosive wind energy exists during the months of March through May and November.

As discussed earlier, information in addition to prevailing wind erosion direction (PWED) and preponderance should be considered when designing windbreaks. Frequency of erosive winds from all directions for selected or desired time intervals (monthly or weekly) should be an equally important criteria for orienting such practices. Tables 4 through 37 summarize these data for Portage County. Variability in the direction of erosive winds for Portage County suggests that the orientation of wind barriers, especially wind strips, should be re-evaluated. Consideration should perhaps focus on the design of strips in configurations other than straight rows perpendicular to the PWED. Specifically, Figure 16 illustrates two design configurations based on the concept of total soil protection from all erosive winds regardless of direction. Wind strip barriers, comprised of perennial grasses, are maintained as either (a) sinuously-curving, rather than straight, rows oriented generally perpendicular to the PWED, or (b) circular bands parallel with crop rows. A critical difference between these designs and straight-row wind strips is that the fetch of exposed soil between crop rows acted upon by erosive winds perpendicular to the PWED does not equal the entire field length. Because the fetch of exposed soil is substantially reduced, soil loss



(a) Sinuous-curving wind strips



(b) Circular wind strips parallel to crop rows

FIGURE 16: ALTERNATIVE WIND STRIP DESIGNS PROVIDING MAXIMUM SOIL PROTECTION

rates could also be significantly reduced under virtually all erosive wind conditions.

Figures 19.1 through 34 (Appendix A) graphically categorize various magnitudes of wind events to given return periods. Return periodicity of selected wind events could be used as a guide or "design criteria" for selected wind erosion control practices. For example, if wind strips are used to protect soil from wind erosion, then the design specifications of those strips can be dictated by the desired level of protection. In other words, if the soil is to be protected from a wind event having a recurrence interval of 12.7 years for the month of April, the wind strips should be designed so as to significantly reduce or abate the soil loss otherwise resulting from a 6-hour duration, 33 mph (13 m/sec) wind (Fig. 19.3, App. A). Similarly, a wind strip providing the same level of protection (12.7 year recurrence for the month of April) from a given erosive wind would have to be designed so as to significantly reduce or abate the soil loss otherwise resulting from an 18-hour duration erosive wind (Fig. 26, App. A). However, additional research to evaluate all types and orientations of wind erosion control practices is necessary before these data can be used as design criteria.

Crop Damage Abatement

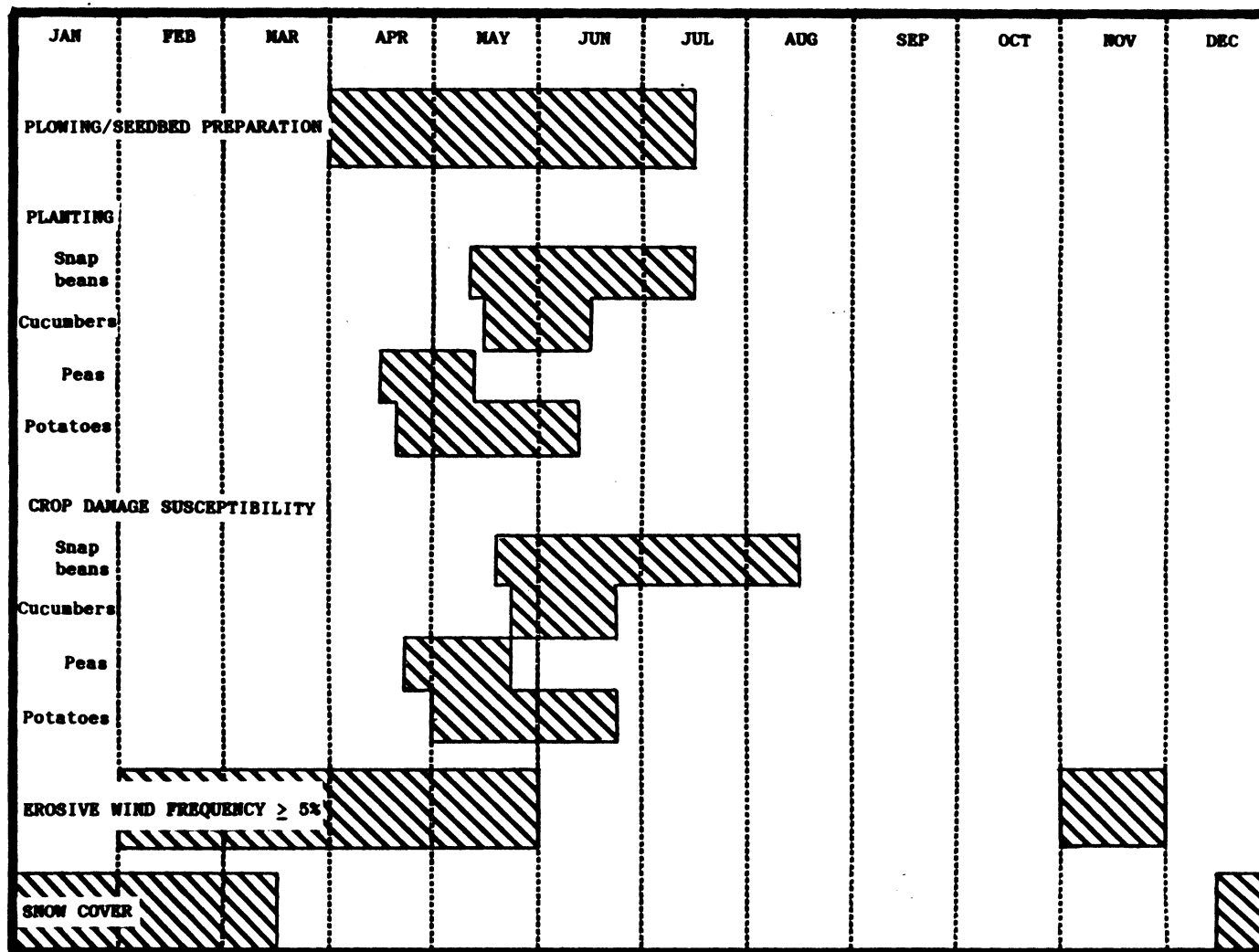
Table 3 suggests several applications of wind climatology data for crop damage abatement planning purposes. Assessment of erosive wind frequency, duration and prevailing direction can indicate what practices are needed, the proper orientation and placement of those practices and what level of crop management and practice maintenance are required to

reduce or prevent wind erosion crop damage. This information can assist both the farmer or crop consultant and the soil conservationist in selecting the desired level of crop protection.

Vegetable crops are typically most susceptible to damage by abrasive flux during April 22 through August 15 (depending on the crop), corresponding to the early growth stages of these crops (Fig. 17). Monthly erosive wind frequencies indicate that May and June are the most critical months (Tables 8 and 9, respectively). Weekly erosive wind frequencies indicate that the weeks of May 17 through 23 and June 21 through 27 are usually the most severe (Tables 25 and 30, respectively). Severe erosive winds were observed in Portage County during the week of June 21 through 27 in both 1984 and 1985 as well. Such variation in the timing of severe erosive winds in association with crop growth stages susceptible to damage by abrasive flux suggests that temporal or other time-specific efforts to prevent crop damage may not be effective.

All crops have varying resistance to damage by abrasive flux. Figure 18 illustrates the relationship of crop tolerances to soil loss rates. The annual soil loss rates listed are **significantly less** than soil loss "T" values related to soil productivity. Therefore, implementation of wind erosion control practices on sandy soils may reduce soil losses to "tolerable levels" yet provide little if any substantial protection to individual vegetable crops, especially snap beans, peas and cucumbers. Local vegetable growers must understand the consequences of this so as to prevent the expectation that implementation of soil erosion control practices that protect soil productivity ($<T$) will **necessarily** result in

FIGURE 17: GOLDEN SANDS AREA VEGETABLE CROP CALENDAR



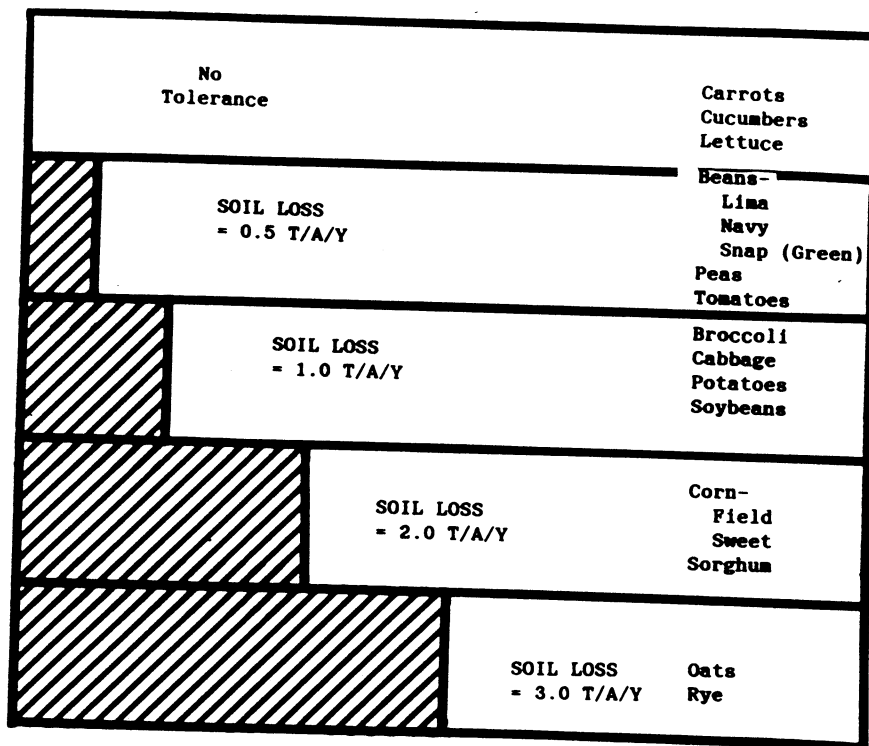


FIGURE 18: CROP TOLERANCES TO WIND EROSION
(From: WI SCS Tech. Guide)

crop damage abatement. Only those wind erosion control practices which reduce significant soil losses occurring during critical crop growth stages (i.e., most susceptible to abrasive flux damage) will be beneficial in reducing abrasive flux crop damages. Use of Figure 11 or Table 38 will assist in computing more reliable estimates of soil loss per crop growth stage periods which, in turn, should better aid planners to prescribe the types of practices necessary to reduce soil losses in order to reduce crop damage.

In designing wind barriers and other wind erosion control practices to abate crop damage, it is imperative to focus on the period of time during which the crop is most susceptible to abrasive flux damage. Figures 17 and 18 can help to assess the level of protection necessary to prevent such damage by determining the susceptibility of the crop. Generally speaking, providing adequate soil erosion control to maintain soil losses < 0.5 T/A during the months of May and June should substantially reduce the probability of sustaining significant damage to any vegetable crop. Wind barriers should be oriented perpendicular to the southwest, the PWED, but should also provide protection from erosive winds perpendicular to the PWED. Tables 28 through 30 indicate that erosive winds nearly perpendicular (e.g., those blowing from N, NW or SE) to the PWED for June may account for 13 to 24% of all erosive winds observed during the weeks of June 7 through 27. Any erosive wind during this period could cause abrasive flux damage to vegetable crops. Therefore, more emphasis is needed on total protection to crops via total protection of the soil from wind erosion.

Figures 19.1 through 34 (Appendix A) graphically categorize various magnitudes of wind events to given return periods. Knowledge of the recurrence intervals of such events can be used by crop consultants to assess the probability of extensive crop damage and/or substantial pest distribution versus the inherent costs of providing the necessary level of crop protection. In short, return periodicity data can be used to assess the likelihood of sustaining significant crop damage, prescribing the desired or necessary level of protection to avert such damage, or determine the design specifications of selected wind erosion control practices. For example, 35 mph (14 m/sec) winds can cause significant damage to peas and snap beans (Bubbenzer and Weis, 1974). Table 9 indicates that only 0.5% of all erosive winds during June exceed this velocity. In addition, the recurrence intervals of a 1-hour maximum average wind event exceeding 35 mph during the weeks of May 31 through June 6 and June 21 through 27 are 19 and 10 years, respectively, and that, on the average, once each 16.5 years a 3-hour duration wind will exceed 35 mph during the week of June 21 through 27. These data and Table 9 suggest a low probability of observing such severe wind events; however, these data are based on probabilities and actual observations may even occur more frequently for any number of consecutive years. Figure 14 graphically illustrates this possibility of observing severe erosive winds for a period of five consecutive years (1950 through 1954) in Stevens Point.

Perhaps practices which can control soil erosion during all periods would benefit crop damage abatement efforts as well since there are other means of crop damage (e.g., diseases, nematodes, etc.) which are not

necessarily associated only with wind erosion events occurring at crop growth stages most susceptible to abrasive flux damage. For example, the movement of wind-borne soil particles during spring (March 15 to early May) may contribute to the distribution of cysts of several genera of nematodes which may in turn parasitize snap beans, peas or potatoes (Table 41). The utilization of soil erosion control practices to reduce soil movement could help reduce the widespread distribution of such pests which could aid efforts of pest management to deal with more isolated cases when and where they might occur. For these reasons, practices to integrate both soil erosion control and crop damage/pest distribution erosion control measures based only on probabilities is likely to result in as much damage to one's crop as an individual's possibility of incurring significant debt by neglecting common sense while engaging in any form of gambling!

TABLE 41: NEMATODES PARASITIC ON CENTRAL SANDS AREA VEGETABLE CROPS

<u>Nematode Species</u>	<u>Crops Affected</u>
Meloidogyne hapla (L ₂)	Bean, pea, potato, carrot, celery, mint, onion
Pratylenchus penetrans P. scribneri P. crenatus	Bean, pea, potato carrot, mint, onion, corn
Ditylenchus destructor	Potato
Pratylenchoides sp.	Mint
Langidonus breviannulatus	Corn

RESEARCH NEEDS

Several authors have previously identified research needs to improve our understanding of wind erosion mechanics, to adapt practical applications of the wind erosion equation for conservation planning purposes, and to determine interrelationships of soils, vegetation and climate in the wind erosion process (Woodruff and Siddoway, 1965; Skidmore, 1974; Woodruff, 1975; and Fryrear and Lyles, 1977). Due to the functional nature of the wind erosion equation (WEE) and especially to the interrelationships of climatic variables to the other factors of WEE, it is imperative that additional research focus on better definition and quantitative description of these interrelationships. Therefore, the following topics are suggested for future research regarding the influence of climate in the overall processes and effects of wind erosion.

Prediction of Erosive Winds

Additional efforts to determine probability functions of various wind events should also attempt to relate general weather observations (e.g., barometric pressure, cyclonic and frontal weather pattern tracking, etc.) to various magnitudes of winds observed. By doing so, regression equations could be developed so as to provide a regional predictive tool for forecasting erosive wind potential. This information may also be useful to establish the necessary climatic variables for development of a stochastic wind erosion model, or soil-flux equation, to better estimate soil loss due to wind for a selected time interval (e.g., annual, monthly, weekly, individual event).

Assessment of Cycle of Wind Erosion Occurrence

The 18-year database used in this research was not sufficient to attempt identification of a cyclic pattern for years of severe wind erosion. Therefore, additional wind climatology data must be collected and analyzed at locations where wind erosion is significant. Several methodologies for comparing years should then be utilized so as to identify one "standard" methodology which could be employed anywhere without geographic limitations. Due to the research capabilities and location of the University of Wisconsin-Extension Research Station at Hancock (Waushara County), a wind climatology and natural erosion data collection facility should be established there permanently to gather baseline data for use in appropriate analyses.

In-field Measurement of Erosion Rates

The UW-Extension Research Station at Hancock would provide a logical and central location for a natural wind erosion data collection facility. Information is needed to quantify the types and proportions of soil particles moved in each of the three transport mechanisms (creep, saltation, and suspension) and how each of these mechanisms is initiated and affected by wind velocity and direction. Further chemical and other analysis of this material can then be used to relate to productivity changes over time and to be used to compute soil loss and its relationship to soil loss tolerance (T) values. Instantaneous wind data collection along with sampling equipment to measure soil flux in surface creep, saltation and suspension for varying soil-crop conditions would be necessary in order to analyze probability functions of soil loss occurring with a wind event of a given magnitude and direction.

Instantaneous velocity and directional components of gustiness and vertical movement of winds are also essential in order to better understand the threshold velocities necessary under changing unstabilized and stabilized soil surface conditions.

In-field Measurement of Crop Damage and Pest Distribution

Numerous wind tunnel studies have focused on wind velocities necessary to cause sandblast damage to certain crops. Limited research has likewise centered on distribution of soil-borne pests and diseases. Part of the previously described wind climatology and erosion data collection facility should also incorporate sampling devices to collect wind-blown, soil-borne pests and diseases. In addition, in-field research plots should assess the actual damage to vegetable crops associated with various wind events for known soil conditions and crop growth stages. Then, predictive regression equations could be developed and used by growers to assess their susceptibility to sustain serious crop damage by sandblast effect.

Local offices of SCS and county land conservation departments should continue recent efforts of documenting crop damages due to wind erosion on an annual basis. By doing so, actual costs can be attributed to known losses which should help to sustain on-going soil conservation programs and justify additional needed research.

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APPENDIX A
EXTREME WIND EVENT ANALYSIS

FIGURE 19.1: RETURN PERIOD OF MAXIMUM AVERAGE APRIL WIND VELOCITY

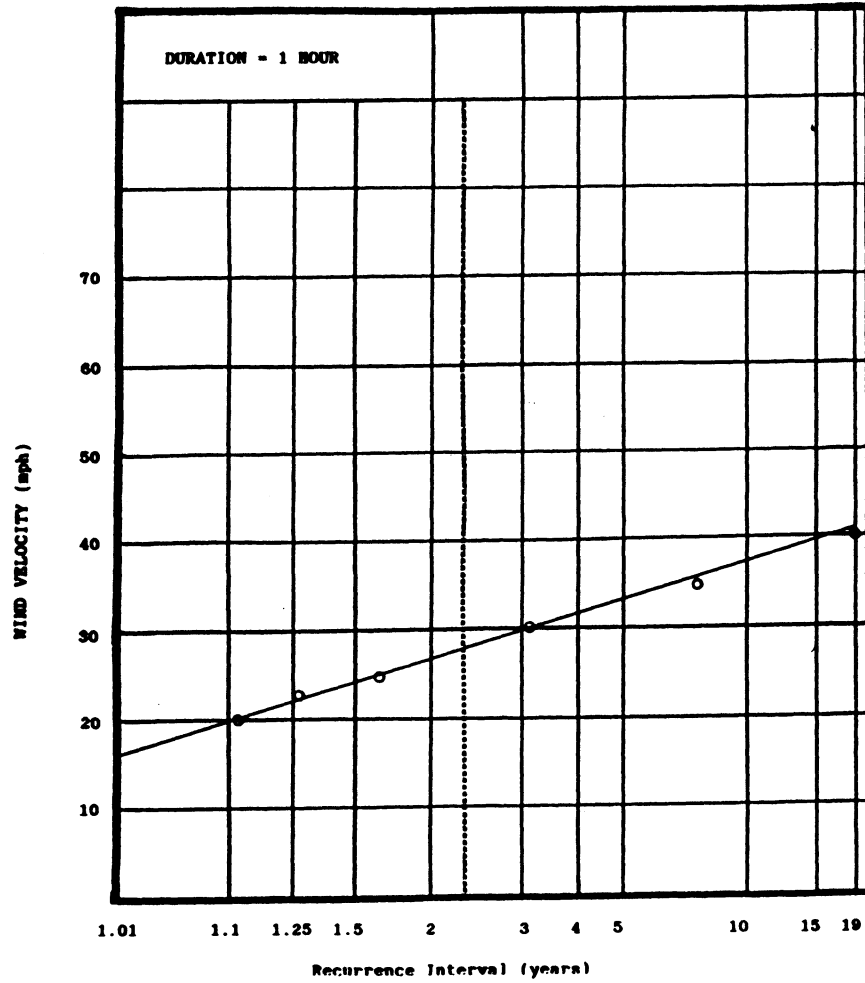


FIGURE 19.2: RETURN PERIOD OF MAXIMUM AVERAGE APRIL WIND VELOCITY

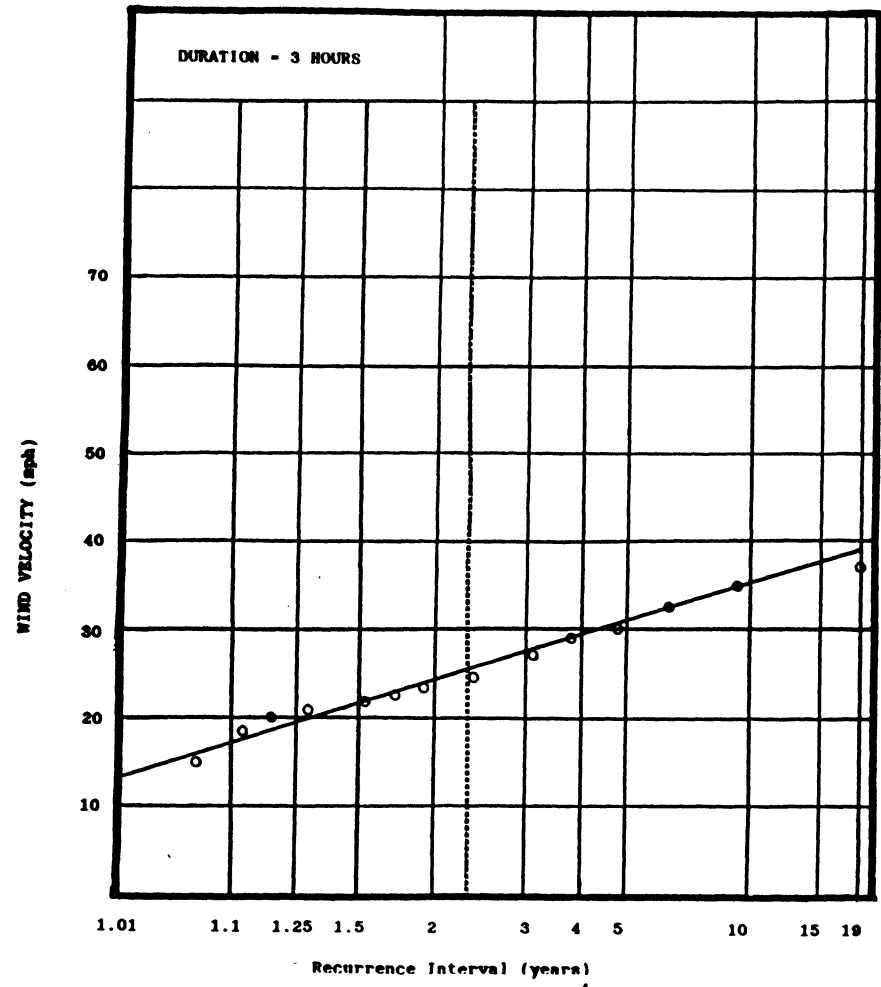


FIGURE 19.3: RETURN PERIOD OF MAXIMUM AVERAGE APRIL WIND VELOCITY

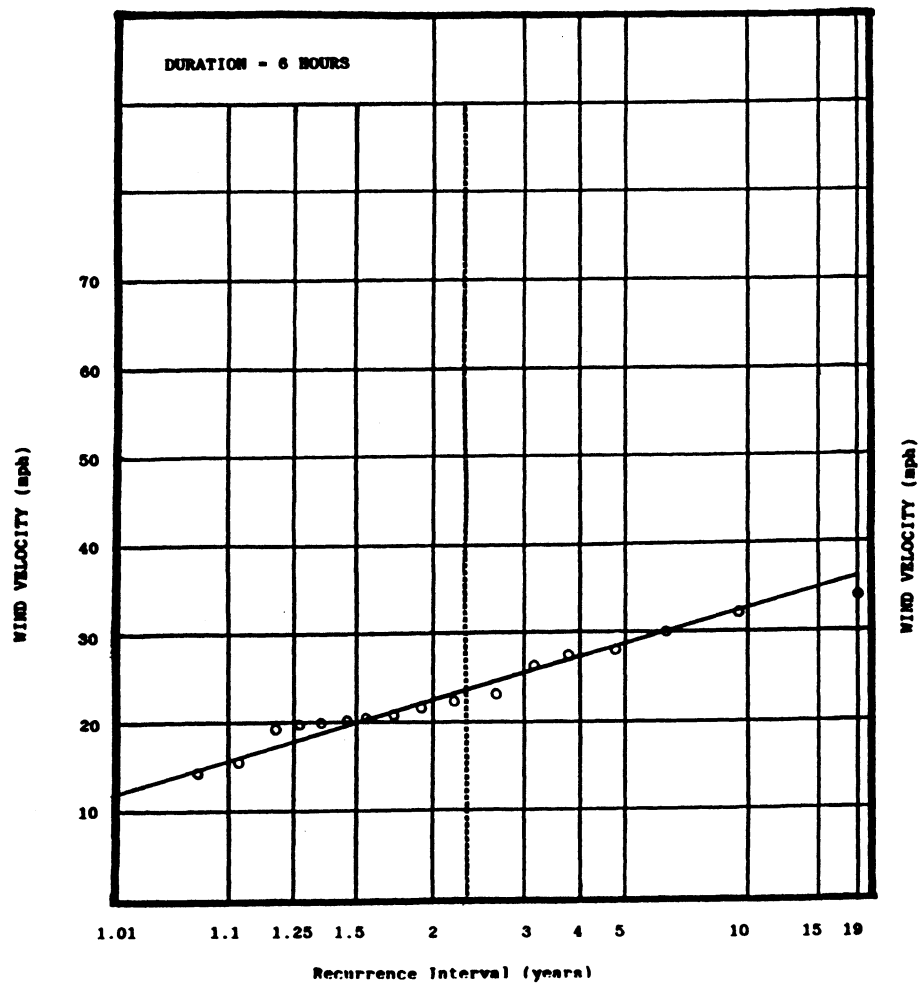


FIGURE 19.4: RETURN PERIOD OF MAXIMUM AVERAGE APRIL WIND VELOCITY

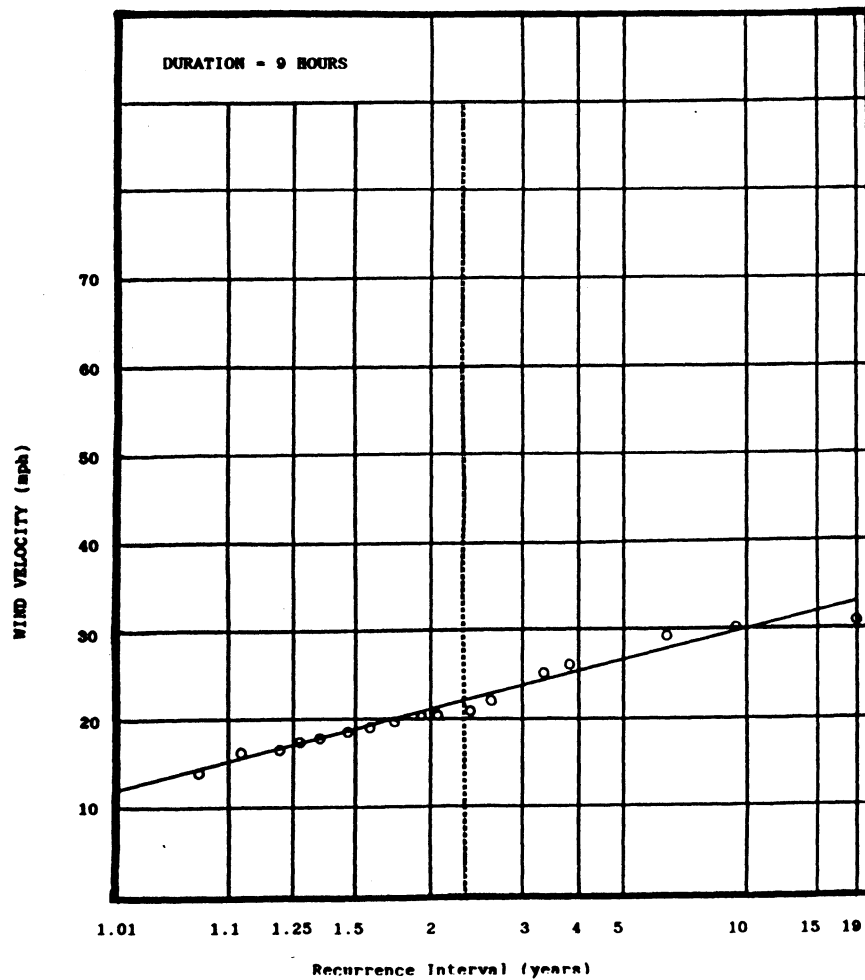


FIGURE 19.5: RETURN PERIOD OF MAXIMUM AVERAGE APRIL WIND VELOCITY

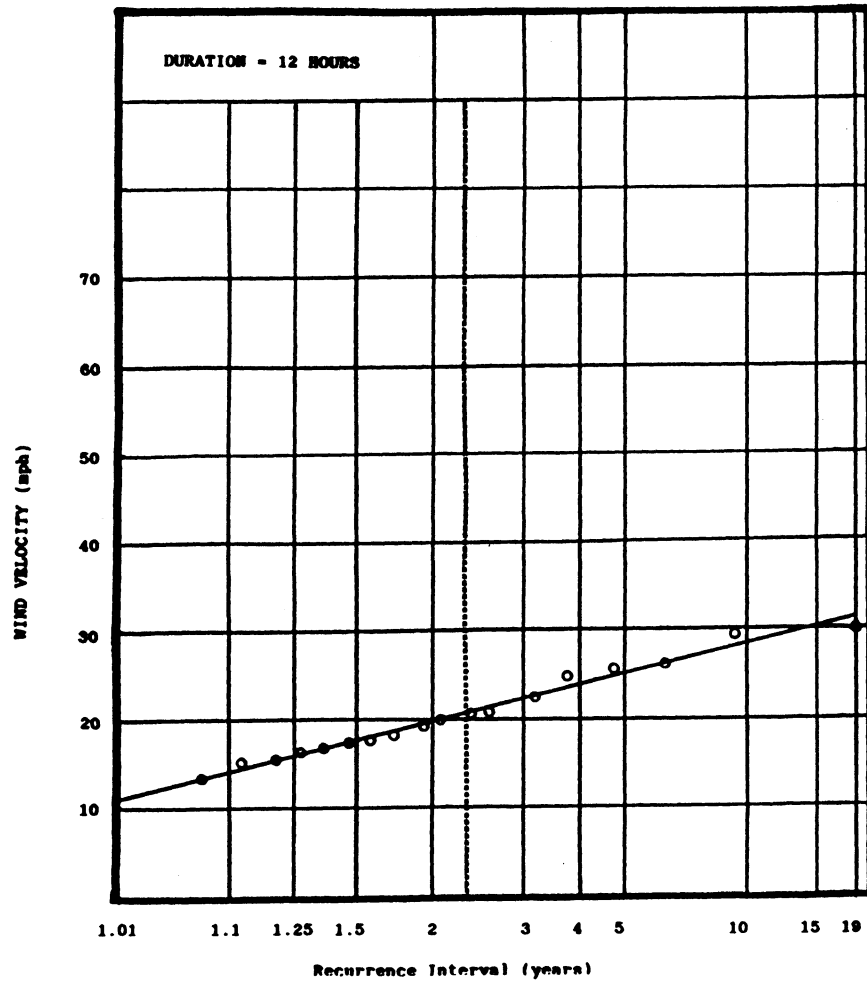


FIGURE 20.1: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY. MARCH 29 THROUGH APRIL 4

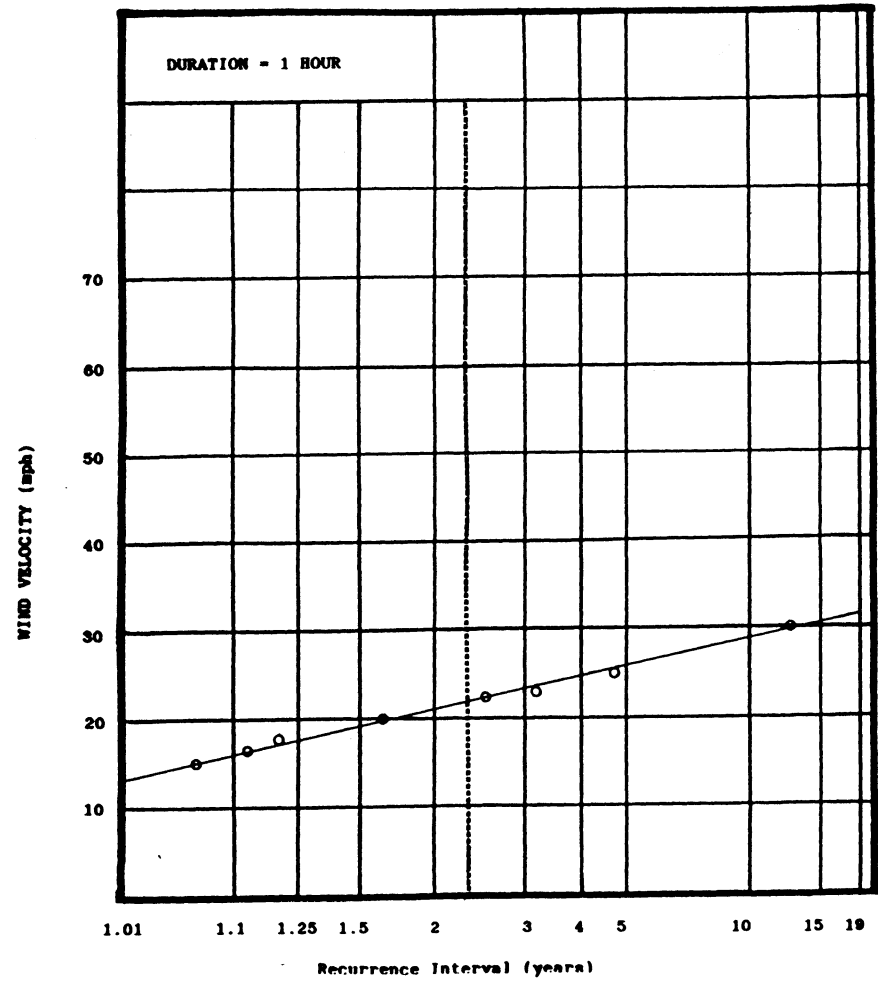


FIGURE 20.2: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY,
MARCH 29 THROUGH APRIL 4

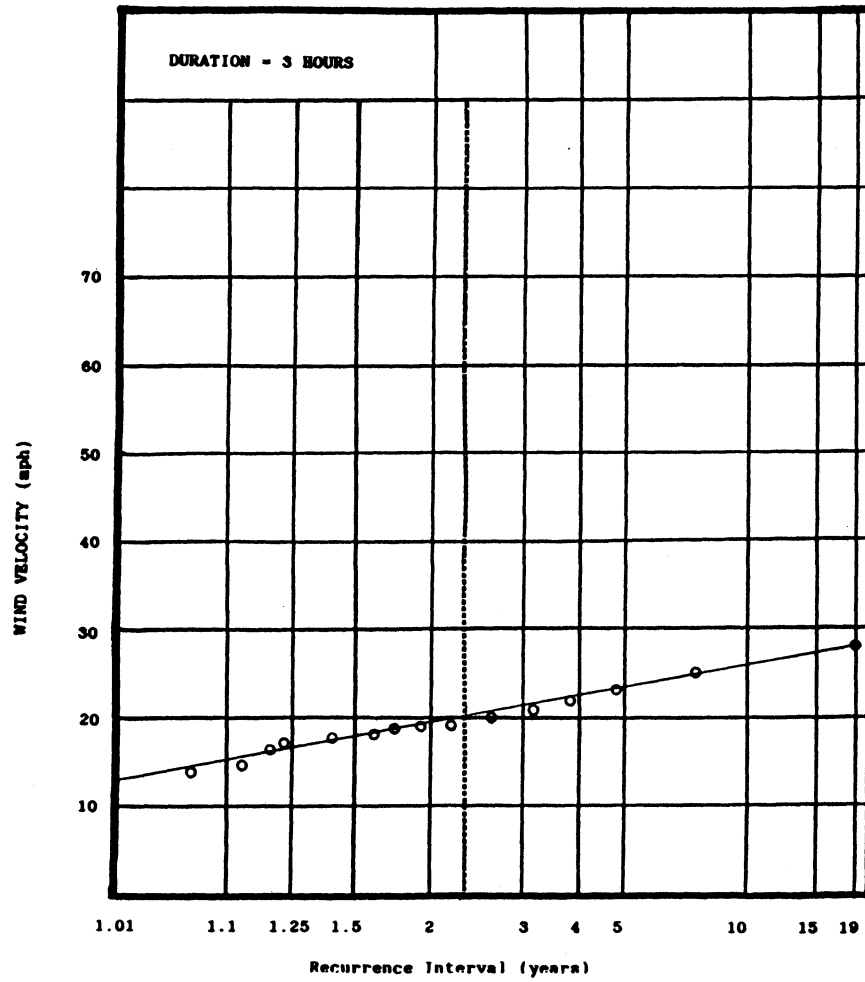


FIGURE 20.3: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY,
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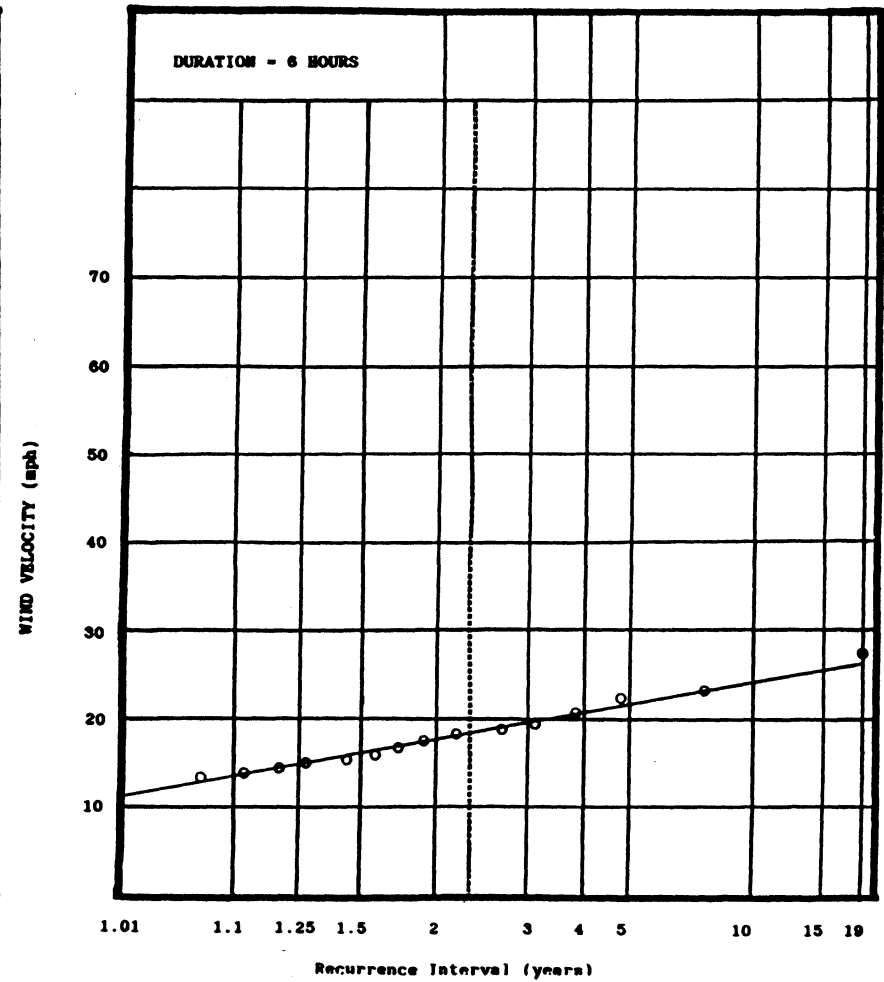


FIGURE 20.4: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY,
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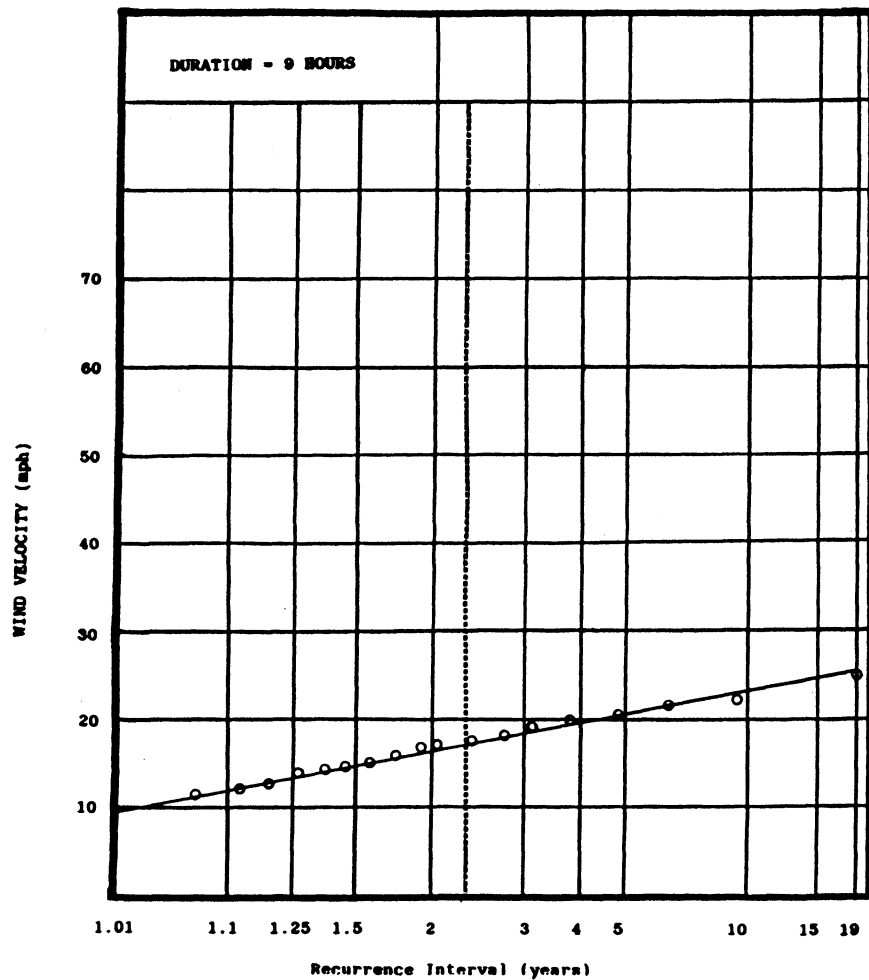


FIGURE 20.5: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY,
MARCH 29 THROUGH APRIL 4

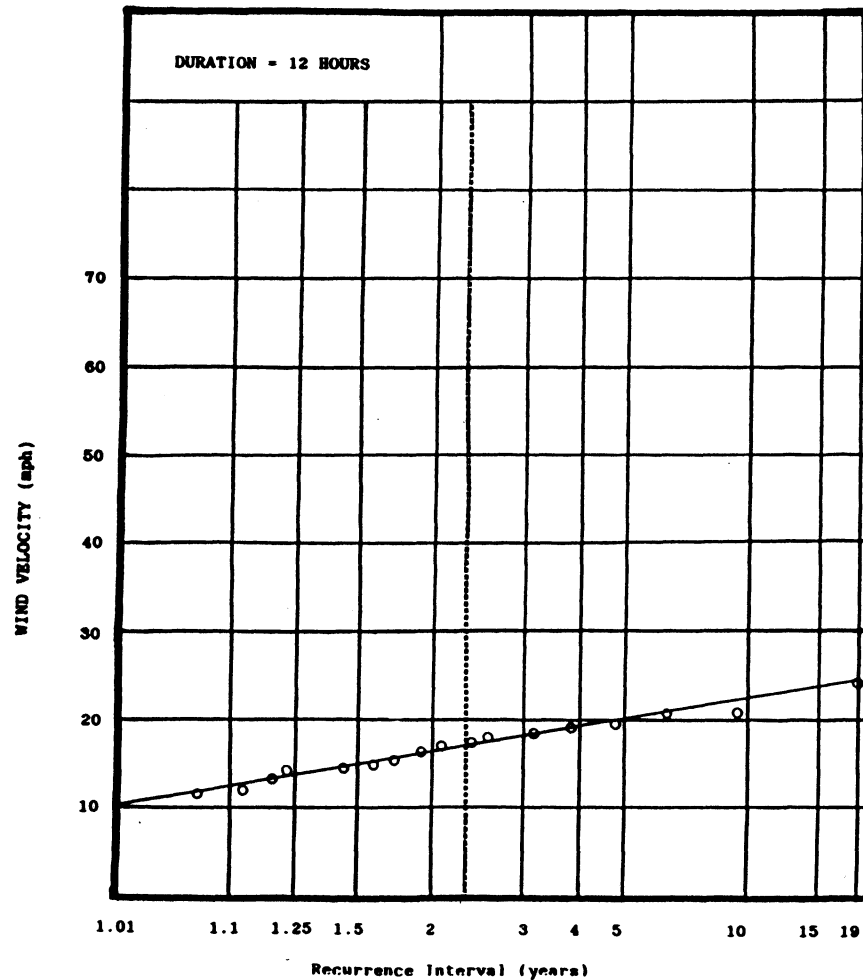


FIGURE 21.2: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY.
APRIL 5 THROUGH APRIL 11

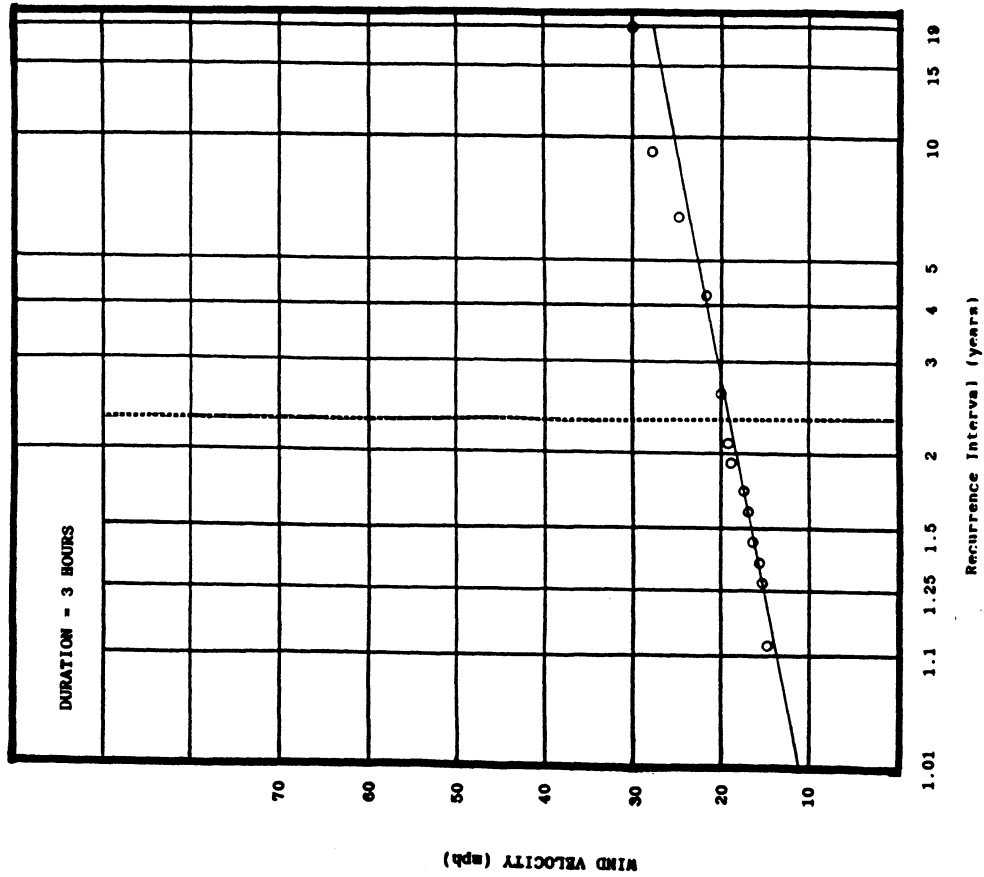


FIGURE 21.1: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY.
APRIL 5 THROUGH APRIL 11

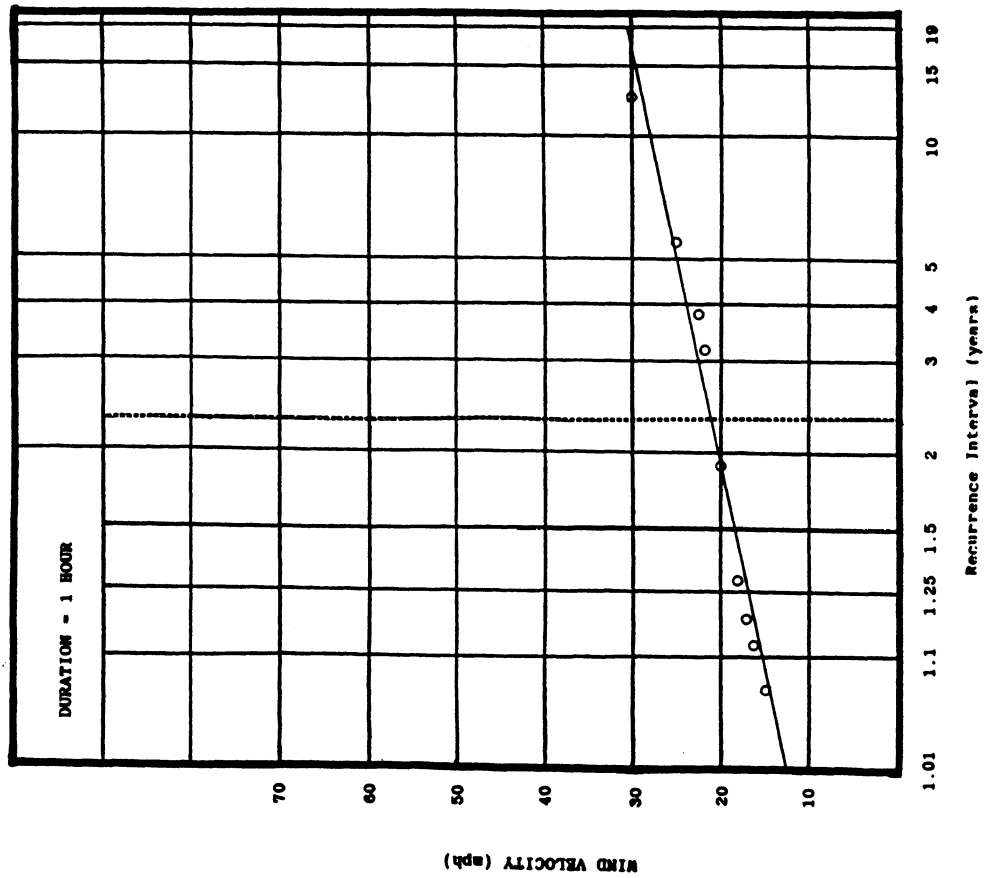


FIGURE 21.3: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY,
APRIL 5 THROUGH APRIL 11

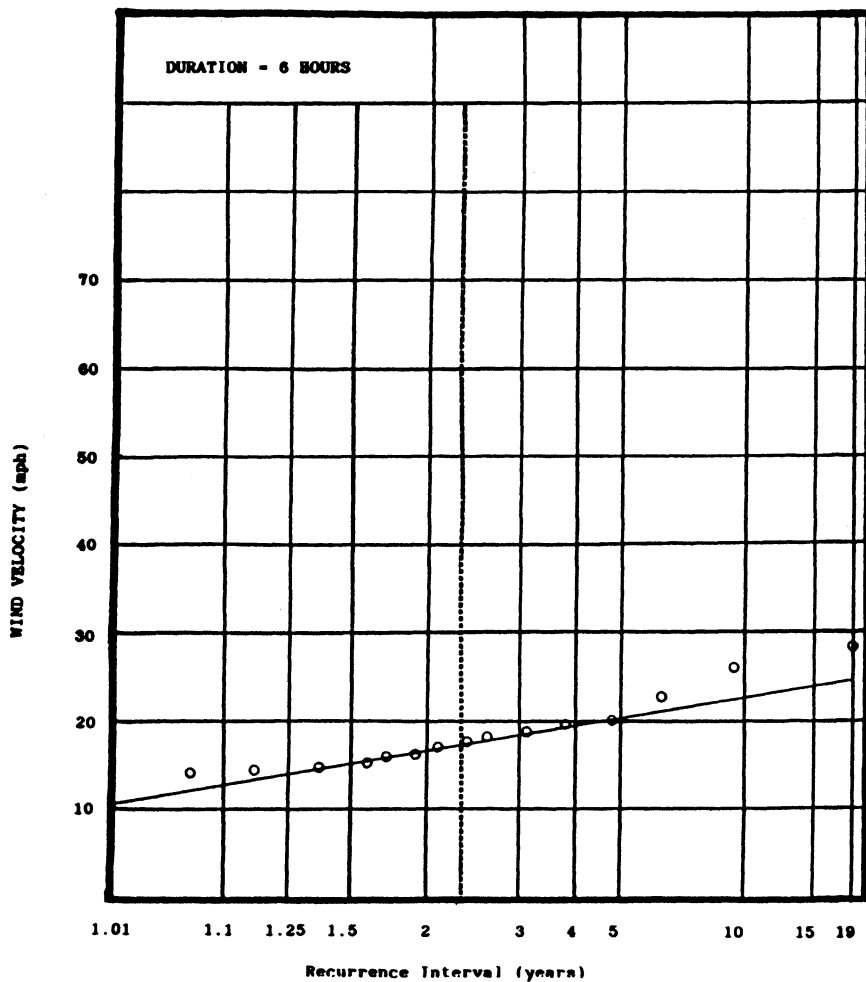


FIGURE 21.4: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY,
APRIL 5 THROUGH APRIL 11

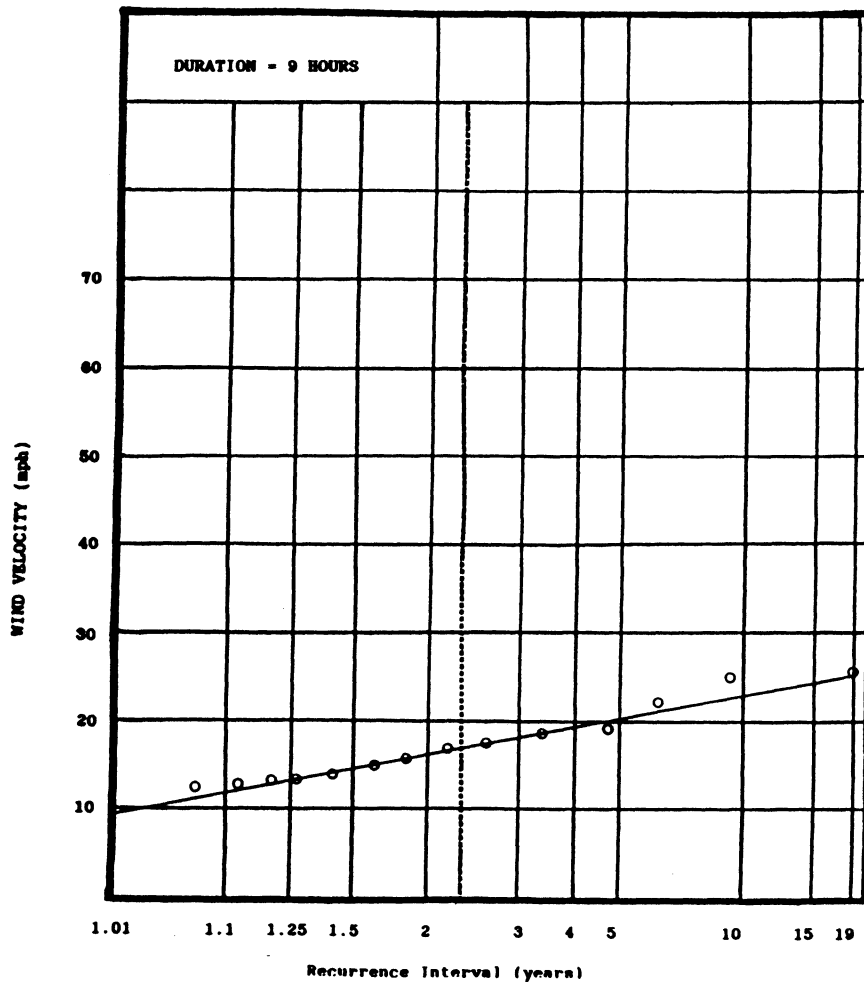


FIGURE 22.1: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY, APRIL 12 THROUGH APRIL 18

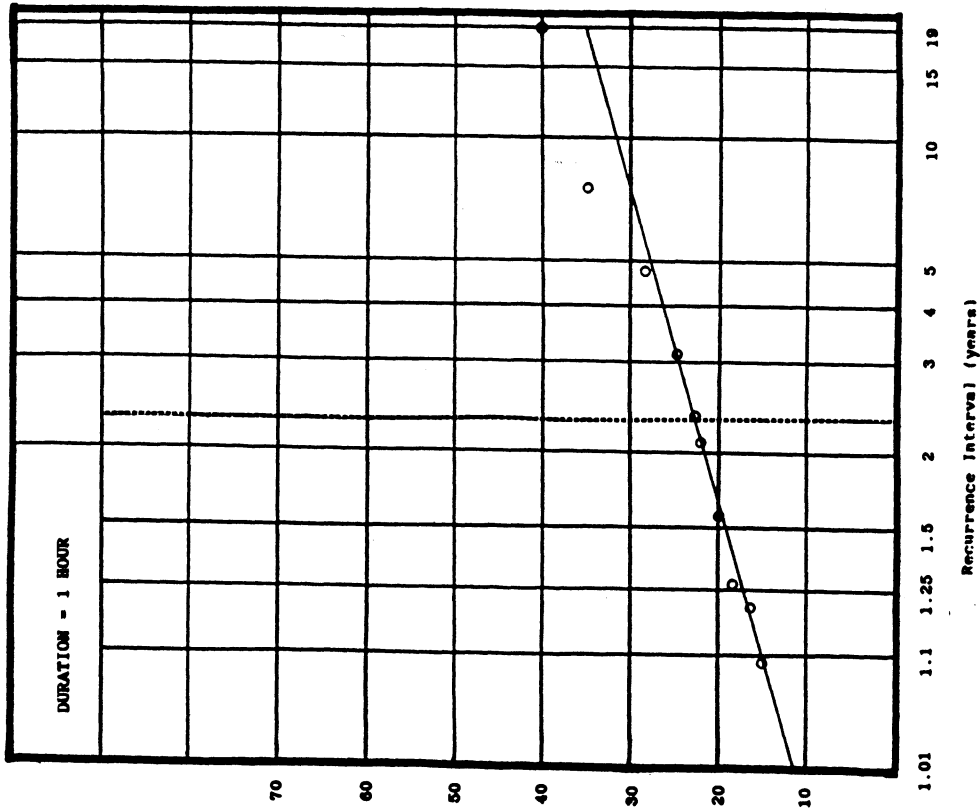


FIGURE 21.5: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY, APRIL 5 THROUGH APRIL 11

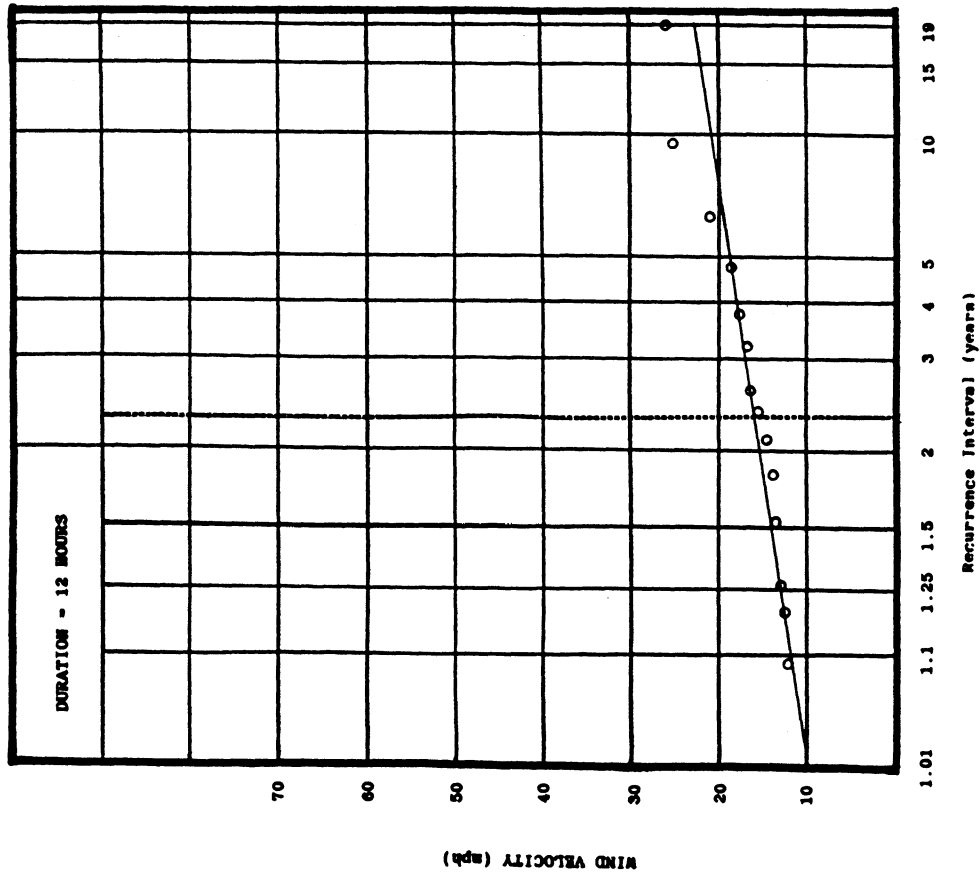


FIGURE 22.2: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY,
APRIL 12 THROUGH APRIL 18

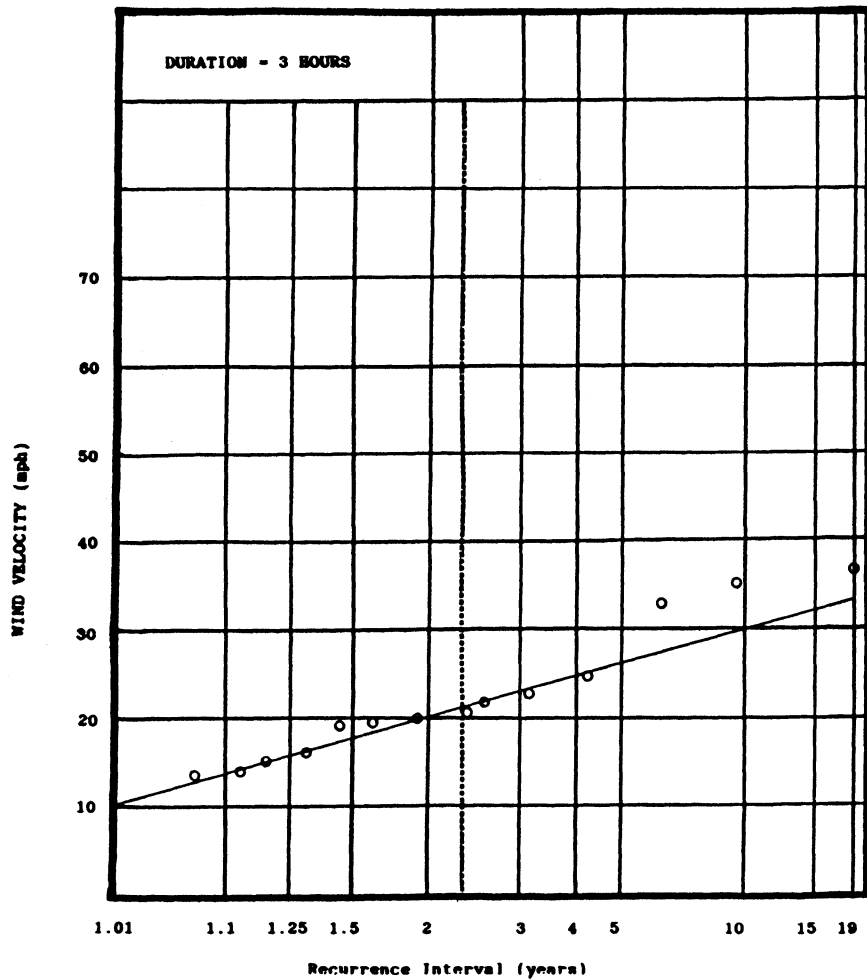


FIGURE 22.3: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY,
APRIL 12 THROUGH APRIL 18

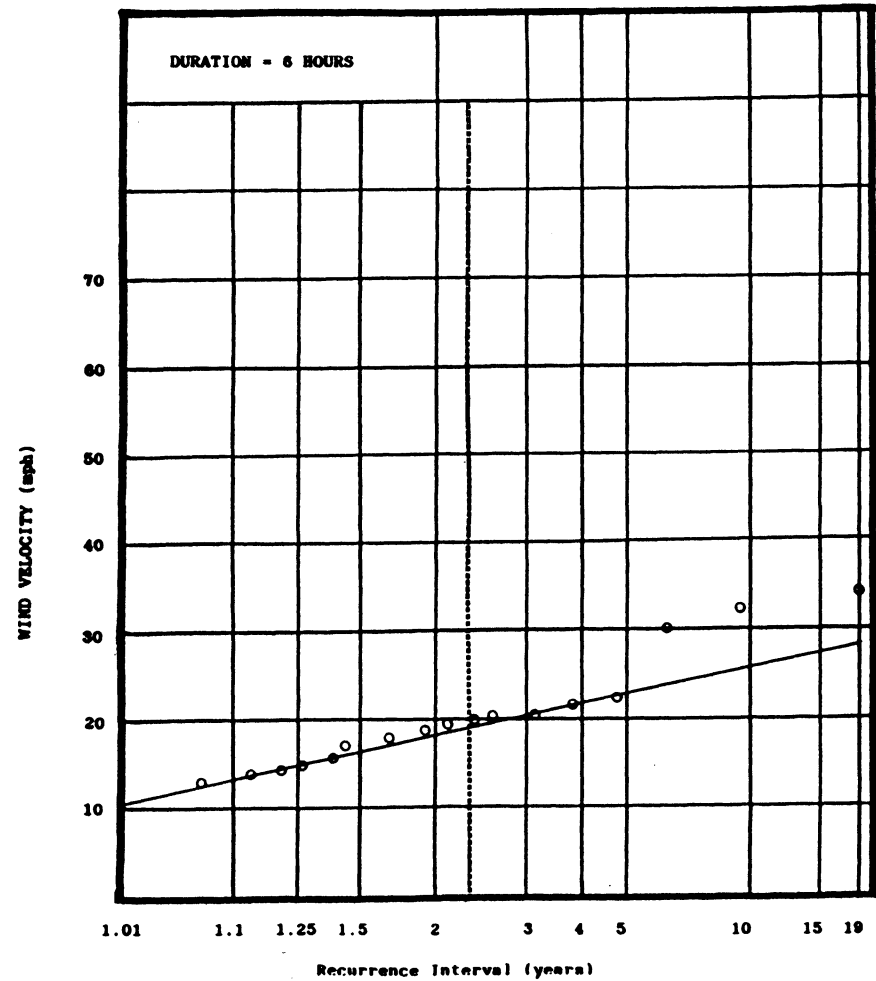


FIGURE 22.3: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY, APRIL 12 THROUGH APRIL 18

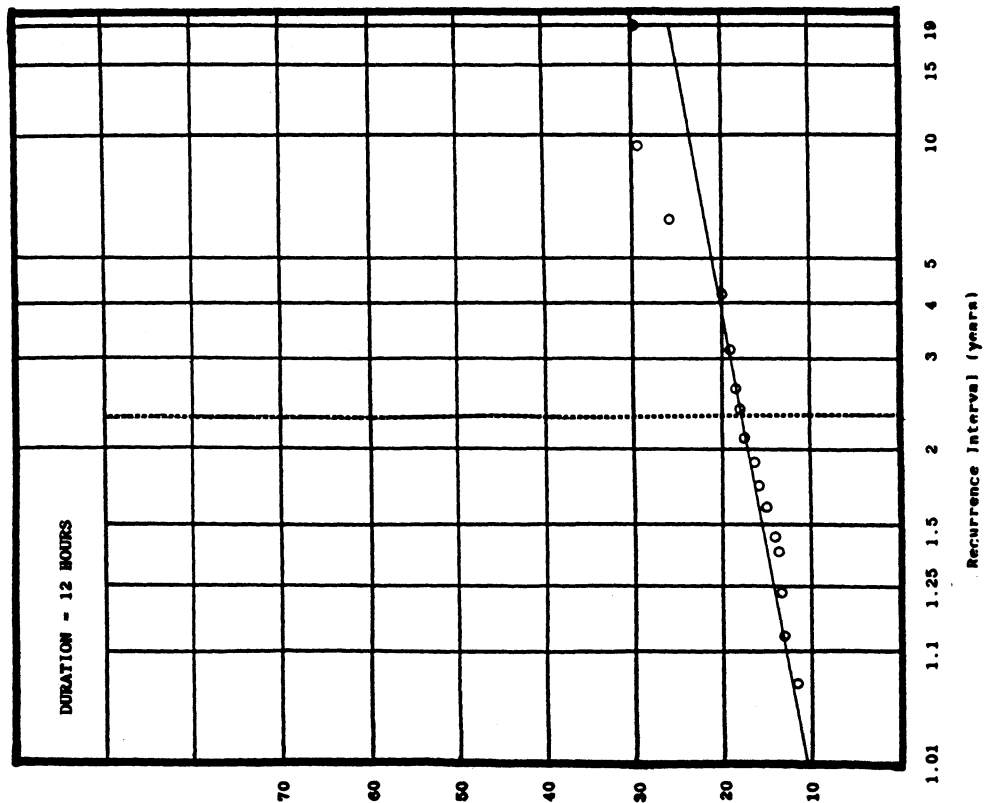


FIGURE 22.4: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY, APRIL 12 THROUGH APRIL 18

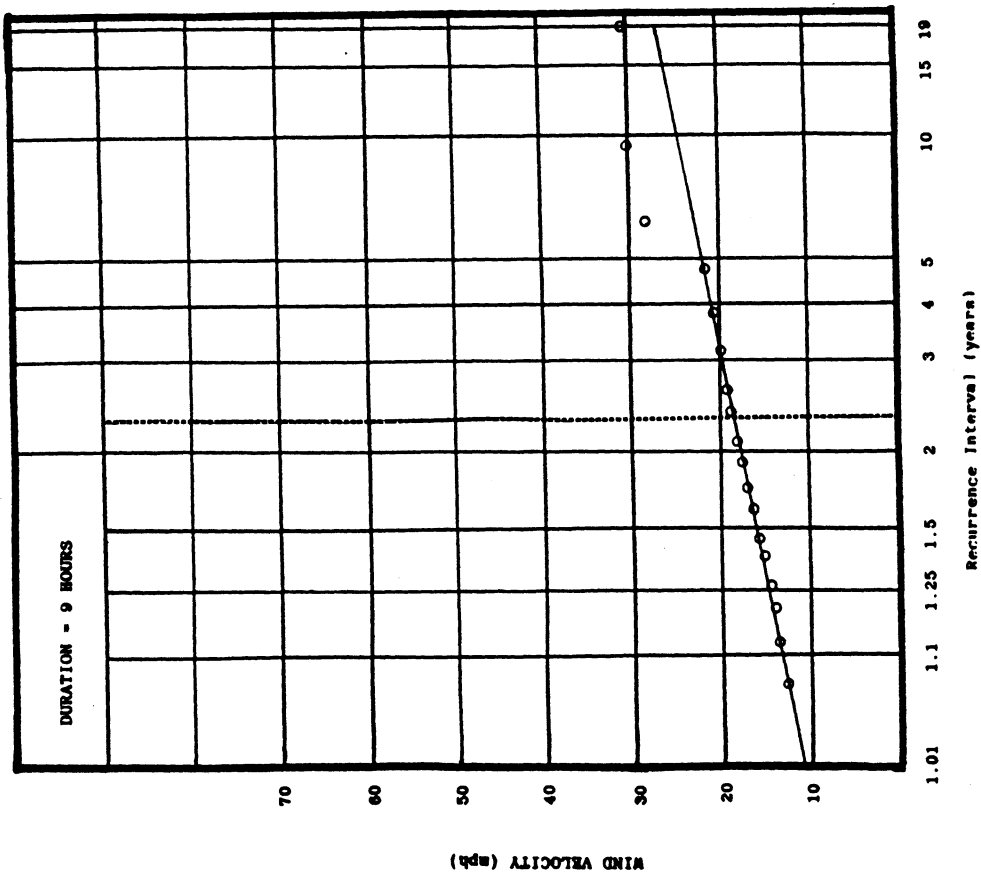


FIGURE 23.1: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY.
APRIL 19 THROUGH APRIL 25

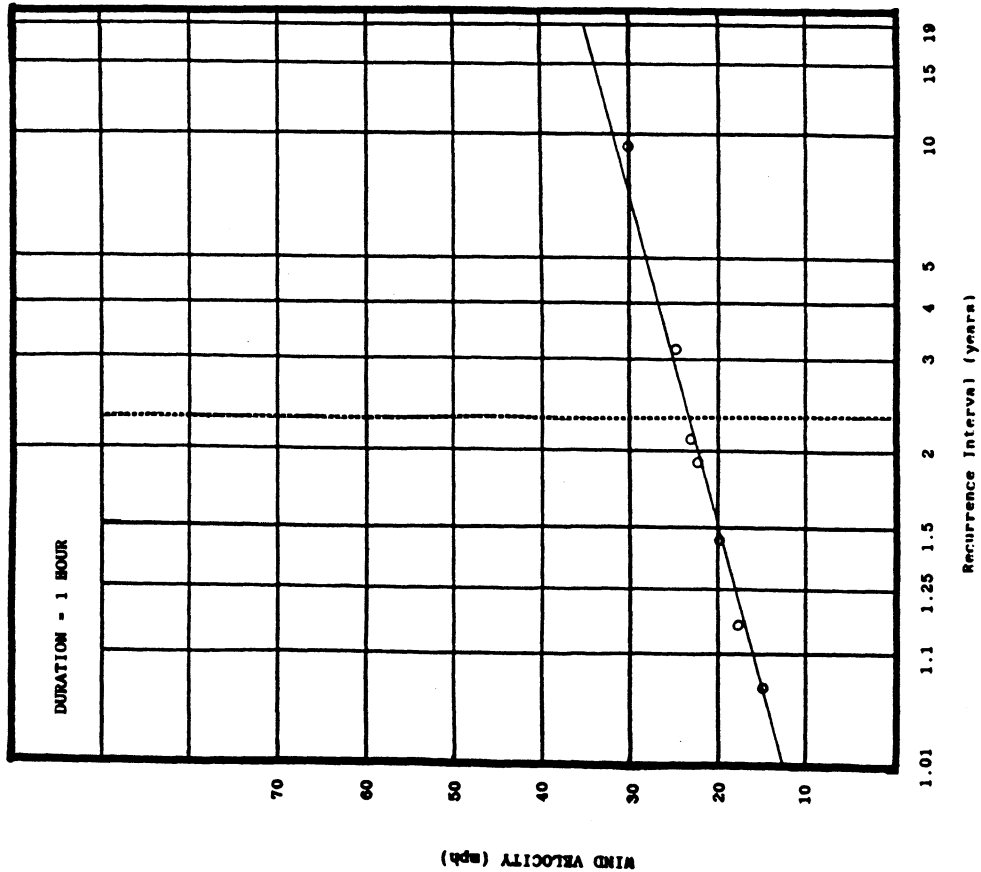


FIGURE 23.2: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY.
APRIL 19 THROUGH APRIL 25

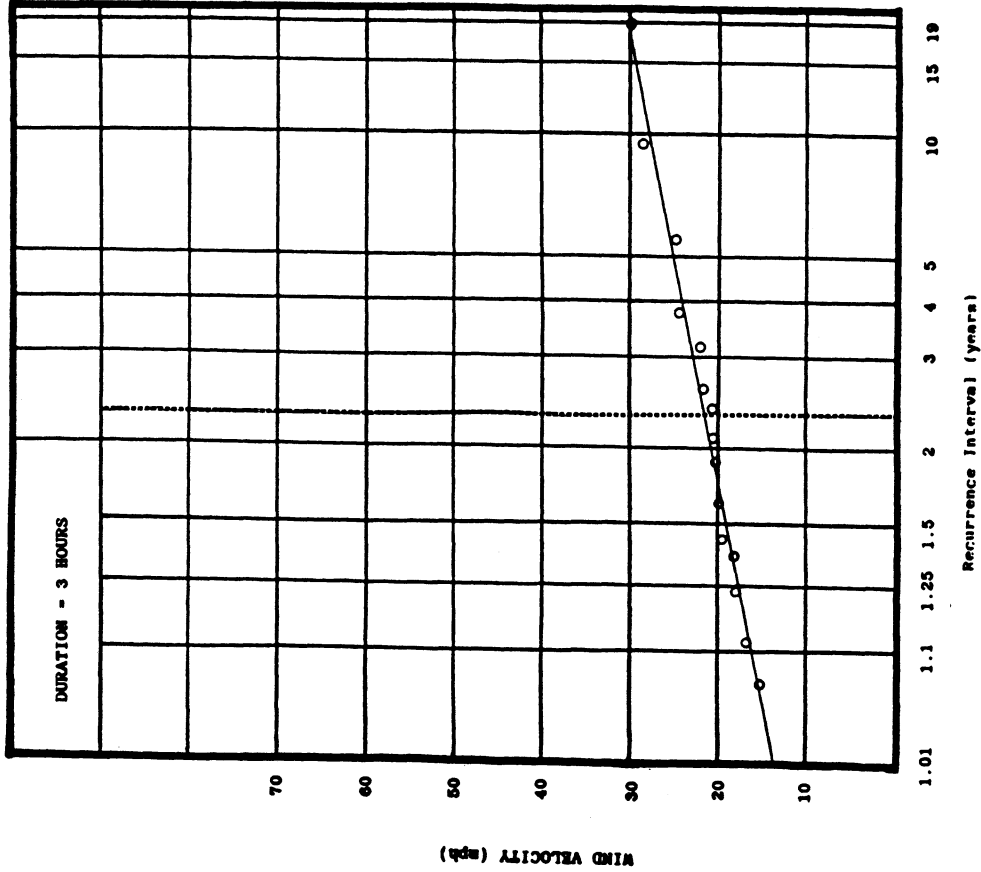


FIGURE 23.3: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY,
APRIL 19 THROUGH APRIL 25

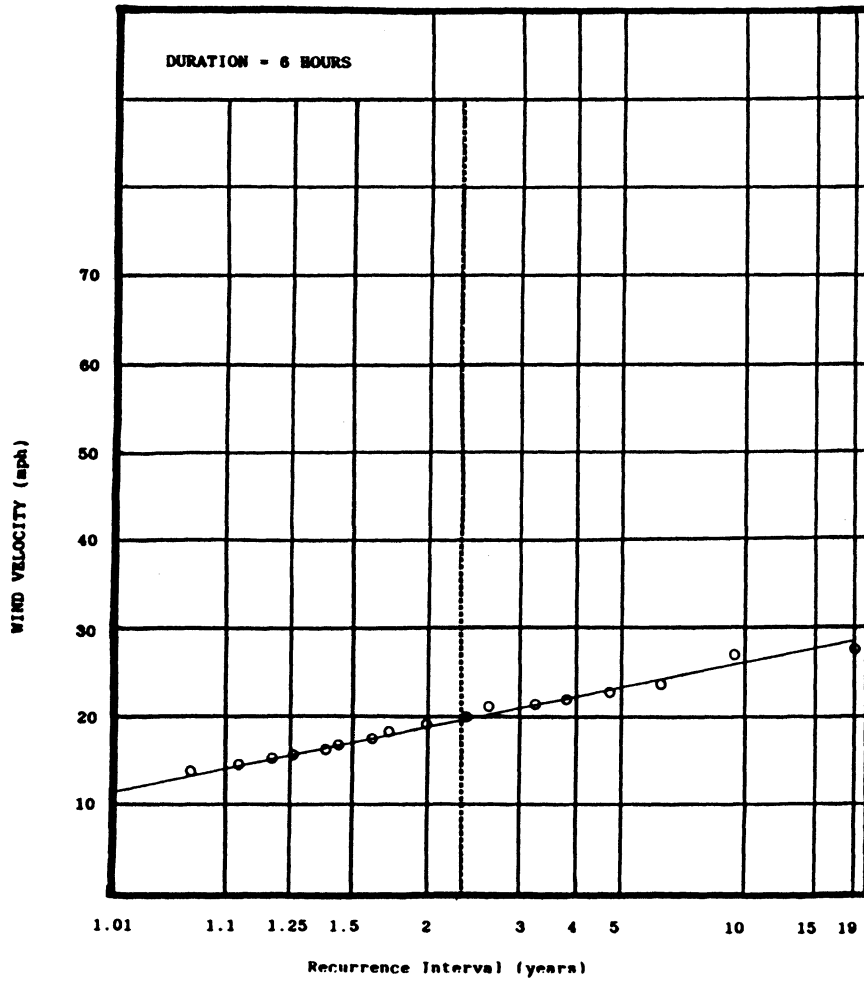


FIGURE 23.4: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY,
APRIL 19 THROUGH APRIL 25

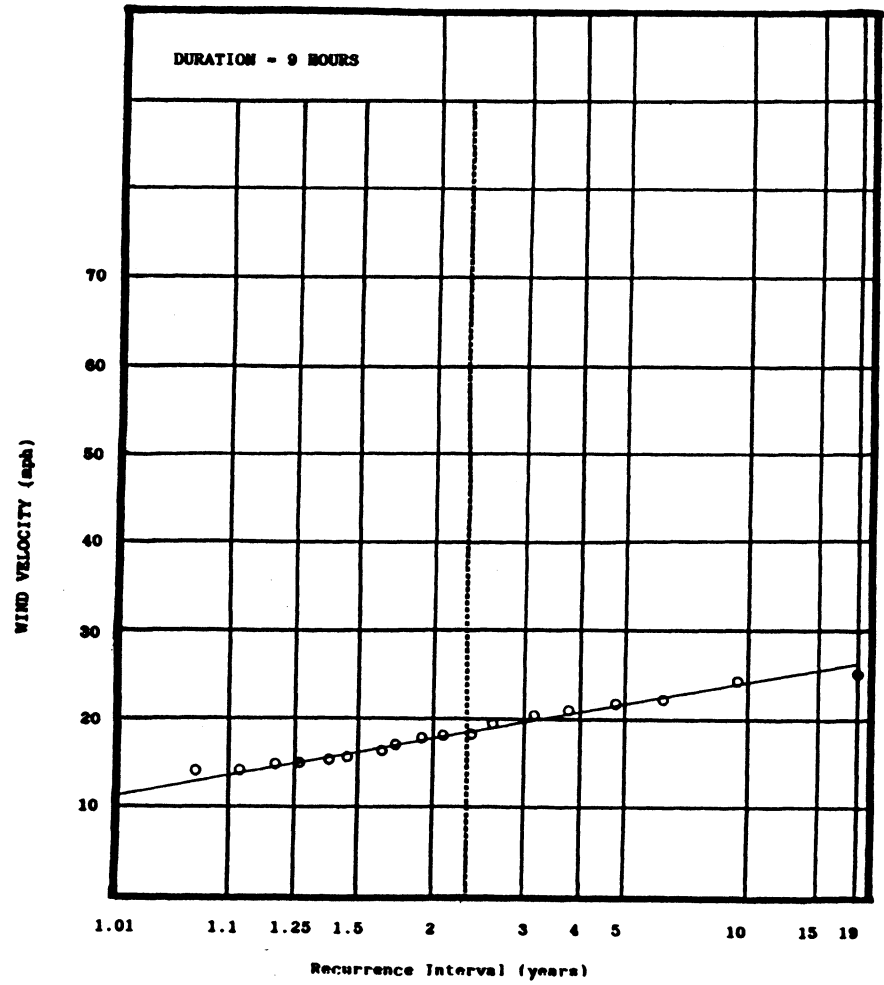


FIGURE 24.1: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY.
APRIL 26 THROUGH MAY 2

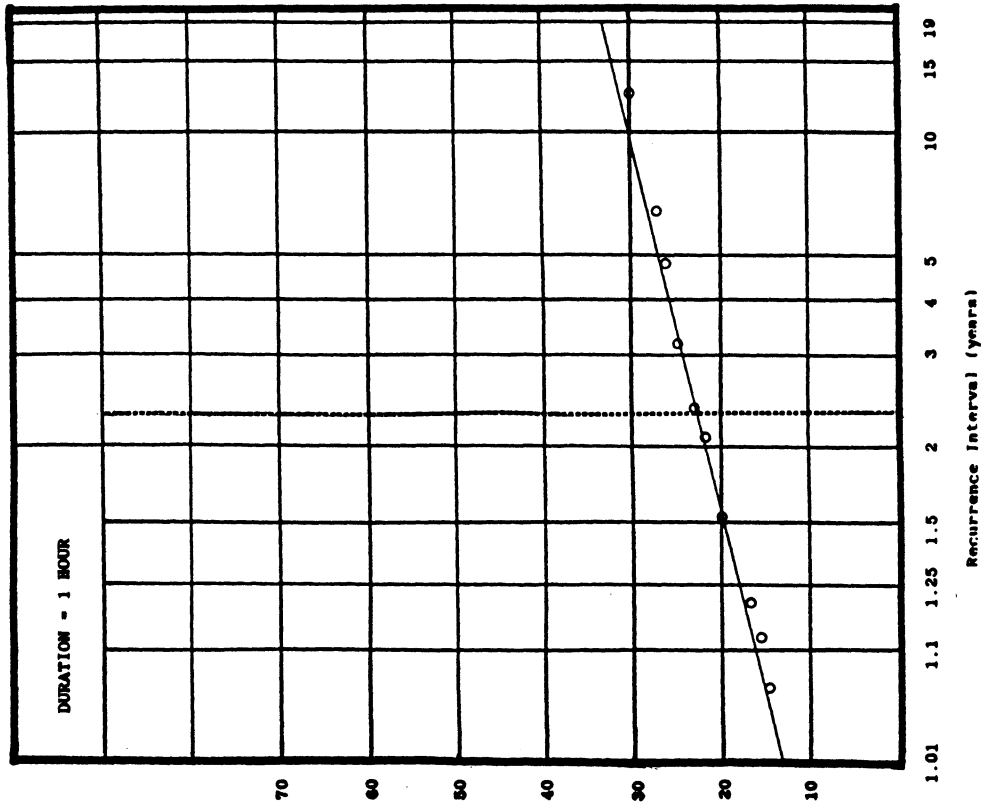


FIGURE 23.5: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY.
APRIL 19 THROUGH APRIL 25

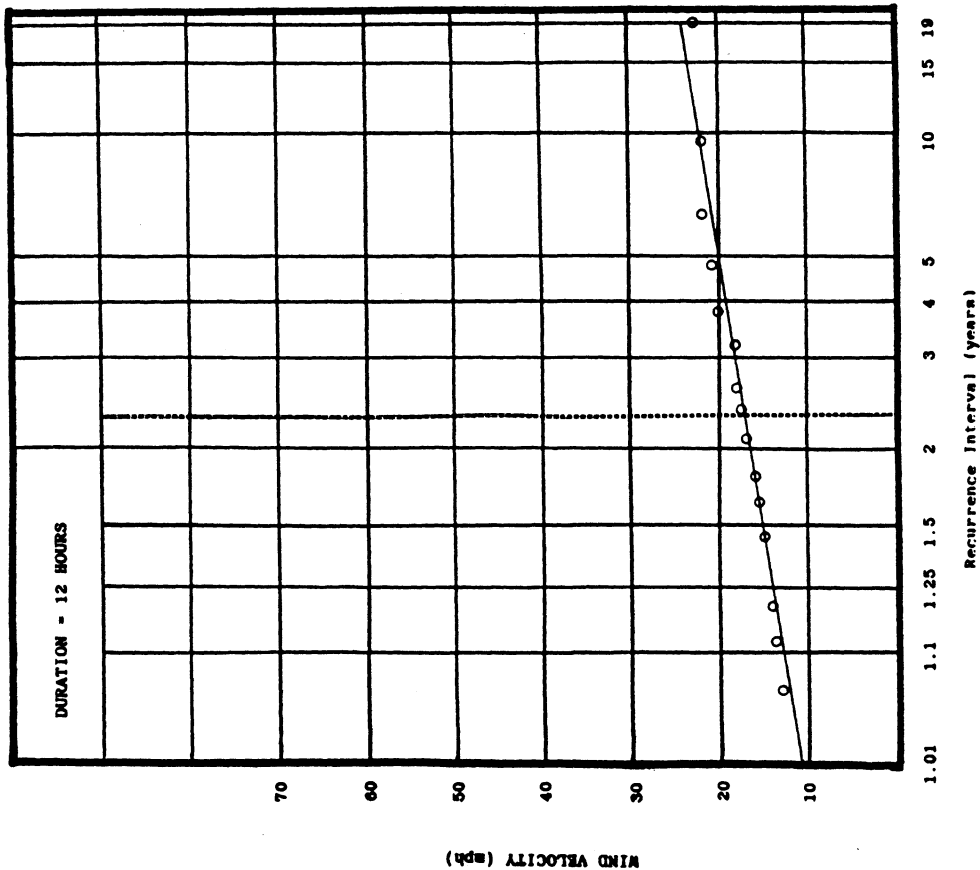


FIGURE 24.2: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY.
APRIL 26 THROUGH MAY 2

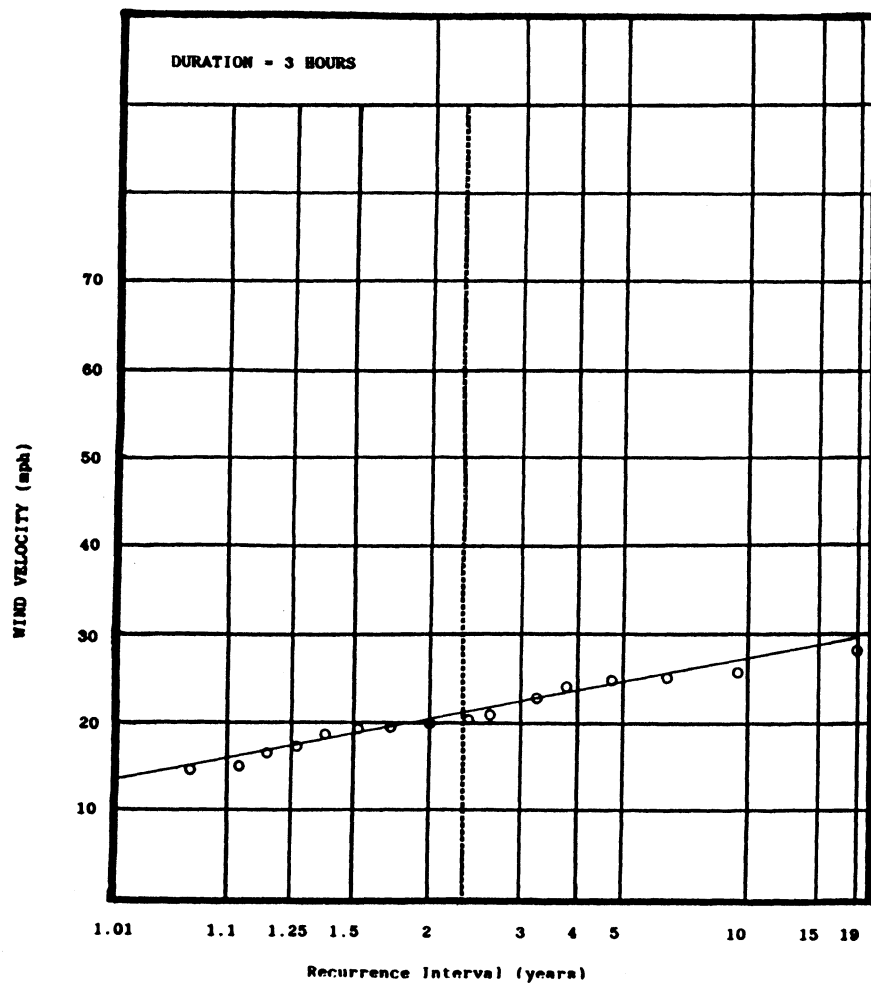


FIGURE 24.3: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY.
APRIL 26 THROUGH MAY 2

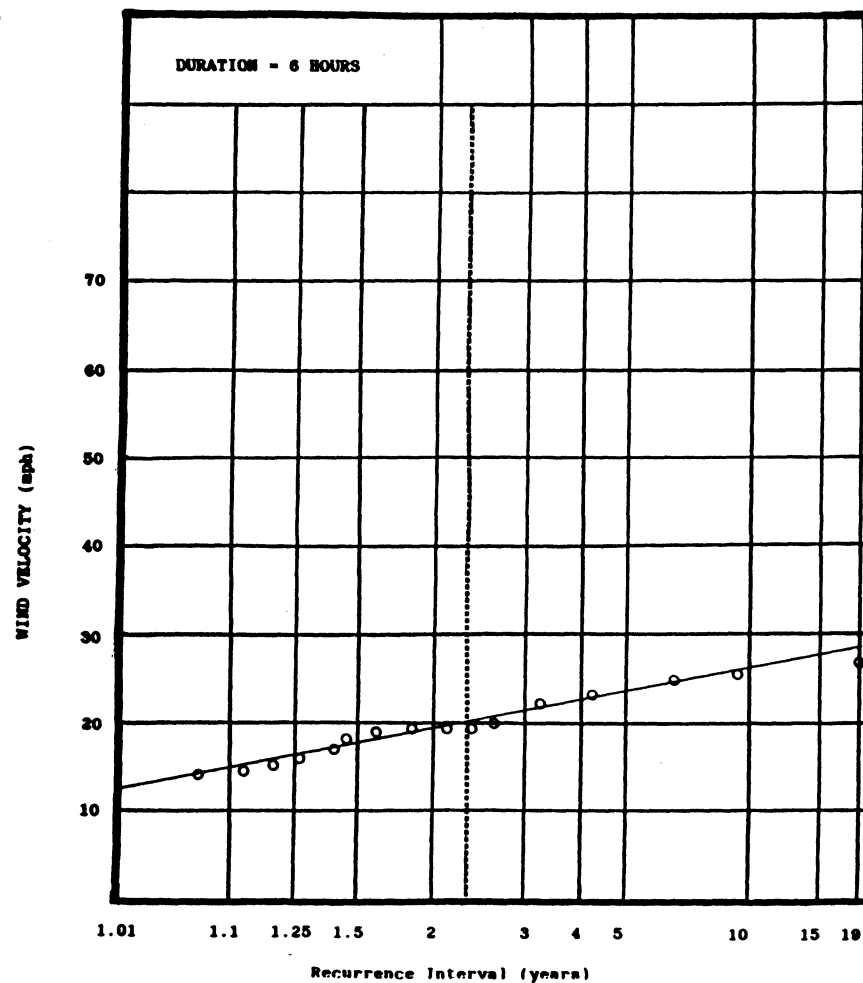


FIGURE 24.4: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY,
APRIL 26 THROUGH MAY 2

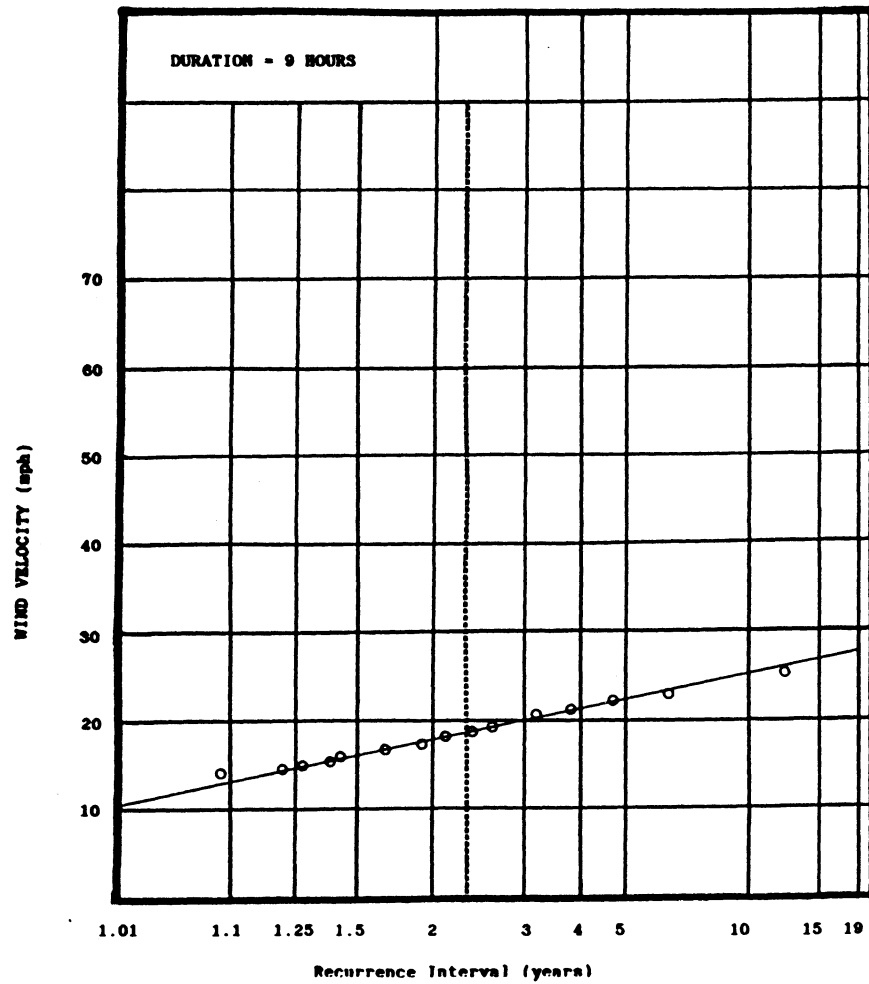


FIGURE 24.5: RETURN PERIOD OF MAXIMUM AVERAGE WIND VELOCITY,
APRIL 26 THROUGH MAY 2

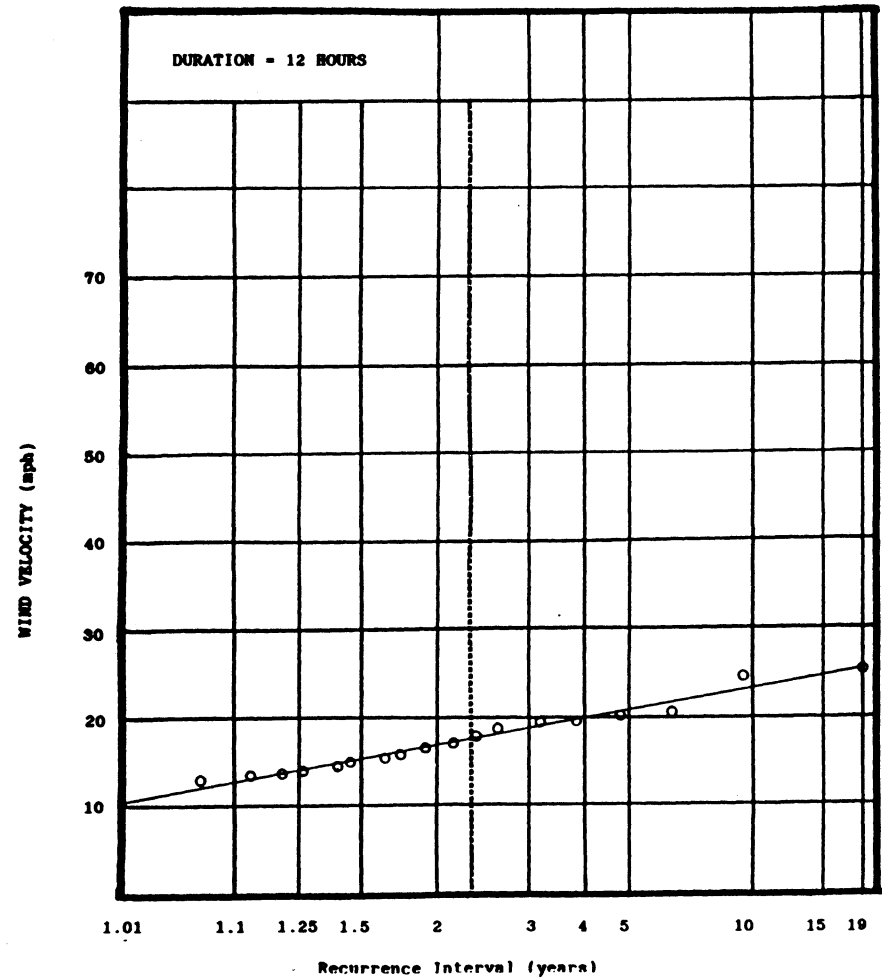


FIGURE 26: RETURN PERIOD OF EXTREME EROSIIVE WIND DURATION

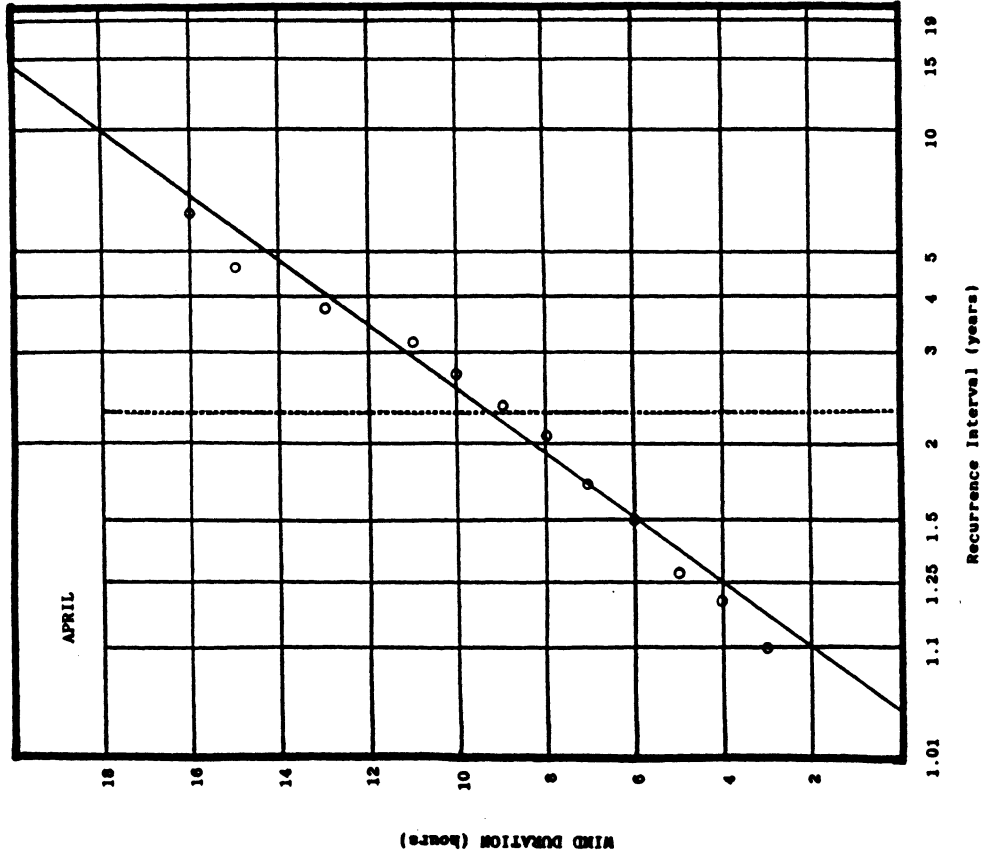


FIGURE 25: RETURN PERIOD OF EXTREME EROSIIVE WIND DURATION

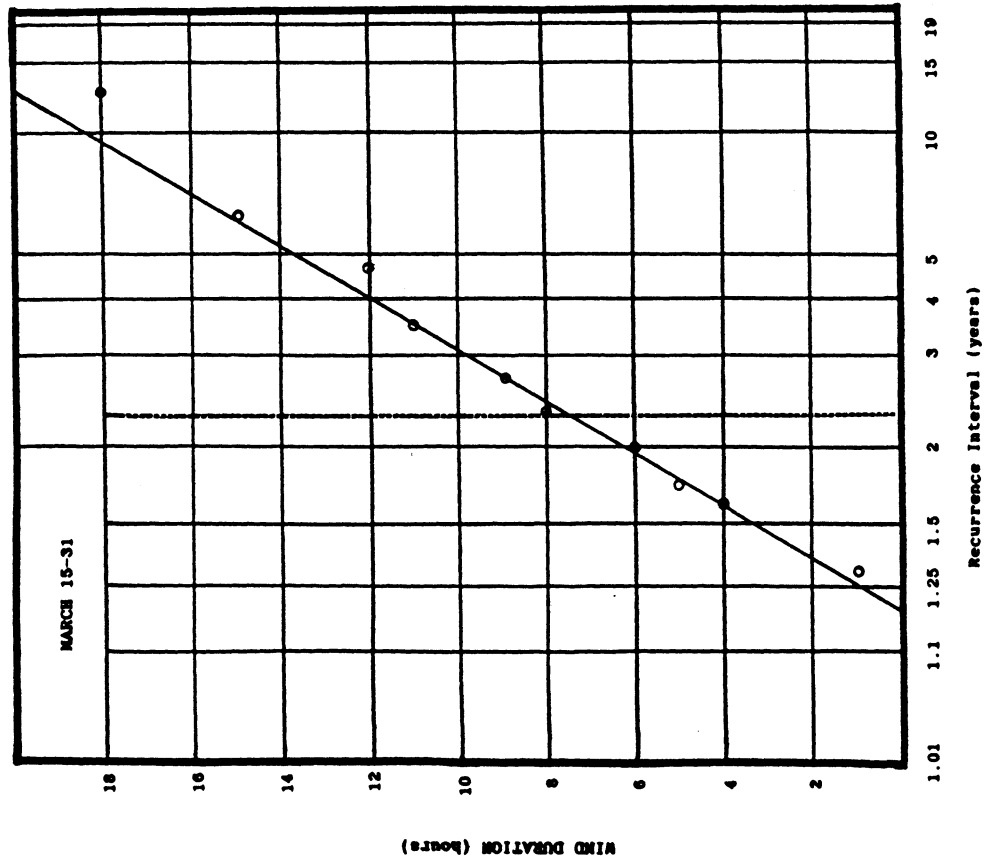


FIGURE 26: RETURN PERIOD OF EXTREME EROSIIVE WIND DURATION

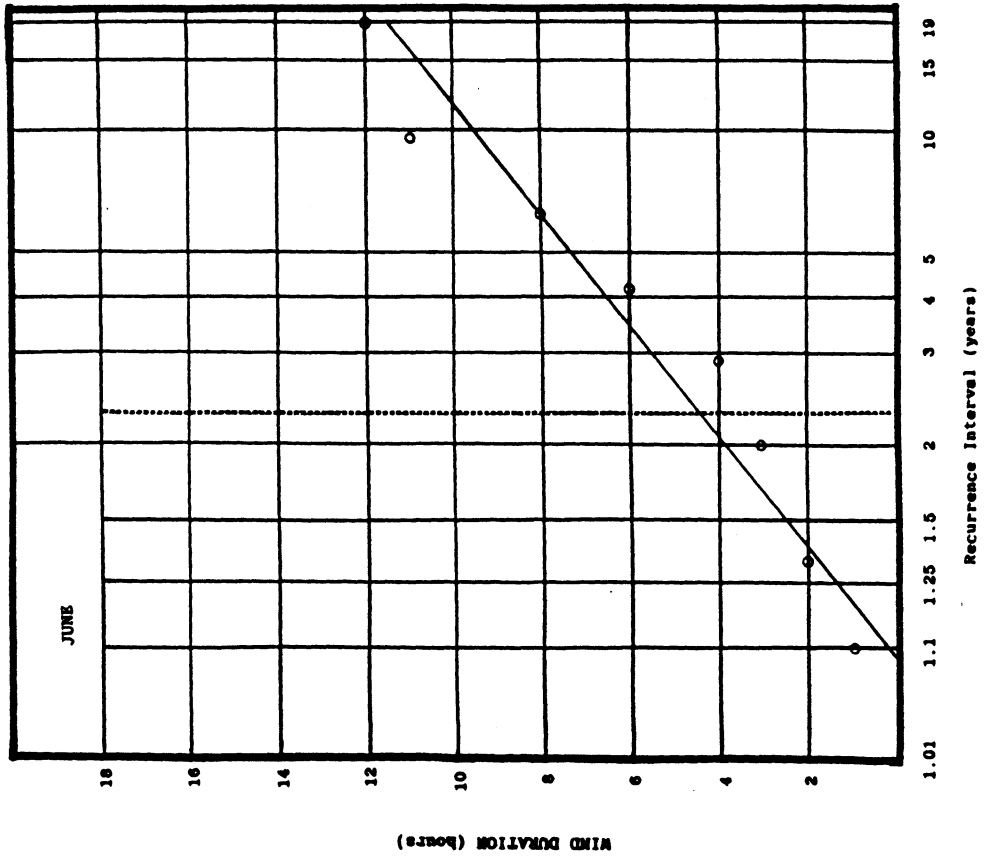


FIGURE 27: RETURN PERIOD OF EXTREME EROSIIVE WIND DURATION

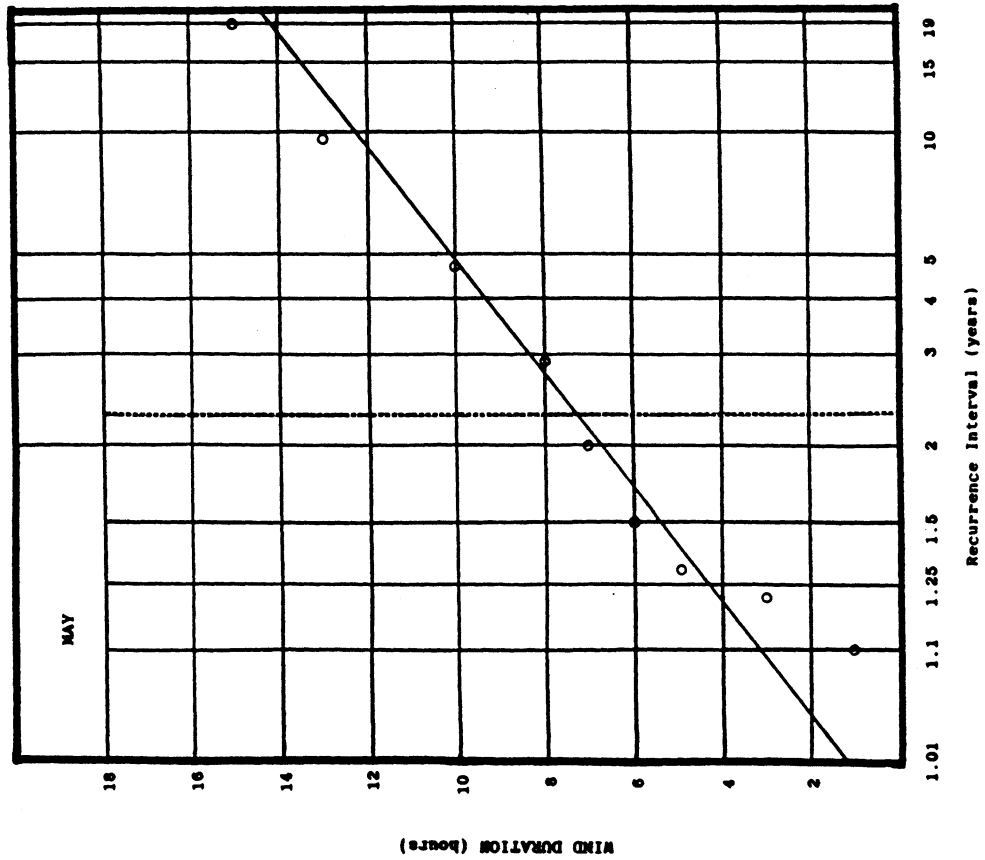


FIGURE 30: RETURN PERIOD OF EXTREME EROSIIVE WIND DURATION

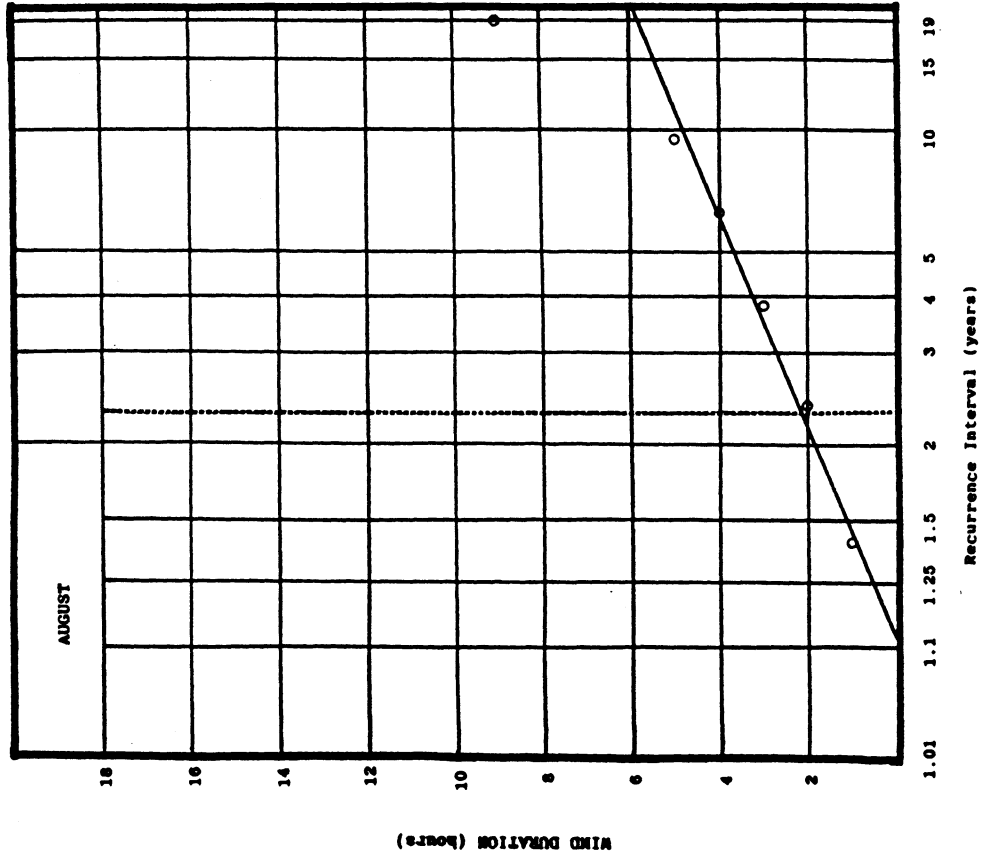


FIGURE 29: RETURN PERIOD OF EXTREME EROSIIVE WIND DURATION

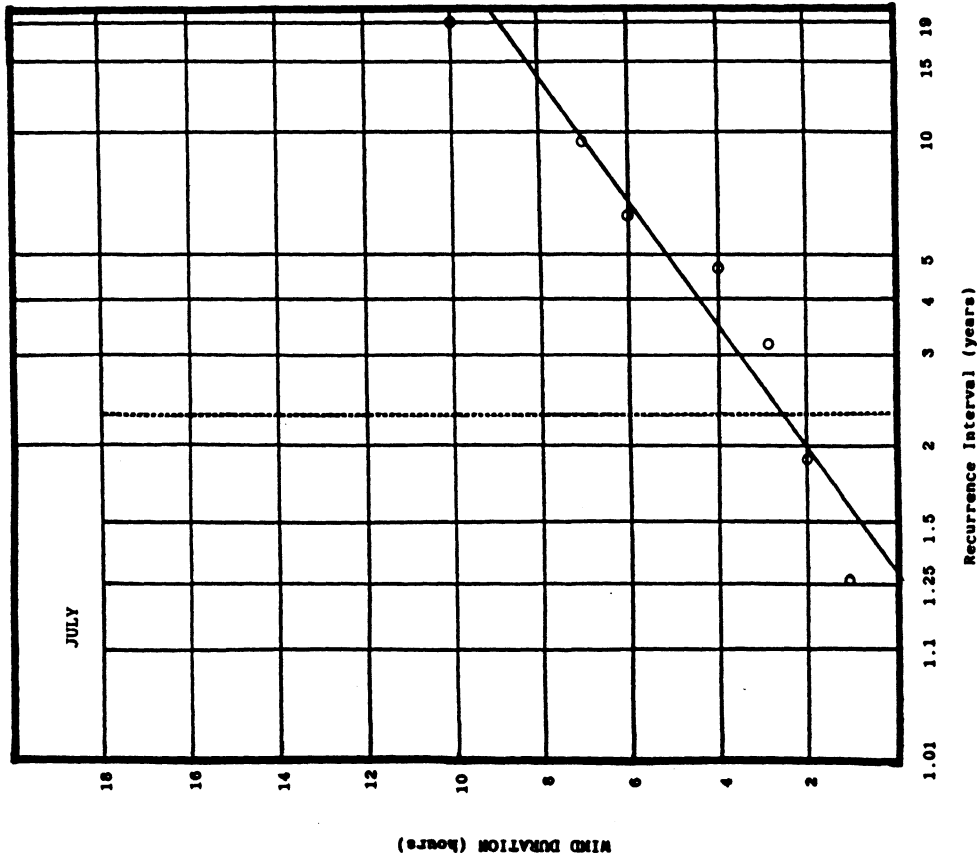


FIGURE 32: RETURN PERIOD OF EXTREME EROSIIVE WIND DURATION

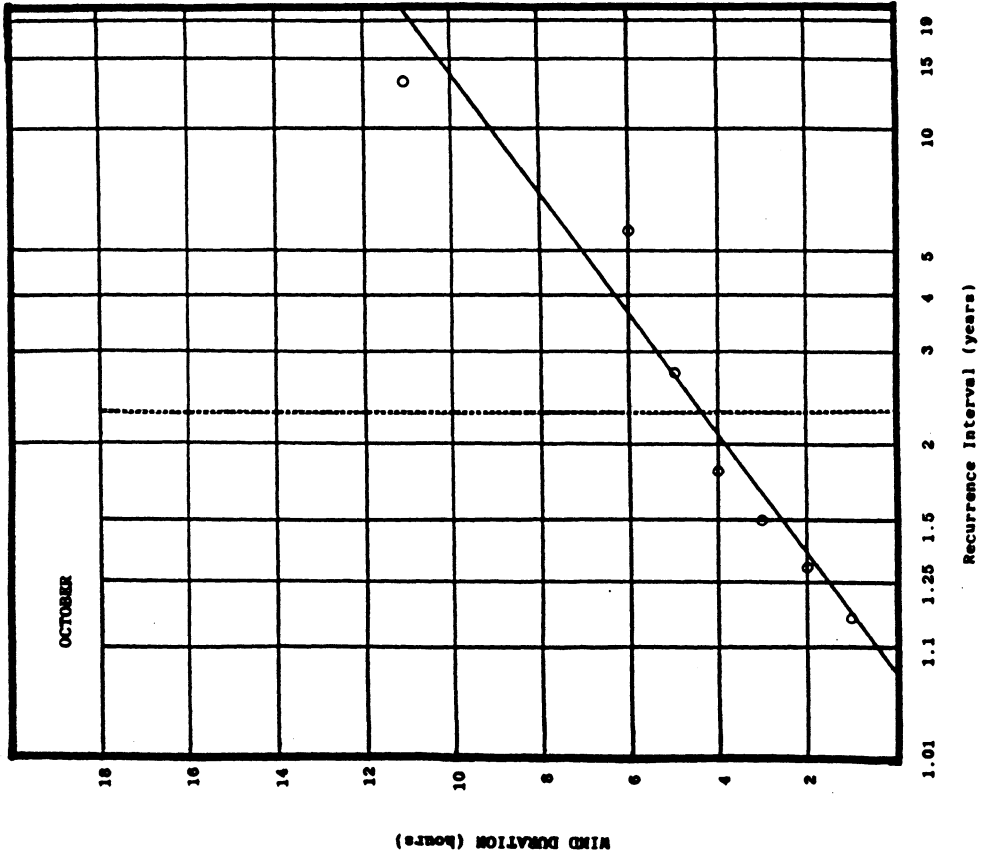


FIGURE 31: RETURN PERIOD OF EXTREME EROSIIVE WIND DURATION

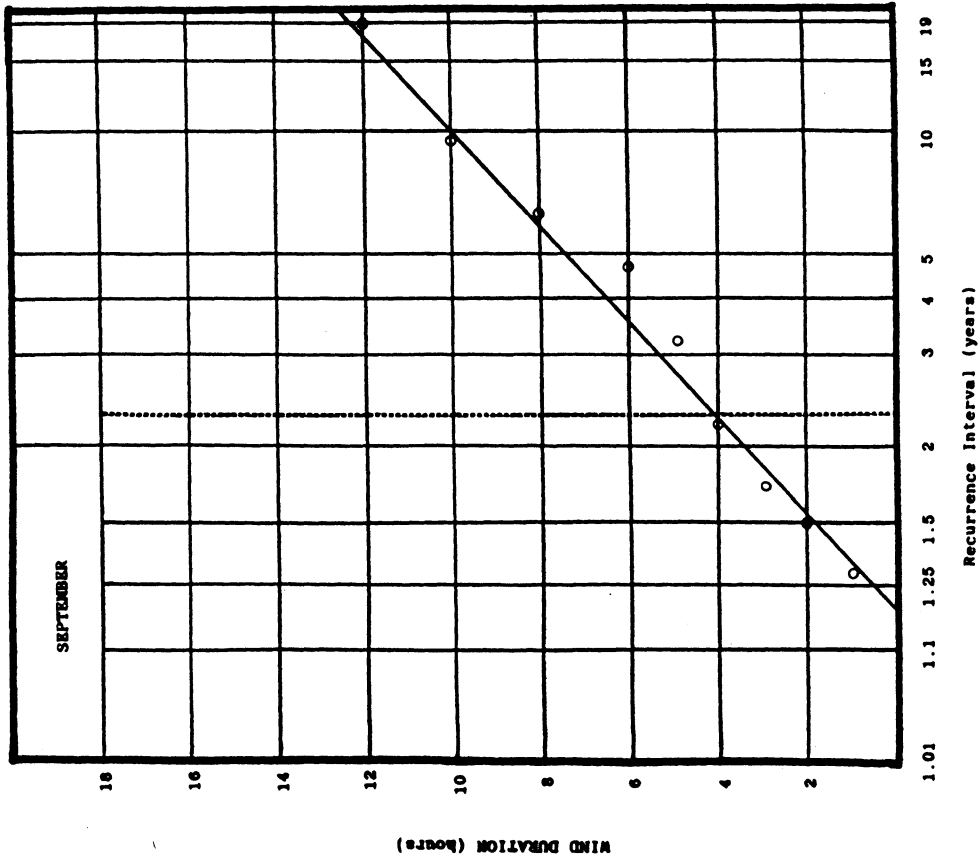


FIGURE 34: RETURN PERIOD OF EXTREME EROSIIVE WIND DURATION

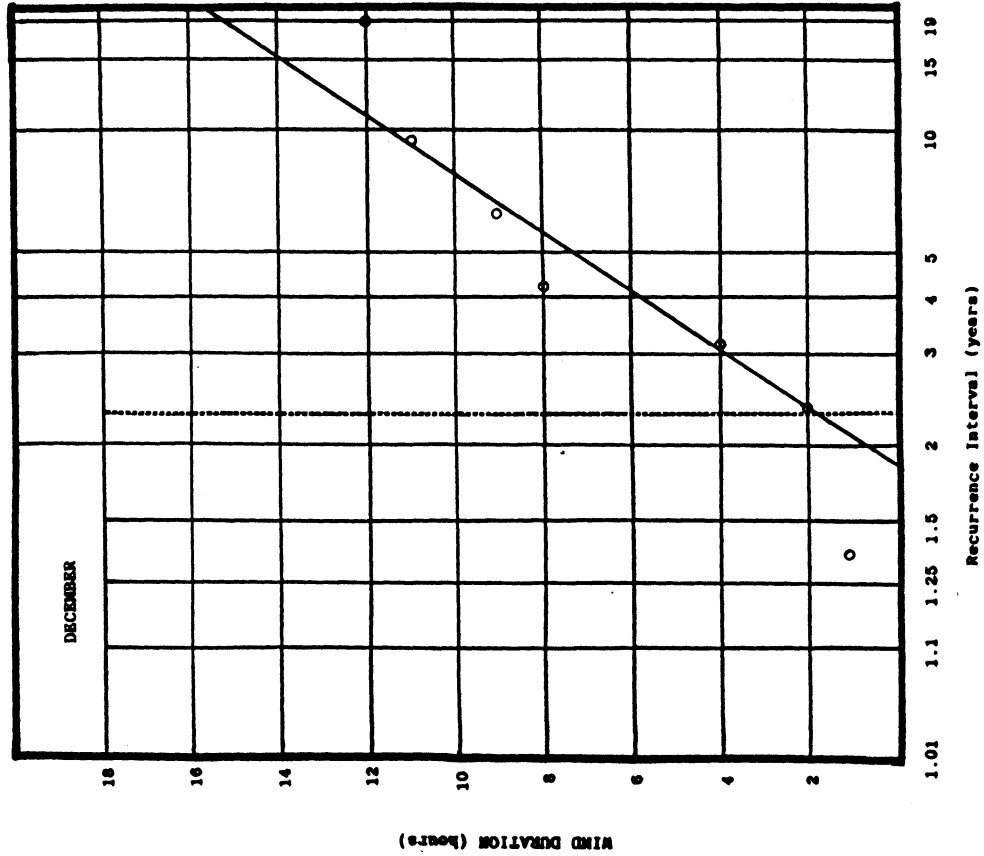
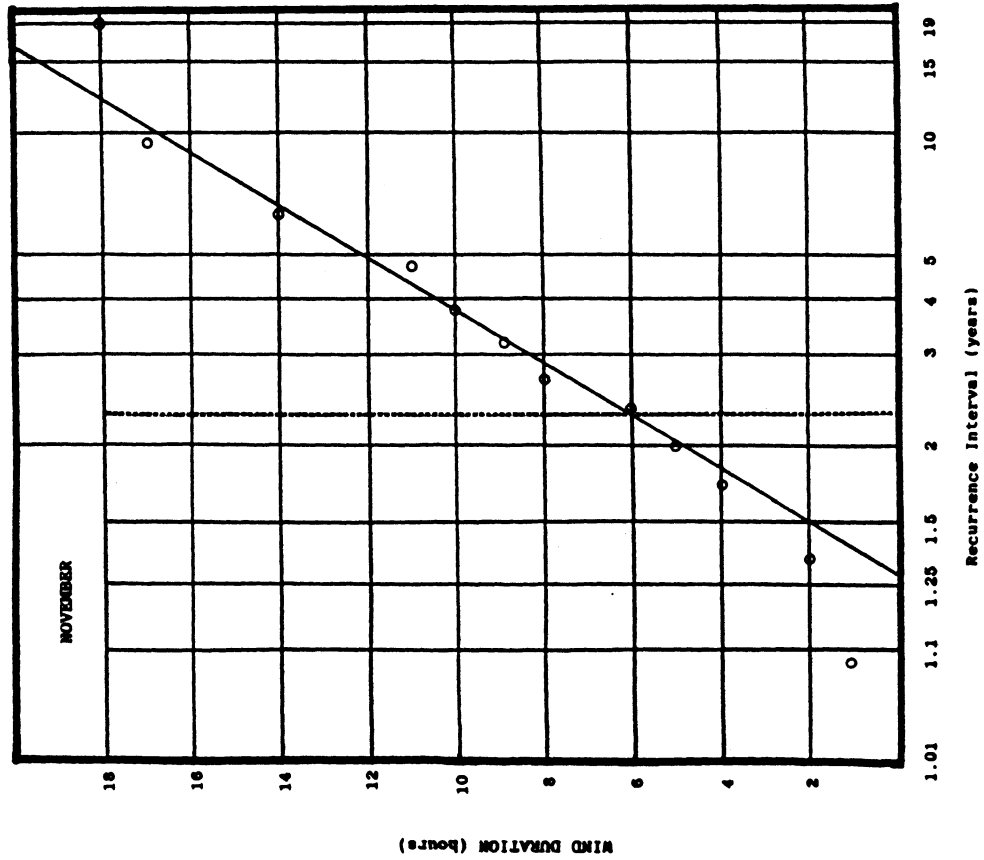


FIGURE 33: RETURN PERIOD OF EXTREME EROSIIVE WIND DURATION



APPENDIX B

COMPUTER-PROGRAMMED METHODOLOGIES

WINDANAL/DAY
WINDANAL/MONTH
WINDANAL
WEIBULL/DISTRIBUTION
WEIBULL/SPT
WIND EROSION FORCES
ROLLINGAVERAGE

WINDANAL/DAY

FILE ATTRIBUTES FOR: FIN TITLE=(10494)WINDANAL/DAY ON ACAD PIND=PACK INTMODE=ERC
 MAXRECSIZE=14 BLOCKSIZE=420 FRAMESIZE=48 FILEUSE=ID BUFFERS=2 TRANSLATE=FULLTR
 AREALENGTH=15120 FLEXIBLE LASTRECORD=107 FILEFIND=FORTRAN SYMBOL ROWSINUSE=1 US
 LASTACCESSDATE=12/19/85(85353) CYCLE=1 VERSION=0 SAVEFACTOR=30 SECURITYTYPE=CLA

```

1E1 $RESET FREE
2E1 FILE 6(KIND=PRINTER)
3E1 FILE 7(KIND=DISK,FILETYPE=7,TITLE='SPT/WIND')
4E1 DIMENSION MDAY(10,8),INDX(6600,3),NCODE(22),NOIR(22),NBLK(22),
5E1 * PER(10,8),ICMON(12)
6E1 DATA IDMON/31,29,31,30,31,30,31,31,30,31,30,31/
7E1 C
8E1 C LOAD THE INDEX ARRAY
9E1 C
10E1 DO 10 I=1,6600
11E1 READ(7,5,END=15)(INX(I,J),J=1,2)
12E1 5 FORMAT(2I2)
13E1 INX(I,3)=I
14E1 10 CONTINUE
15E1 15 NREC=I-1
16E1 C
17E1 C SET UP INPUT-OUTPUT LOOP KEYED TO THE MONTH AND DAY NUMBER
18E1 C
19E1 DO 200 NM=1,12
20E1 DO 195 ND=1,IDMON(NM)
21E1 DO 25 I=1,10
22E1 DO 20 J=1,8
23E1 MDAY(I,J)=0
24E1 20 CONTINUE
25E1 25 CONTINUE
26E1 C
27E1 C SEARCH THE INDEX ARRAY FOR RECORDS FOR APPROPRIATE MONTH AND
28E1 C DAY
29E1 C
30E1 DO 65 M=1,NREC
31E1 IF (INX(M,1).EQ.NM.AND.INX(M,2).EQ.ND) GO TO 40
32E1 GO TO 65
33E1 C
34E1 40 READ(7=INX(M,3),50)(NCODE(I),NOIR(I),I=1,22),NBLK
35E1 50 FORMAT(6X,22(I1,I2),T7,22(A1,2X))
36E1 C
37E1 C UPDATE STORAGE MATRIX
38E1 C
39E1 DO 60 L=1,22
40E1 IF (NBLK(L).EQ.' ') GO TO 65
41E1 NCODE(L)=NCODE(L)+1
42E1 IF (NCODE(L).GT.9) GO TO 60
43E1 J=0
44E1 IF (NOIR(L).EQ.0) J=1
45E1 IF (NOIR(L).GE.1.AND.NOIR(L).LE.17) J=2
46E1 IF (NOIR(L).GE.18.AND.NOIR(L).LE.26) J=3
47E1 IF (NOIR(L).GE.27.AND.NOIR(L).LE.35) J=4
48E1 IF (NOIR(L).GE.36.AND.NOIR(L).LE.44) J=5
49E1 IF (NOIR(L).GE.45.AND.NOIR(L).LE.53) J=6
50E1 IF (NOIR(L).GE.54) J=7
  
```

```

51E1      IF (J.EQ.0) GO TO 60
52E1      MDAY(NCODE(L),J)=MDAY(NCODE(L),J)+1
53E1      60 CONTINUE
54E1      65 CONTINUE
55E1 C
56E1 C      BUILD A PRINTING LOOP -- FIRST FOR INDIVIDUAL DAYS
57E1 C
58E1
59E1      WRITE(6,80)NM,ND
60E1      80  FORMAT('1',////'0', 'MONTH ---',I3/' ', 'DAY -----',I3)
61E1      WRITE(6,85)
62E1      85  FORMAT(//'0', 'DIRECTION'/' ',I3, 'CODE',I5, '0',T20, '1-17',T26,
63E1      *   '18-26',T34, '27-35',T41, '36-44',T48, '45-53',T56, '54+',T63,
64E1      *   'TOTAL'/'')
65E1 C
66E1 C      FIND ROW TOTALS
67E1 C
68E1      DO 100 I=1,9
69E1          DO 90 J=2,6
70E1              MDAY(I,8)=MDAY(I,8)+MDAY(I,J)
71E1          90  CONTINUE
72E1      100  CONTINUE
73E1 C
74E1 C      FIND COLUMN TOTALS
75E1 C
76E1      DO 120 J=1,8
77E1          DO 110 I=1,9
78E1              MDAY(10,J)=MDAY(10,J)+MDAY(I,J)
79E1          110  CONTINUE
80E1      120  CONTINUE
81E1 C
82E1 C      ZERO OUT PERCENT MATRIX
83E1 C
84E1      DO 140 I=1,10
85E1          DO 130 J=1,8
86E1              PER(I,J)=0.0
87E1          130  CONTINUE
88E1      140  CONTINUE
89E1 C
90E1 C      CALCULATE PERCENTAGE MATRIX
91E1 C
92E1      DO 160 I=1,10
93E1          DO 150 J=1,8
94E1              IF (MDAY(10,8).NE.0)PER(I,J)=FLOAT(MDAY(I,J))/
95E1      *   MDAY(10,8)*100.
96E1          150  CONTINUE
97E1          160  CONTINUE
98E1          DO 190 I=1,9
99E1              WRITE(6,170)(I-1),(MDAY(I,J),J=1,8),(PER(I,J),J=2,6),
100E1      *   PER(I,8)
101E1          170  FORMAT('0',3X,I1,5X,8I7/' ',5X,'%',10X,5F7.2,8X,F7.2)
102E1          180  CONTINUE
103E1          WRITE(6,190)(MDAY(10,J),J=1,8),(PER(I,J),J=2,6),PER(I,8)
104E1          190  FORMAT('0',1X,'TOTALS',2X,8I7/' ',5X,'%',10X,5F7.2,8X,F7.2)
105E1          195  CONTINUE
106E1          200  CONTINUE
107E1          STOP
108E1          END
FILE CONTAINS 108 RECORDS
CCROS PROCESSED

```

WINDANAL/MONTH

FILE ATTRIBUTES FOR: FIN TITLE=(10494)WINDANAL/MONTH ON ACAD KIND=PACK INTMODE=
 MAXRECSIZE=14 BLOCKSIZE=420 FRAMESIZE=48 FILEUSE=IQ BUFFERS=2 TRANSLATE=FULLT
 AREA LENGTH=15120 FLEXIBLE LASTRECORD=107 FILEIND=FCRTRANSYMRCL ROWSINUSE=1 I
 LASTACCESSDATE=12/19/85(85353) CYCLE=1 VERSION=0 SAVEFACTOR=30 SECURITYTYPE=CL

```

1E1 $RESET FREE
2E1 FILE 6(KIND=PRINTER)
3E1 FILE 7(KIND=DISK, FILETYPE=7, TITLE='SPT/WIND')
4E1 DIMENSION MOAY(10,8), INOX(6600,3), NCCODE(22), NOIR(22), NBLK(22),
5E1 * PER(10,8), ICMON(12)
6E1 DATA 10MON/31,29,31,30,31,30,31,31,30,31,30,31/
7E1 C
8E1 C LOAD THE INDEX ARRAY
9E1 C
10E1 DO 10 I=1,6600
11E1 READ(7,5,END=15)(INOX(I,J),J=1,2)
12E1 5 FORMAT(2I2)
13E1 INOX(I,3)=I
14E1 10 CONTINUE
15E1 15 NREC=I-1
16E1 C
17E1 C SET UP INPUT-OUTPUT LOOP KEYED TO THE MONTH AND DAY NUMBER
18E1 C
19E1 DO 200 NM=8,12
20E1
21E1 DO 25 I=1,10
22E1 DO 20 J=1,8
23E1 MDAY(I,J)=0
24E1 20 CONTINUE
25E1 25 CONTINUE
26E1 C
27E1 C SEARCH THE INDEX ARRAY FOR RECORDS FOR APPROPRIATE MONTH AND
28E1 C DAY
29E1 C
30E1 DO 65 M=1,NREC
31E1 IF (INOX(M,1).EQ.NM) GO TO 40
32E1 GO TO 65
33E1
34E1 40 READ(7=INOX(M,3),50)(NCCODE(I),NOIR(I),I=1,22),NBLK
35E1 50 FORMAT(6X, 22(I1,I2),T7,22(A1,2X))
36E1 C
37E1 C UPDATE STORAGE MATRIX
38E1 C

```

```

39E1      DO 60 L=1,22
40E1      IF (NBLK(L).EQ.0) GO TO 65
41E1      NCODE(L)=NCODE(L)+1
42E1      IF (NCODE(L).GT.9) GO TO 60
43E1      J=0
44E1      IF (NDIR(L).EQ.0) J=1
45E1      IF (NDIR(L).GE.1.AND.NDIR(L).LE.17) J=2
46E1      IF (NDIR(L).GE.18.AND.NDIR(L).LE.26) J=3
47E1      IF (NDIR(L).GE.27.AND.NDIR(L).LE.35) J=4
48E1      IF (NDIR(L).GE.36.AND.NDIR(L).LE.44) J=5
49E1      IF (NDIR(L).GE.45.AND.NDIR(L).LE.53) J=6
50E1      IF (NDIR(L).GE.54) J=7
51E1      IF (J.EQ.0) GO TO 60
52E1      MDAY(NCODE(L),J)=MDAY(NCODE(L),J)+1
53E1      60 CONTINUE
54E1      65 CONTINUE
55E1 C
56E1 C      BUILD A PRINTING LOOP -- FIRST FOR INDIVIDUAL DAYS
57E1 C
58E1 C
59E1      WRITE(6,80) NM
60E1      80  FORMAT('1',///'0', 'MONTH ---', I3)
61E1      WRITE(6,85)
62E1      85  FORMAT(///'0', 'DIRECTION'/' ', I3, 'CODE', I15, '0', T20, '1-17', T26,
63E1      *   '18-26', T34, '27-35', T41, '36-44', T48, '45-53', T56, '54+', T63,
64E1      *   'TOTAL'/' )
65E1 C
66E1 C      FIND ROW TOTALS
67E1 C
68E1      DO 100 I=1,9
69E1          DO 90 J=2,6
70E1              MDAY(I,8)=MDAY(I,8)+MDAY(I,J)
71E1          90  CONTINUE
72E1      100  CONTINUE
73E1 C
74E1 C      FIND COLUMN TOTALS
75E1 C
76E1      DO 120 J=1,8
77E1          DO 110 I=1,9
78E1              MDAY(10,J)=MDAY(10,J)+MDAY(I,J)
79E1          110  CONTINUE
80E1      120  CONTINUE
81E1 C
82E1 C      ZERO OUT PERCENT MATRIX
83E1 C
84E1      DO 140 I=1,10
85E1          DO 130 J=1,8
86E1              PER(I,J)=0.0
87E1          130  CONTINUE
88E1      140  CONTINUE
89E1 C
90E1 C      CALCULATE PERCENTAGE MATRIX
91E1 C
92E1      DO 160 I=1,10
93E1          DO 150 J=1,8
94E1              IF (MDAY(10,8).NE.0) PER(I,J)=FLOAT(MDAY(I,J))/
95E1      *   MDAY(10,8)*100.
96E1          150  CONTINUE
97E1      160  CONTINUE
98E1      DO 180 I=1,9
99E1          WRITE(6,170)(I-1),(MDAY(I,J),J=1,8),(PER(I,J),J=2,6),
100E1      *   PER(I,8)
101E1          170  FORMAT('0',3X,I1,5X,8I7/' ',5X,'%',10X,5F7.2,4X,F7.2)
102E1      180  CONTINUE
103E1          WRITE(6,190)(MDAY(10,J),J=1,8),(PER(I,J),J=2,6),PER(I,8)
104E1          190  FORMAT('0',1X,'TOTALS',2X,8I7/' ',5X,'%',10X,5F7.2,8X,F7.2)
105E1      195  CONTINUE
106E1      200  CONTINUE
107E1      STOP
108E1      END
FILE CONTAINS 108 RECORDS
CORDS PROCESSED

```

WINDANAL

```

1E1 $RESET FREE
2E1 FILE 6(KIND=REMOTE)
3E1 FILE 7(KIND=DISK,FILETYPE=7,TITLE='SPT/WIND')
4E1     DIMENSION MDAY(10,8,366),MMON(10,8,12),NCODE(22),NOIR(22),NBLK(22)
5E1     * ,PER(10,8)
6E1     DO 30 I=1,10
7E1       DO 20 J=1,8
8E1         DO 10 K=1,366
9E1           MDAY(I,J,K)=0
10E1          IF (K.GT.12) GO TO 10
11E1          MMON(I,J,K)=0
12E1    10   CONTINUE
13E1    20   CONTINUE
14E1    30   CONTINUE
15E1 C
16E1 C   BEGINNING OF ACCUMULATION LOOP
17E1 C
18E1    40 READ(7,50,END=70)MON,IDAY,IYR,(NCODE(I),NOIR(I),I=1,22),NBLK
19E1    50 FORMAT(3I2,22(I1,I2),T7,22(A1,2X))
20E1 C
21E1 C   DETERMINE DAY MATRIX NUMBER
22E1 C
23E1    CALL DAYS(MON, IDAY, IYR, JD)
24E1    IF (JD.LT.1.OR.JD.GT.366) GO TO 40
25E1 C
26E1 C   UPDATE STORAGE MATRIX
27E1 C
28E1    DO 60 L=1,22
29E1      IF (NBLK(L).EQ.0) GO TO 40
30E1      NCODE(L)=NCODE(L)+1
31E1      IF (NCODE(L).GT.8) GO TO 60
32E1      J=0
33E1      IF (NOIR(L).EQ.0) J=1
34E1      IF (NOIR(L).GE.1.AND.NOIR(L).LE.17) J=2
35E1      IF (NOIR(L).GE.18.AND.NOIR(L).LE.26) J=3
36E1      IF (NOIR(L).GE.27.AND.NOIR(L).LE.35) J=4
37E1      IF (NOIR(L).GE.36.AND.NOIR(L).LE.44) J=5
38E1      IF (NOIR(L).GE.45.AND.NOIR(L).LE.53) J=6
39E1      IF (NOIR(L).GE.54) J=7
40E1      IF (J.EQ.0) GO TO 60
41E1      MDAY(NCODE(L),J, IDAY)=MDAY(NCODE(L),J, IDAY)+1
42E1      MMON(NCODE(L),J,MON)=MMON(NCODE(L),J,MON)+1
43E1    60 CONTINUE
44E1 C
45E1 C   BUILD A PRINTING LOOP -- FIRST FOR INDIVIDUAL DAYS
46E1 C
47E1    70 DO 200 K=1,1
48E1      WRITE(6,80)K
49E1      90  FORMAT('1',///)'0', 'DAY ---',I4)
50E1      *PIT(6,95)
51E1      95  FORMAT(///)'0', 'DIRECTION'/' ' ,T3, 'CODE',T15, '0',T21, '1-17',T26,
52E1      * '18-26',T34, '27-35',T41, '36-44',T48, '45-53',T56, '54+',T63,
53E1      * 'TOTAL'/' )
54E1 C
55E1 C   FIND ROW TOTALS
56E1 C
57E1    DO 100 I=1,8
58E1      DO 90 J=2,6
59E1        MDAY(I,9,K)=MDAY(I,8,K)+MDAY(I,J,K)
60E1    90   CONTINUE
61E1    100  CONTINUE
62E1 C
63E1 C   FIND COLUMN TOTALS
64E1 C
65E1    DO 120 J=1,9
66E1      DO 110 I=1,9

```

```

67E1          MDAY(10,J,K)=MDAY(10,J,K)+MDAY(I,J,K)
68E1  110      CONTINUE
-----
69E1  120      CONTINUE
70E1  C
71E1  C          ZERO OUT PERCENT MATRIX
72E1  C
73E1          DO 140 I=1,10
74E1          DO 130 J=1,8
-----
75E1          PER(I,J)=0.0
76E1  130      CONTINUE
77E1  140      CONTINUE
-----
79E1  C
79E1  C          CALCULATE PERCENTAGE MATRIX
80E1  C
81E1          DO 160 I=1,10
82E1          DO 150 J=1,8
-----
83E1          IF (MDAY(10,8,K).NE.0)PER(I,J)=FLOAT(MDAY(I,J,K))/
84E1          *      MDAY(10,8,K)*100.
85E1  150      CONTINUE
86E1  160      CONTINUE
-----
87E1          DO 180 I=1,9
88E1          WRITE(6,170)(I-1),(MDAY(I,J,K),J=1,8),(PER(I,J),J=2,6),
89E1          *      PER(I,8)
90E1  170      FORMAT('0',3X,I1,5X,8I7/' ',5X,'%',10X,5F7.2,8X,F7.2)
91E1  180      CONTINUE
92E1          WRITE(6,190)(MDAY(10,J,K),J=1,8),(PER(I,J),J=2,6),PER(I,8)
93E1  190      FORMAT('0',1X,'TOTALS',2X,8I7/' ',5X,'%',10X,5F7.2,8X,F7.2)
94E1  200      CONTINUE
95E1          STOP
-----
96E1  C
97E1  C          BUILD PRINT LOOP FOR MONTHS
98E1  C
99E1          DO 320 K=1,12
100E1         WRITE(6,210)K
101E1  210      FORMAT('1',////'0', 'MONTH ---',I4)
102E1         WRITE(6,85)
103E1  C
104E1  C          FIND ROW TOTALS
105E1  C
106E1          DO 230 I=1,8
107E1          DO 220 J=2,6
-----
108E1          MMON(I,8,K)=MMON(I,8,K)+MMON(I,J,K)
109E1  220      CONTINUE
110E1  230      CONTINUE
-----
111E1  C
112E1  C          FIND COLUMN TOTALS

```

```

113E1 C
114E1      DO 250 J=1,8
115E1      DO 240 I=1,9
116E1      MMON(I,8,K)=MMON(I,8,K)+MMON(I,J,K)
117E1      240 CONTINUE
118E1      250 CONTINUE
119E1 C
120E1 C      ZERO OUT PERCENT MATRIX
121E1 C
122E1      DO 270 J=1,10
123E1      DO 260 J=1,8
124E1      PER(I,J)=0.0
125E1      260 CONTINUE
126E1      270 CONTINUE
127E1 C
128E1 C      CALCULATE PERCENTAGE MATRIX
129E1 C
130E1      DO 290 I=1,10
131E1      DO 280 J=1,8
132E1      IF (MMON(10,8,K).NE.0) PER(I,J)=FLOAT(MMON(I,J,K))/
133E1      MMON(10,8,K)*100.
134E1      280 CONTINUE
135E1      290 CONTINUE
136E1      DO 310 I=1,9
137E1      WRITE(6,170)(I-1,(MMON(I,J,K),J=1,8),(PER(I,J),J=2,6),
138E1      PER(I,8))
139E1      310 CONTINUE
140E1      WRITE(6,190)(MMON(10,J,K),J=1,8),(PER(I,6),J=2,6),PER(I,8)
141E1      320 CONTINUE
142E1      STOP
143E1      END
144E1 C
145E1 C -----
146E1 C
147E1      SUBROUTINE DAYS(MON,IDAY,IYR,JD)
148E1      DIMENSION IDMON(12)
149E1      DATA IDMON/31,28,31,30,31,30,31,31,30,31,30,31/
150E1      JD=0
151E1      IF (MON.NE.1) GO TO 10
152E1      JD=IDAY
153E1      RETURN
154E1 C
155E1 C      CHECK FOR FEBRUARY
156E1 C
157E1      10 IF (MON.GT.2) GO TO 20
158E1      JD=31+MON
159E1      RETURN
160E1 C
161E1 C      CHECK FOR LEAP YEAR
162E1 C
163E1      20 LEAP=IYR/4
164E1      LEAP=LEAP*4
165E1      IF (LEAP.NE.IYR) GO TO 30
166E1      JD=JD+1
167E1      30 DO 40 I=1,(MON-1)
168E1      JD=JD+IDMON(I)
169E1      40 CONTINUE
170E1      JD=JD+IDAY
171E1      RETURN
172E1      END
- FILE CONTAINS 172 RECORDS
RECORDS PROCESSED

```

WEIBULL/DISTRIBUTION

FILE ATTRIBUTES FOR: FIN TITLE=(10494)WEIBULL/DISTRIBUTION ON ACAD KIND=PACK
 MINRECSIZE=0 MAXRECSIZE=14 BLOCKSIZE=420 FRAME SIZE=48 FILEUSE=16 BUFFERS=2
 AREAS=1 AREALENGTH=15120 FLEXIBLE LASTRECORD=126 FILE*IND=FORTRAN SYMBOL ROW
 CREATION DATE=12/19/85(85353) LAST ACCESS DATE=12/19/85(85353) CYCLE=1 VERSION=0
 PACNAME=ACAD

```

1E1 XRESET FREE
2E1 FILE 5(KIND=DISK, FILETYPE=7, TITLE='WEIBULL/SPT')
3E1 FILE 6(KIND=PRINTER)
4E1 C
5E1 C PROGRAM TO CALCULATE WEIBULL PARAMETERS AND POWER
6E1 C
7E1 DIMENSION A(14,8), B(13,9), X(2,22), C(9), CC(13), CC(13), R2(13),
8E1 * P(13), OMO(14)
9E1 10 FORMAT (22A3)
10E1 11 FORMAT (F3,0,11X,3F6.2)
11E1 12 FORMAT (9F6.2)
12E1 N=1
13E1 15 READ (5,10,END=80)((X(I,J),J=1,22),I=1,2)
14E1 READ(5,12)(C(I),I=1,9)
15E1 L=C(9)
16E1 I=1
17E1 20 READ(5,11)OMO(I),(A(I,J),J=1,L)
18E1 IF (OMO(I).EQ.0..OR.OMO(I).EQ.99.) GO TO 21
19E1 I=I+1
20E1 GO TO 20
21E1 21 K=I-1
22E1 C
23E1 C DATA FOR XI
24E1 C
25E1 I=1
26E1 DO 18 J=1,8
27E1 IF (C(J).EQ.0.) GO TO 18
28E1 C(I)=ALOG(C(J))
29E1 I=I+1
30E1 18 CONTINUE
31E1 C
32E1 C DATA FOR YEAR 1
33E1 C
34E1 DO 22 I=1,K
35E1 B(I,9)=0.
36E1 DO 22 J=1,L
37E1 22 B(I,9)=B(I,9)+A(I,J)
38E1 C
39E1 C SUM OF FREQUENCIES
40E1 C
41E1 DO 31 I=1,K
42E1 C
43E1 C IF (C(10).EQ.0.0) GO TO 25
44E1 C SUM=0.
45E1 C SUM=A(I,1)+A(I,2)+A(I,3)+A(I,4)+A(I,5)+A(I,6)+A(I,7)+A(I,8)
46E1 C IF (SUM.EQ.100.00) GO TO 25
47E1 S=100.-B(I,9)
48E1 B(I,9)=B(I,9)+S
49E1 A(I,1)=A(I,1)+S
50E1 C

```

```

51E1 C      DATA FOR Y1 AND N1
52E1 C
53E1      25 DO 30 J=1,L
54E1          B(I,J)=A(I,J)/(B(I,9)+.001)
55E1          A(I,1)=B(I,1)
56E1          IF (J.GT.1)A(I,J)=B(I,J)+A(I,J-1)
57E1      30 CONTINUE
58E1          B(I,9)=A(I,L)
59E1          DO 31 J=1,L
60E1          IF (A(I,J).EQ.0.0) A(I,J)=.001
61E1      31 A(I,J)=ALOG(ABS(ALOG(1.-A(I,J))))
62E1          PTOT=0.
63E1 C
64E1 C      REGRESSION
65E1 C
66E1      DO 40 I=1,M
67E1          SNX2=0.
68E1          SNX=0.
69E1          SNY=0.
70E1          SNY2=0.
71E1          SNXY=0.
72E1          DO 39 J=1,L
73E1              SNY=SNY+A(I,J)*B(I,J)
74E1              SNY2=SNY2+A(I,J)*A(I,J)+B(I,J)
75E1              SNX=SNX+C(J)*B(I,J)
76E1              SNX2=SNX2+C(J)*C(J)+B(I,J)
77E1      39 SNXY=SNXY+A(I,J)*B(I,J)+C(J)
78E1              SNXY=SNXY-SNX*SNY/B(I,9)
79E1              SNX2=SNX2-SNX*SNX/B(I,9)
80E1              SNY2=SNY2-SNY*SNY/B(I,9)
81E1              CK(I)=SNXY/SNX2
82E1              AA=(SNY-CK(I)*SNX)/B(I,9)
83E1              CC(I)=EXP(-AA/CK(I))
84E1              R2(I)=SNXY+SNXY/(SNY2 +SNX2)
85E1 C
86E1 C      CALCULATE POWER
87E1 C
88E1          V=B.
89E1          PP=0.
90E1          DO 50 M=1,12
91E1              DT=EXP(-(V/CC(I))+CK(I))-EXP(-((V+1.)/CC(I))+CK(I))
92E1              PP=PP+DT*(V+.5)*.3
93E1      50 V=V+1.
94E1          P(I)=PP
95E1          IF (I.EQ.13) GO TO 40
96E1          PTOT=PTOT+P(I)
97E1      40 CONTINUE
98E1 C
99E1 C      OUTPUT

```

```

1005I C
101E1 61 FORMAT(3X,F3.0,3F10.2,1F12.0,2F12.1)
102E1 62 FORMAT(1X,'MONTH',3X,'WEIRULLPARAMETERS',1X,'COEFFICIENT',1X,
103E1 * 'WIND ENERGY',3X,'PERCENT',5X,'CUMULATIVE')
104E1 63 FORMAT(12X,'C(M/S)',4X,'K',5X,'DETERMINATION (M/S)**3 ',2X,'OF ANN
105E1 *UAL',5X,'PERCENT')
106E1 64 FORMAT(1X,22A3)
107E1 65 FORMAT(1H1,22A3)
108E1 GO TO (67,68,69),N
109E1 67 PRINT 65,(X(1,J),J=1,22)
110E1 GO TO 69
111E1 68 PRINT 64,(X(1,J),J=1,22)
112E1 69 PRINT 64,(X(2,J),J=3,22)
113E1 N=N+1
114E1 IF (N.GT. 3) N=1
115E1 PRINT 62
116E1 PRINT 63
117E1 PP1=J.
118E1 DO 70 I=1,N
119E1 PP=100.*P(I)/PTOT
120E1 PP1=PP1+PP
121E1 IF (I.EQ.13) PP=10J.
122E1 70 PRINT 61,DMC(I),CC(I),K(I),R2(I),P(I),PP,PP1
123E1 PRINT 64
124E1 IF (DMC(K+1).EQ.0.) GO TO 15
125E1 PRINT 65
126E1 80 STOP
127E1 END
FILE CONTAINS 127 RECORDS
ECC405 PROCESSED

```

WEIBULL/SPT

FILE ATTRIBUTES FOR: FIN TITLE=(10494)WEIBULL/SPT ON ACAD KIND=PACK INTMODE=
 MAXRECSIZE=14 BLOCKSIZE=420 FRAMESIZE=48 FILEUSE=10 BUFFERS=2 TRANSLATE=FU
 AREALENGTH=15120 FLEXIBLE LASTRECORD=16 FILEKIND=DATA ROWSINUSE=1 USERINFC
 LASTACCESSDATE=12/19/85(85353) CYCLE=1 VERSION=0 SAVEFACTOR=30 SECURITYTYPE

1E1 STEVENS POINT, WI								
2E1 MONTH	MPH	1-3	4-12	13-24	25-31	32-46		
3E1	1.56	5.59	10.95	14.08	20.79			5.00 1.00
4E1	1		8.7	68.1	21.3	1.3	0.6	
5E1	2		7.6	65.4	25.5	1.3	0.2	
6E1	3		5.2	61.1	30.7	2.8	0.2	
7E1	4		4.0	55.5	37.8	2.5	0.2	
8E1	5		4.5	61.6	32.7	0.9	0.3	
9E1	6		6.4	68.9	23.7	0.9	0.1	
10E1	7		8.0	75.3	16.0	0.2	0.0	
11E1	8		9.0	75.3	15.0	0.2	0.0	
12E1	9		8.4	69.4	21.7	0.4	0.1	
13E1	10		6.1	67.3	26.1	0.5	0.0	
14E1	11		5.8	64.7	27.7	1.7	0.1	
15E1	12		7.6	70.1	21.5	0.8	0.0	
16E1	13		6.7	66.7	25.3	1.2	0.1	
17E1								

EOF - FILE CONTAINS 17 RECORDS
 17 RECORDS PROCESSED

WIND EROSION FORCES

1 *JOB ,P=200, TIME=(1,20) *Applied Weather Research*
00001000 C PROGRAM FOR ASSESSING WIND EROSION FORCES *6-11-68*
00002000 C DEFINITION:
00003000 C (1) U(I) IS THE MEAN WINDSPEED WITHIN THE ITH GOUP
00004000 C (2) F(I,J) IS A DURATION FACTOR WHICH IS EXPRESSED AS THE PERCENTAGE
00005000 C OF THE TOTAL OBSERVATIONS THAT OCCUR IN THE JTH DIRECTION WITHI
N 00006000 C THE ITH SPEED GROUP
00007000 C (3) TOTAL IS THE TOTAL NUMBER OF OBSERVATIONS
00008000 C (4) A1(I,J) IS THE NUMBER OF OBSERVATIONS IN THE J TH DIRECTION WITH
IN 00009000 C THE ITH SPEED GROUP
00010000 C (5) R(J) THE MAGNITUDE OF A WIND EROSION FORCE IN THE JTH DIRECTION
00011000 C (6) SUM IS THE SUM OF MAGNITUDE OF WIND EROSION FORCES
00012000 C (7) DELTR1 IS THE ANGLE OF ORIENTATION FOR OBTAINING THE MAXIMUM
00013000 C PREPONDERANCE-PREVAILING WIND EROSION DIRECTION
00014000 C (8) CMAX IS THE MAXIMUM PREPONDERANCE
00015000 C (9) FPP IS THE POSITIVE PARALELL FORCE
00016000 C (10) FPN IS THE NEGATIVE PARALELL FORCE
00017000 C (11) M IS THE NUMBER OF DATA GROUPS
00018000 C (12) N IS THE NUMBER OF WIND SPEED GROUPS
00019000 C (13) CARD(I) GIVES ADDRESS DATA AND LOCATION OF DATA SOURCE
00020000 C (14) JJ INDICATES DATA TYPE (SEE CARD SETUP)
00021000 C (15) TOTAL IS THE TOTAL NUMBER OF OBSERVATIONS (SEE CARD SETUP)
00022000 C
00023000 C*****THE VALUE OF N SHOULD BE SUBSTITUTED FOR THE NUMBER OF
00024000 C INTEGER CONSTANTS TO BE TRANSMITTED IN FORMAT STATEMENT
00025000 C NUMBERS 301 AND 200. *****
00026000 C
00027000 C*****IF DATA IS LISTED AS .0 THEN ENTER .05 *****
**00028000 C
00029000 C
CC

```

C 00030000
C
C 00031000
C
C 00032000
C (1) THE FIRST CARD: ONE INTEGER M INDICATES THE NUMBER OF DATA
00033000
C GROUPS WHICH WE USE. (FORMAT I3) E.G. SALINA JAN, FEB, & MAR-
00034000
C 3 DATA GROUPS. 1 M CARD PER RUN.
00035000
C
C 00036000
C (2) THE FIRST CARD OF EACH DATA GROUP: ONE INTEGER N INDICATES THE
00037000
C NUMBER OF WIND SPEED GROUPS IN THIS DATA GROUP. (FORMAT I2).
00038000
C
C 00039000
C (3) THE 2ND CARD OF EACH DATA GROUP: IS THE ADDRESS CARD - LOCATION
00040000
C DATE AND RECORD.
00041000
C
C 00042000
C (4) THE 3RD CARD READ JJ, TOTAL IS TYPE OF DATA (FORMAT I3,F6.1)
00043000
C HOW DATA APPEARS WHEN:
00044000
C JJ = 10 DATA IN DECIMAL FORM. EXAMPLE TAMPA FL 42-51
00045000
C TOTAL = 0 PUNCHED IN CARDS WITHOUT DECIMAL.
00046000
C JJ = 20 TOTAL .NE. 0 DODGE DITY DATA IS EXAMPLE.
00047000
C DATA APPEARS AS NUMBER OF OBSERVATIONS.
00048000
C JJ = 30 DATA IN PERCENT WITH DECIMAL FORMAT.
00049000
C TAMPA FL 42-72 AND SALINA KS. NO TOTAL ENTRY
00050000
C
C 00051000
C (5) THE 4TH CARD IS FIRST DATA CARD: TOTAL OF 16 DATA CARDS. ONE
00052000
C FOR EACH CARDINAL DIRECTION. (FORMAT NF5.2).
00053000
C
C 00054000
C (6) AFTER THE 16 DATA CARDS HAVE A CARD THAT HAS THE MEAN WINDSPEED
00055000
C IN MPH FOR EACH OF THE WINDSPEED GROUPS (FORMAT NF6.3).
00056000
C
C 00057000
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
CC00058000
C DECLARARION:
00059000
1 REAL F(14,16),U(14),UF(360),DF(360),R(16),
00060000
1 1DR(360),AT,ACO,ASI,SUM,CR(360),DELTR1,
00061000
2CMAX,D1,U1,U2,AT1,CO1,ACO1,FPP,FPN,
00062000
3DDR,CAT,ACAT,SAT,ASAT,TOTAL

```

```

00063000
  2      INTEGER F1(15,16),A1(14,16),CARD(15)
00064000
C I/O FORMAT SEQUENCE
00065000
  3      30 FORMAT(I3)
00066000
  4      10 FORMAT(15A4)
00067000
  5      20 FORMAT(1X,15A4////)
00068000
  6      40 FORMAT(I3,F6.1)
00069000
  7      50 FORMAT(3I5)
00070000
  8      100 FORMAT(I2)
00071000
  9      111 FORMAT(1H1)
00072000
 10      112 FORMAT(' ','DF(',I3,') IS LESS THAN OF EQUAL TO 0.0 .')
00073000
 11      200 FORMAT(5F5.2)
00074000
 12      300 FORMAT(4I5)
00075000
 13      301 FORMAT(5F5.2)
00076000
 14      400 FORMAT(1X,'J=1:N J=2:NE J=3:E J=4:SE J=5:S'/1X,
00077000
        1'J=6:SW J=7:W J=8:NW '/')
00078000
 15      500 FORMAT(1X,'MAGNITUDE OF WIND EROSION FORCES'/1X,
00079000
        1'FROM J=1 TO J=8'//)
00080000
 16      600 FORMAT(1X,'R(',I2,')= ',F10.3)
00081000
 17      700 FORMAT(1X,'SUM OF MAGNITUDE OF ALL WIND EROSION FORCES=',F11.3//
/)00082000
 18      800 FORMAT(1X,'ANGLE OF ORIENTATION = ',F5.1/1X,
00083000
        1'THE PREPONDERANCE R= ',F5.2/1X,
00084000
        2'POSITIVE PARALELL FORCE= ',F6.3/1X,
00085000
        3'NEGATIVE PARALELL FORCE= ',F6.3/////))
00086000
 19      900 FORMAT(1X,'OBTAINING THE MAXIMUM PREPONDERANCE')
00087000
C READ IN THE DATA AND DO SOME PROPER TRANSFORMATION:
00088000
 20      READ(5,30) M
00089000
 21      DO 10000 KKK=1,M
00090000
 22      READ(5,100) N
00091000
 23      102 READ(5,10) (CARD(I),I=1,15)
00092000
 24      READ(5,40) JJ, TOTAL
00093000
 25      IF(TOTAL.EQ.0.0) GO TO 101
00094000
 26      READ(5,50) ((A1(I,J),I=1,N),J=1,8)
00095000
 27      DD 1980 I=1,N
00096000

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```

28          DO 1980 J=1,8
00097000
29          1980 F(I,J)=A1(I,J)*100.0/TOTAL
00098000
30          101 IF(JJ.EQ.30) GO TO 70
00099000
31          IF(JJ.EQ.20) GO TO 60
00100000
32          READ(5,300)((F1(I,J),I=1,N),J=1,8)
00101000
33          DO 1977 I=1,N
00102000
34          DO 1977 J=1,8
00103000
35          1977 F(I,J)=F1(I,J)/100.0
00104000
36          GO TO 60
00105000
37          70 READ(5,301)((F(I,J),I=1,N),J=1,8)
00106000
38          60 READ(5,200)(U(I),I=1,N)
00107000
C CALCULATE THE WIND EROSION FOECES AND THEIR SUM
00108000
39          SUM=0.0
00109000
40          DO 1 J=1,8
00110000
41          R(J)=0.0
00111000
42          DO 2 I=1,N
00112000
43          2 R(J)=R(J)+((U(I)/10.0)**3)*F(I,J)
00113000
44          SUM=SUM+R(J)
00114000
45          1 CONTINUE
00115000
C CALCULATE THE PREPONDERANCE:
00116000
46          DDR=ARSIN(1.0)/90.0
00117000
47          DO 3 K=1,360
00118000
48          UF(K)=0.
00119000
49          DF(K)=0.
00120000
1 50          DR(K)=DDR*(K-1)
00121000
51          DO 4 J=1,8
00122000
52          J1=J-1
00123000
53          AT=(J1*45.*DDR)-DR(K)
00124000
54          CAT=COS(AT)
00125000
55          ACAT=ABS(CAT)
00126000
56          SAT=SIN(AT)
00127000
57          ASAT=ABS(SAT)
00128000
58          ACO=ACAT*R(J)
00129000
59          ASI=ASAT*R(J)
00130000
60          UF(K)=UF(K)+ACO

```

```

00131000
  61      DF(K)=DF(K)+ASI
00132000
  62      4 CONTINUE
00133000
  63      IF (DF(K).EQ. 0.0)
00134000
    1WRITE(6,112) K
00135000
  64      IF (DF(K).EQ. 0.0)
00136000
    160 TO 3
00137000
  65      CR(K)=UF(K)/DF(K)
00138000
  66      3 CONTINUE
00139000
C FIND THE ANGLE OF ORIENTATION, POSITIVE PARALELL FORCE AND NEGATIVE
00140000
C PARALELL FORCE FOR OBTAINING THE MAXIMUM PREPONDERANCE:
00141000
  67      CMAX=CR(1)
00142000
  68      DELTR1=DR(1)
00143000
  69      DO 6 K=1,360
00144000
  70      IF(CR(K).LT.CMAX) GO TO 6
00145000
  71      CMAX=CR(K)
00146000
  72      DELTR1=DR(K)
00147000
  73      6 CONTINUE
00148000
  74      U1=0.
00149000
  75      U2=0.
00150000
  76      D1=0.
00151000
  77      DO 7 J=1,8
00152000
  78      J1=J-1
00153000
  79      AT1=J1*45.*DDR-DELTR1
00154000
  80      CO1=R(J)*COS(AT1)
00155000
  81      ACO1=ABS(CO1)
00156000
  82      D1=D1+ACO1
00157000
  83      IF(CO1.GE.0.) GO TO 11
00158000
  84      U2=U2+CO1
00159000
  85      GO TO 7
00160000
  86      11 U1=U1+CO1
00161000
  87      7 CONTINUE
00162000

```

```

      88          FPP=U1/D1
00163000
      89          FPN=U2/D1
00164000
      90          FPNA=ABS(FPN)
00165000
      91          FPPA=FPP
00166000
      92          DELTR1=DELTR1/DDR
00167000
      93          IF(FPNA.LE.FPPA) GO TO 1978
00168000
      94          FPP=FPNA
00169000
      95          FPN=-FPPA
00170000
      96          DELTR1=DELTR1-180.0
00171000
      97          IF(DELTR1.GE.0.) GO TO 1978
00172000
      98          DELTR1 = DELTR1 + 360
00173000
      C PRINT OUT THE RESULTS:
00174000
      99          1978 WRITE(6,111)
00175000
      100         WRITE(6,20) (CARD(I),I=1,15)
00176000
      101         WRITE(6,400)
00177000
      102         WRITE(6,500)
00178000
      103         WRITE(6,600) (J,R(J),J=1,8)
00179000
      104         WRITE(6,700) SUM
00180000
1  105         WRITE(6,900)
00181000
      106         WRITE(6,800) DELTR1,CMAX,FPP,FPN
00182000
      107         10000 CONTINUE
00183000
      108         WRITE(6,111)
00184000
      109         STOP
00185000
      110         END
00186000
0  $ENTRY
00187000
1  STEVENS POINT,WI JAN

```

```

J=1:N J=2:NE J=3:E J=4:SE J=5:S
J=6:SW J=7:W J=8:NW

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MAGNITUDE OF WIND EROSION FORCES
FROM J=1 TO J=8

```

R(1)= 136.056
 R(2)= 81.117
 R(3)= 239.952
 R(4)= 43.226
 R(5)= 112.857
 R(6)= 65.609
 R(7)= 905.786
 R(8)= 54.305
 SUM OF MAGNITUDE OF ALL WIND EROSION FORCES= 1638.907

OBTAINING THE MAXIMUM PREPONDERANCE
 ANGLE OF ORIENTATION = 270.0
 THE PREPONDERANCE R= 3.13
 POSITIVE PARALELL FORCE= 0.751
 NEGATIVE PARALELL FORCE= -0.249

1
 STEVENS POINT, WI FEB

J=1:N J=2:NE J=3:E J=4:SE J=5:S
 J=6:SW J=7:W J=8:NW

MAGNITUDE OF WIND EROSION FORCES
 FROM J=1 TO J=8

R(1)= 106.445
 R(2)= 175.656
 R(3)= 335.376
 R(4)= 24.490
 R(5)= 90.508
 R(6)= 47.916
 R(7)= 406.014
 R(8)= 84.323
 SUM OF MAGNITUDE OF ALL WIND EROSION FORCES= 1270.727

OBTAINING THE MAXIMUM PREPONDERANCE
 ANGLE OF ORIENTATION = 270.0
 THE PREPONDERANCE R= 2.26
 POSITIVE PARALELL FORCE= 0.512
 NEGATIVE PARALELL FORCE= -0.488

1
 STEVENS POINT, WI MAR

J=1:N J=2:NE J=3:E J=4:SE J=5:S
 J=6:SW J=7:W J=8:NW

MAGNITUDE OF WIND EROSION FORCES
 FROM J=1 TO J=8

R(1)= 294.566
 R(2)= 141.006
 R(3)= 285.772
 R(4)= 17.037

R(5) = 86.464
 R(6) = 85.161
 R(7) = 311.282
 R(8) = 88.582
 SUM OF MAGNITUDE OF ALL WIND EROSION FORCES = 1309.867

OBTAINING THE MAXIMUM PREPONDERANCE
 ANGLE OF ORIENTATION = 270.0
 THE PREPONDERANCE R = 1.35
 POSITIVE PARALELL FORCE = 0.522
 NEGATIVE PARALELL FORCE = -0.478

1
 STEVENS POINT, WI APR

J=1:N J=2:NE J=3:E J=4:SE J=5:S
 J=6:SW J=7:W J=8:NW

MAGNITUDE OF WIND EROSION FORCES
 FROM J=1 TO J=8

R(1) = 143.952
 R(2) = 122.224
 R(3) = 256.809
 R(4) = 48.981
 R(5) = 77.730
 R(6) = 52.175
 R(7) = 366.878
 R(8) = 89.443
 SUM OF MAGNITUDE OF ALL WIND EROSION FORCES = 1158.192

OBTAINING THE MAXIMUM PREPONDERANCE
 ANGLE OF ORIENTATION = 270.0
 THE PREPONDERANCE R = 1.91
 POSITIVE PARALELL FORCE = 0.553
 NEGATIVE PARALELL FORCE = -0.447

1
 STEVENS POINT, WI MAY

J=1:N J=2:NE J=3:E J=4:SE J=5:S
 J=6:SW J=7:W J=8:NW

MAGNITUDE OF WIND EROSION FORCES
 FROM J=1 TO J=8

R(1)= 81.774
 R(2)= 80.279
 R(3)= 236.170
 R(4)= 62.608
 R(5)= 279.427
 R(6)= 99.015
 R(7)= 394.617
 R(8)= 67.082
 SUM OF MAGNITUDE OF ALL WIND EROSION FORCES= 1300.972

OBTAINING THE MAXIMUM PREPONDERANCE
 ANGLE OF ORIENTATION = 270.0
 THE PREPONDERANCE R= 1.47
 POSITIVE PARALELL FORCE= 0.603
 NEGATIVE PARALELL FORCE= -0.397

1
 STEVENS POINT, WI JUN

J=1:N J=2:NE J=3:E J=4:SE J=5:S
 J=6:SW J=7:W J=8:NW

MAGNITUDE OF WIND EROSION FORCES
 FROM J=1 TO J=8

R(1)= 127.776
 R(2)= 29.814
 R(3)= 80.925
 R(4)= 20.231
 R(5)= 302.595
 R(6)= 150.827
 R(7)= 384.561
 R(8)= 52.175
 SUM OF MAGNITUDE OF ALL WIND EROSION FORCES= 1148.904

OBTAINING THE MAXIMUM PREPONDERANCE
 ANGLE OF ORIENTATION = 225.0
 THE PREPONDERANCE R= 1.15
 POSITIVE PARALELL FORCE= 0.782
 NEGATIVE PARALELL FORCE= -0.218

1
 STEVENS POINT, WI JUL

J=1:N J=2:NE J=3:E J=4:SE J=5:S
 J=6:SW J=7:W J=8:NW

MAGNITUDE OF WIND EROSION FORCES
 FROM J=1 TO J=8

R(1)= 72.395
 R(2)= 57.499
 R(3)= 135.218
 R(4)= 62.823

$R(5) = 257.681$
 $R(6) = 140.542$
 $R(7) = 281.084$
 $R(8) = 105.415$
 SUM OF MAGNITUDE OF ALL WIND EROSION FORCES= 1112.656

OBTAINING THE MAXIMUM PREPONDERANCE
 ANGLE OF ORIENTATION = 270.0
 THE PREPONDERANCE R= 1.15
 POSITIVE PARALELL FORCE= 0.674
 NEGATIVE PARALELL FORCE= -0.326

1
 STEVENS POINT, WI AUG

$J=1:N$ $J=2:NE$ $J=3:E$ $J=4:SE$ $J=5:S$
 $J=6:SW$ $J=7:W$ $J=8:NW$

MAGNITUDE OF WIND EROSION FORCES
 FROM $J=1$ TO $J=8$

$R(1) = 91.980$
 $R(2) = 153.331$
 $R(3) = 76.666$
 $R(4) = 51.110$
 $R(5) = 262.348$
 $R(6) = 195.923$
 $R(7) = 143.090$
 $R(8) = 136.294$
 SUM OF MAGNITUDE OF ALL WIND EROSION FORCES= 1110.742

OBTAINING THE MAXIMUM PREPONDERANCE
 ANGLE OF ORIENTATION = 225.0
 THE PREPONDERANCE R= 1.27
 POSITIVE PARALELL FORCE= 0.639
 NEGATIVE PARALELL FORCE= -0.361

1
 STEVENS POINT, WI SEP

$J=1:N$ $J=2:NE$ $J=3:E$ $J=4:SE$ $J=5:S$
 $J=6:SW$ $J=7:W$ $J=8:NW$

MAGNITUDE OF WIND EROSION FORCES
 FROM $J=1$ TO $J=8$

R(1)= 61.758
 R(2)= 21.296
 R(3)= 111.804
 R(4)= 85.806
 R(5)= 372.656
 R(6)= 114.556
 R(7)= 344.709
 R(8)= 57.499
 SUM OF MAGNITUDE OF ALL WIND EROSION FORCES= 1170.085

OBTAINING THE MAXIMUM PREPONDERANCE
 ANGLE OF ORIENTATION = 270.0
 THE PREPONDERANCE R= 1.03
 POSITIVE PARALELL FORCE= 0.713
 NEGATIVE PARALELL FORCE= -0.287

1
 STEVENS POINT, WI OCT

J=1:N J=2:NE J=3:E J=4:SE J=5:S
 J=6:SW J=7:W J=8:NW

MAGNITUDE OF WIND EROSION FORCES
 FROM J=1 TO J=8

R(1)= 92.638
 R(2)= 68.147
 R(3)= 110.739
 R(4)= 83.054
 R(5)= 258.746
 R(6)= 148.074
 R(7)= 256.650
 R(8)= 94.767
 SUM OF MAGNITUDE OF ALL WIND EROSION FORCES= 1112.816

OBTAINING THE MAXIMUM PREPONDERANCE
 ANGLE OF ORIENTATION = 225.0
 THE PREPONDERANCE R= 1.06
 POSITIVE PARALELL FORCE= 0.707
 NEGATIVE PARALELL FORCE= -0.293

1
 STEVENS POINT, WI NOV

J=1:N J=2:NE J=3:E J=4:SE J=5:S
 J=6:SW J=7:W J=8:NW

MAGNITUDE OF WIND EROSION FORCES
 FROM J=1 TO J=8

R(1)= 165.009
 R(2)= 38.333
 R(3)= 107.545
 R(4)= 78.795

$R(5) = 159.924$
 $R(6) = 110.919$
 $R(7) = 445.219$
 $R(8) = 94.971$
 SUM OF MAGNITUDE OF ALL WIND EROSION FORCES= 1200.714

OBTAINING THE MAXIMUM PREPONDERANCE
 ANGLE OF ORIENTATION = 270.0
 THE PREPONDERANCE R= 1.41
 POSITIVE PARALELL FORCE= 0.756
 NEGATIVE PARALELL FORCE= -0.244

1
 STEVENS POINT, WI DEC

$J=1:N$ $J=2:NE$ $J=3:E$ $J=4:SE$ $J=5:S$
 $J=6:SW$ $J=7:W$ $J=8:NW$

MAGNITUDE OF WIND EROSION FORCES
 FROM J=1 TO J=8

$R(1) = 123.936$
 $R(2) = 64.307$
 $R(3) = 238.061$
 $R(4) = 53.659$
 $R(5) = 141.810$
 $R(6) = 151.202$
 $R(7) = 291.109$
 $R(8) = 63.888$
 SUM OF MAGNITUDE OF ALL WIND EROSION FORCES= 1127.971

OBTAINING THE MAXIMUM PREPONDERANCE
 ANGLE OF ORIENTATION = 270.0
 THE PREPONDERANCE R= 1.53
 POSITIVE PARALELL FORCE= 0.580
 NEGATIVE PARALELL FORCE= -0.420

ROLLING AVERAGE

ATTRIBUTES FOR: FIN TITLE=(10494)ROLLING AVERAGE ON ACAD KIND=PACK INTMODE=EE
 SIZE=14 BLOCKSIZE=420 FRAMESIZE=48 FILEUSE=10 BUFFERS=2 TRANSLATE=FULLTRA
 LENGTH=15120 FLEXIBLE LASTRECORD=221 FILEKIND=FORTRANSYMBOL ROWSINUSE=1 USE
 ACCESS DATE=12/19/85(85353) CYCLE=1 VERSION=0 SAVEFACTOR=30 SECURITYTYPE=CLAS

```

1E1 SRESET FREE
2E1 FILE 5(KIND=REMOTE)
3E1 FILE 6(KIND=REMOTE)
4E1 FILE 7(KIND=DISK,FILETYPE=7,TITLE='SPT/WIND');
5E1 DIMENSION NSPD(26)
6E1 COMMON NOATE(7000,3)
7E1 C
8E1 C LOAD THE TIME ARRAY WITH DATES FROM THE FILE
9E1 C
10E1 CALL INIT(NREC)
11E1 5 WRITE(6,10)
12E1 10 FORMAT('0', 'ENTER THE STARTING DATE-FIRST THE MONTH(XX)')
13E1 READ(5,20)M1
14E1 20 FORMAT(I2)
15E1 WRITE(6,30)
16E1 30 FORMAT('0',24X,'-NOW THE DAY(XX)')
17E1 READ(5,20)ND1
18E1 WRITE(6,40)
19E1 40 FORMAT('0',24X,'-AND NOW THE YEAR(XXXX)')
20E1 READ(5,50)IYR1
21E1 50 FORMAT(I4)
22E1 WRITE(6,60)M1,ND1,IYR1
23E1 60 FORMAT('0', 'THE STARTING DATE IS',I3,'/',I2,'/',I4,' IS THIS OK:
24E1 * Y-N')
25E1 READ(5,70)ANS
26E1 70 FORMAT(A1)
27E1 IF (ANS.EQ.'N') GO TO 5
28E1 C
29E1 C QUERY FOR THE ENDING DATE
30E1 C
31E1 80 WRITE(6,90)
32E1 90 FORMAT('0', 'ENTER THE ENDING DATE-FIRST THE MONTH(XX)')
33E1 READ(5,20)M2
34E1 WRITE(6,100)
35E1 100 FORMAT('0',21X,'-NOW THE DAY(XX)')
36E1 READ(5,20)ND2
37E1 WRITE(6,110)
38E1 110 FORMAT('0',21X,'-AND NOW THE YEAR(XXXX)')
39E1 READ(5,50)IYR2
40E1 WRITE(6,120)M2,ND2,IYR2
41E1 120 FORMAT('0', 'THE ENDING DATE IS',I3,'/',I2,'/',I4,' IS THIS OK:Y-N')
42E1 *)
43E1 READ(5,70)ANS
44E1 IF (ANS.EQ.'N') GO TO 80
45E1 C
46E1 C QUERY FOR THE HOURLY INTERVAL TO BE USED
47E1 C
48E1 125 WRITE(6,130)
49E1 130 FORMAT('0', 'KEY THE INTERVAL TO BE USED(XX)')
50E1 READ(5,140)INT
  
```

```

51E1 140 FORMAT(I2)
52E1 WRITE(6,150)INT
53E1 150 FORMAT('0',' IS THE INTERVAL',I3,' O.K.2 Y=N')
54E1 READ(5,70)ANS
55E1 IF (ANS.EQ.'N') GO TO 125
56E1 C
57E1 C DETERMINE THE STARTING AND ENDING RECORD NUMBERS
58E1 C
59E1 DO 160 NFIRST=1,NREC
60E1 CALL CAL(M1,ND1,IYR1,NOATE(NFIRST,1),NOATE(NFIRST,2),
61E1 * NOATE(NFIRST,3),ICD)
62E1 IF (ICD.EQ.2) GO TO 170
63E1 160 CONTINUE
64E1 C
65E1 C NOW FOR THE ENDING RECORD NUMBER
66E1 C
67E1 170 N=NFIRST
68E1 DO 180 NLAST=N,NREC
69E1 CALL CAL(M2,ND2,IYR2,NOATE(NLAST,1),NOATE(NLAST,2),
70E1 * NOATE(NLAST,3),ICD)
71E1 IF (ICD.EQ.2)GO TO 190
72E1 180 CONTINUE
73E1 C
74E1 C USING THE GIVEN TIME INTERVAL FIND THE LARGEST VELOCITY
75E1 C
76E1 190 ALARG=0
77E1 DO 230 N=NFIRST,NLAST
78E1 READ(7=N,200)NSPD
79E1 200 FORMAT(6X,26(1X,I2))
80E1 C
81E1 DO 220 J=1,25
82E1 NSUM=0
83E1 IF ((J+INT-1).GT.26) GO TO 230
84E1 DO 210 K=J,(J+INT-1)
85E1 NSUM=NSUM+NSPD(K)
86E1 210 CONTINUE
87E1 A=FLOAT(NSUM)/INT
88E1 IF (A.LE.ALARG) GO TO 220
89E1 ALARG=A
90E1 220 CONTINUE
91E1
92E1 230 CONTINUE
93E1
94E1 WRITE(6,240)INT,ALARG
95E1
96E1 240 FORMAT('0',' THE LARGEST HOURLY AVERAGE FOR',I3,' HOURS IS',F5.1)
97E1
98E1 WRITE(6,250)
99E1
100E1 250 FORMAT('0',' DO YOU WISH TO TRY ANOTHER INTERVAL? Y=N')
101E1
102E1 READ(5,70)ANS
103E1
104E1 IF (ANS.EQ.'Y') GO TO 125
105E1
106E1 WRITE(6,260)
107E1
108E1 260 FORMAT('0',' HOW ABOUT ANOTHER TIME INTERVAL? Y=N')
109E1
110E1 READ(5,70)ANS
111E1
112E1 IF (ANS.EQ.'Y') GO TO 5
113E1
114E1 STOP

```

```

115E1
116E1      END
117E1
118E1 C
119E1
-----
120E1 C
121E1
122E1 C
123E1
124E1 /WINDY
125E1      SUBROUTINE CAL(M1,ND1,IYR1,M2,N02,IYR2,ICD)
126E1
127E1 C
128E1
129E1 C      ROUTINE TO COMPARE FIRST WITH SECCND DATE AND SET CODE VALUES
130E1
131E1 C          1=FIRST IS EARLIER THAN SECCND
132E1
133E1 C          2=FIRST IS THE SAME AS THE SECCND
134E1
135E1 C          3=FIRST IS LATER THAN SECCND
136E1
137E1 C
138E1
139E1 C      COMPARE YEARS FIRST
140E1
141E1 C
142E1
143E1          IF (IYR1-IYR2) 40,10,50
144E1
145E1 C
146E1
147E1 C      NOW COMPARE THE MONTHS WITHIN THE SAME YEAR
148E1
149E1 C
150E1
151E1      10 IF (M1-M2) 40,20,50
152E1
153E1 C
154E1
155E1 C      NOW COMPARE THE DAYS WITHIN THE SAME MONTH
156E1
157E1 C
158E1
159E1      20 IF (ND1-N02) 40,30,50
160E1
161E1      30 ICD=2
162E1
163E1          RETURN
164E1
165E1      40 ICD=3
166E1
167E1          RETURN
168E1
169E1      50 ICD=1
170E1
171E1          RETURN
172E1
173E1      END
174E1
175E1 C
176E1
-----
177E1 C

```

```

170E1
179E1 C
180E1
181E1      SUBRGUTINE INIT(NREC)
182E1
183E1      COMMON NDATE(7000,3)
184E1
185E1 C
-----
186E1
187E1 C      LOAD THE MATRIX WITH THE DATES FROM THE TAPE
188E1
-----
189E1 C
190E1
191E1      DO 20 NREC=1,7000
-----
192E1
193E1          READ(7,10,END=40)(NDATE(NREC,J),J=1,3)
-----
194E1
195E1      10  FORMAT(3I2)
196E1
197E1      20  CONTINUE
-----
198E1
199E1          WRITE(6,30)
200E1
-----
201E1      30  FORMAT('0', 'EXPAND THE PROGRAM TO HANDLE A LARGER DATA FILE')
202E1
203E1          STOP
-----
204E1
205E1      40  NREC=NREC-1
206E1
-----
207E1 C
208E1
209E1 C      ADD 1900 TO EACH YEAR
-----
210E1
211E1 C
212E1
213E1      DO 50 I=1,NREC
-----
214E1
215E1          NDATE(I,3)=NDATE(I,3)+1900
-----
216E1
217E1      50  CONTINUE
-----
218E1
219E1          RETURN
220E1
221E1          ENQ
222E1
CF - FILE CONTAINS 222 RECORDS
22 RECORDS PROCESSED

```

APPENDIX C: WIND MOVEMENT

Every wind has its weather.
-Bacon-

The wind in the west
Suits everyone best.
-Anonymous-

Do business with men when
the wind is in the northwest.
-Anonymous-

(From Koeppel and DeLong, 1958, pages 14 and 15)

The following discussion is intended to acquaint interested readers with basic climatological principles related to the source and movement of surface winds. More importantly, the latter section describes the types of winds associated with certain weather patterns. Conservationists and crop consultants should acquaint themselves with this information and then use this knowledge to watch for and forecast serious erosive winds during future critical erosion and crop-growth periods. They should then alert area farmers of necessary precautionary measures to reduce significant damage to crops and soils.

Source of Wind

Winds serve two basic climatic functions. By transporting heat from lower to higher altitudes, wind is the principal agent in maintaining the latitudinal heat balance of the earth. Second, winds also provide land masses with much of the moisture necessary for precipitation.

The general circulation of the atmosphere is the average movement of the world's winds. The basic mechanism by which this operates is the

accumulation, transfer and dissipation of heat from the sun. Simply stated, wind is the movement of air; it is initially a gravitational response to pressure differences in the atmosphere. Pressure differentials arise mainly from differences in atmospheric temperature which directly affect the density of air masses.

Only very slight differences in barometric pressure (or density) are sufficient to set the highly sensitive, fluidlike atmosphere in motion. Once in motion, the primary tendency of the atmosphere, in response to the force of gravity, is to flow down what is termed the barometric gradient. Velocity of this motion depends upon the magnitude of the pressure differences. The more marked the pressure differential, the steeper the resulting pressure gradient and the faster the expected gradient wind speed (Fig. 35) (Rumney, 1968). A difference of only 0.15 inch of mercury (5 millibars) in barometric pressure within a distance of slightly more than 17 miles (27 km) will produce a wind speed of 14.5 mph (6.6 m/s) and a 0.30 inch of mercury (10 millibars) difference over the same distance will produce a wind velocity of about 29 mph (13.2 m/s).

Wind velocity and direction are determined by mechanical means. The moment-to-moment variations from which average velocity and direction are computed are preserved if collected by self-recording instruments.

Examination of continuous records would reveal that winds are seldom really steady in either velocity or direction. Instead, they blow with a constantly shifting gustiness that is characteristic of nearly all surface winds. In addition, wind velocities also vary with height (Fig. 36). As a result, it is important to identify the reference heights of

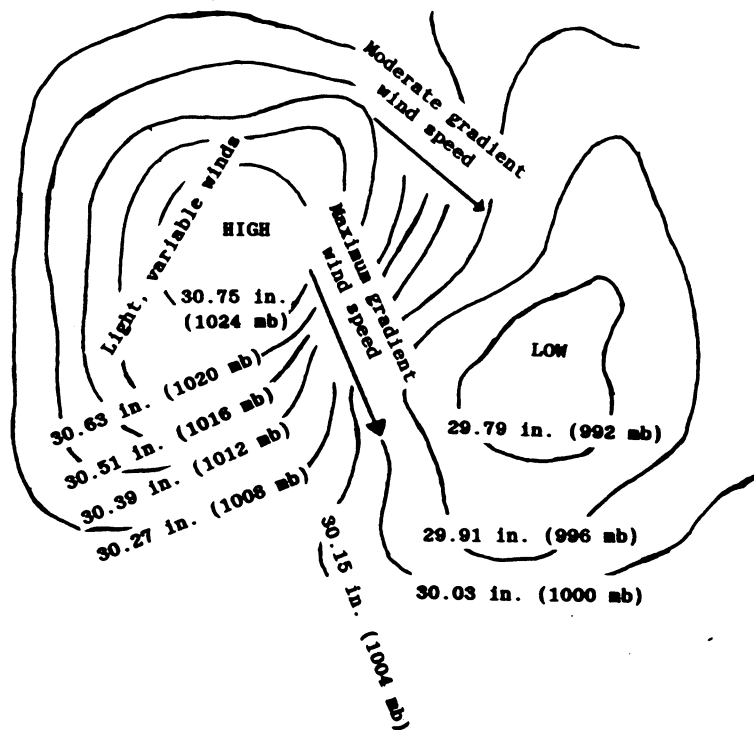


FIGURE 35: WINDSPEED DETERMINATION BY BAROMETRIC GRADIENT ANALYSIS (After Rumney, 1968)

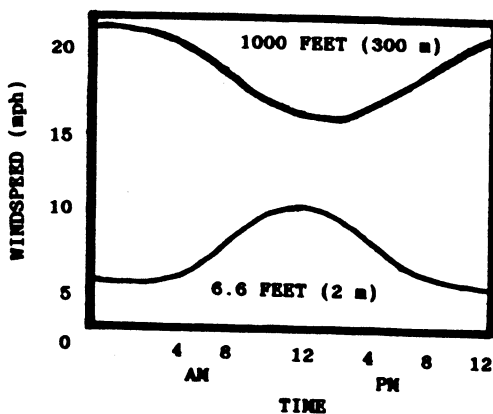


FIGURE 36: WIND VELOCITY VARIATION WITH HEIGHT (After Trewartha, 1968)

such measurements and convert them [Eq. 11] to a standard height of 33 feet (10 m) for purposes of comparison.

$$\text{Eq. [11]} \quad u_r = u_a \left(z_r / z_a \right)^{1/7}$$

where u_r is velocity at reference height (10 m) of interest, u_a is velocity at actual height of instrument, z_r is reference height (10 m) of interest, and z_a is actual height of instrument.

Wind velocity and direction are affected by the force of friction between the moving air and the earth's surface. This frictional force tends to slow the air's movement, a factor of importance regarding surface winds and the process of wind erosion (SEE Chapter 2: WIND AS A SOIL-DISPLACING MEDIUM). Friction also produces turbulence or vertical motion. An air mass itself in which the wind changes with height (Fig. 37) also has a slight amount of internal friction.

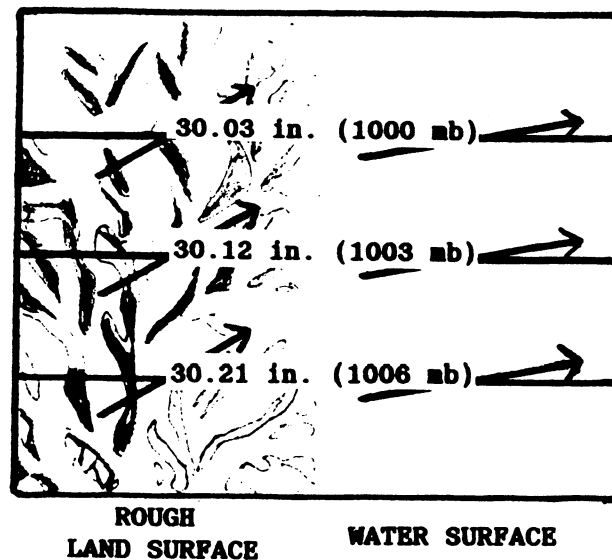


FIGURE 37: EFFECTS OF SURFACE FEATURES ON WIND DIRECTION
(After Trewartha, 1968)

The frictional effects of the land-water surface upon the air flowing over it causes the wind to not flow parallel with the isobars of barometric pressure as it does aloft. Instead, winds cross them at an oblique angle (Fig. 37). The greater the friction, the wider is the angle the wind direction varies from the isobars. Winds over irregular land surfaces usually form angles varying from 20° to 45° with the isobars (Trewartha, 1968).

Local Climatology

The purpose of this section is to draw attention to the variety of small-scale climates which exist near the earth's surface in predominantly rural areas. These "climates" often show characteristics which are in sharp contrast to the broader generalizations of so-called regional climates mainly because of the interaction of the atmosphere with the underlying surface of landscape.

The importance of surface features increases markedly as the scale of climatic reference is reduced and it is only at the very lowest levels of the atmospheric boundary layer that surface influences become strong enough to create various localized phenomena. Contraction of the horizontal as well as the vertical scale of reference may also disclose local modifications within the broadly uniform regional climate, which are obscured when a wider view is taken.

Similarly, the time-scale of atmospheric events is significant since any attempt to synthesize a macroclimate usually relies on an analysis of the steady-state conditions achieved over a period of many years and the

resulting averages "smooth out" the more intermittent local contrasts (Smith, 1975).

Although local climates are necessarily restricted in space and time, they are of great practical significance because virtually all of man's social and economic activities are conducted near the bottom of the atmospheric boundary layer. In a rural context, therefore, local climatic differences are of particular importance for agriculture and forestry.

General categories of climatic systems are presented in Table 42.

TABLE 42: Spatial Systems of Climate
(After Smith, 1975)

System	Approximate characteristic dimensions		
	Horizontal scale	Vertical scale	Time scale
Global wind belts	1250 miles (2000 km)	2-6 miles (3-10 km)	1-6 months
Regional macroclimate	310-625 miles (500-1000 km)	0.6-6 miles (1-10 km)	1-6 months
Local (topo) climate	0.6-6 miles (1-10 km)	30-315 feet (10-100 m)	1-24 hours
Microclimate	315 feet (100 m)	30 feet (10 m)	24 hours

Association and Prediction of Winds with Certain Weather Patterns

The air mass concept is of major importance to modern weather analysis and forecasting. An air mass is a large body of air whose physical properties, particularly temperature and moisture distribution, are the same at all elevations. Weather forecasting is largely recognizing various air masses, determining their characteristics and predicting their behavior.

Air masses can be classified geographically, according to their source regions, as follows: (1) arctic/antarctic (A), (2) polar (P), (3) tropical (T), or (4) equatorial (E). Geographic air masses are further divided into maritime or ocean (M) and continental or land (C). The relative warmth or coldness of an air mass is classified thermodynamically as follows: (1) warm (w), an air mass which is warmer than the underlying surface, or (2) cold (k), an air mass which is colder than the underlying surface. A continental polar cold air mass, therefore, would be designated "cPk" on a weather map. A typical winter weather sequence associated with a continental polar air mass moving over the Great Lakes is illustrated in Figure 38 (Ramsey, 1983).

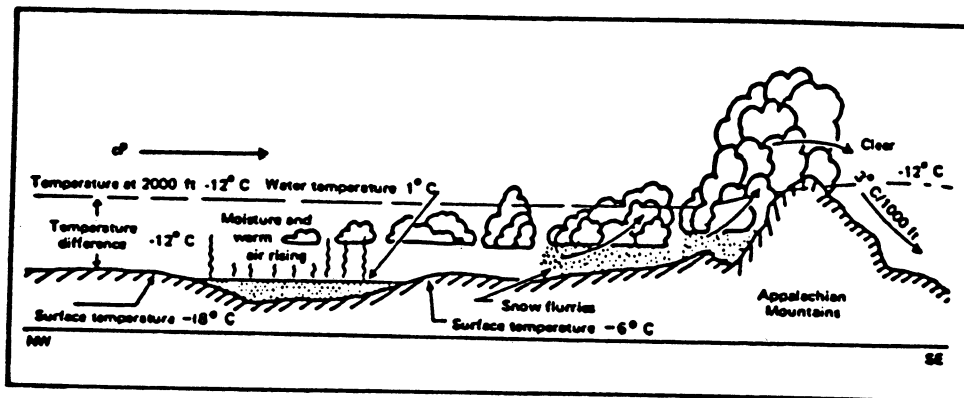


FIGURE 38: Continental Polar Air Mass Moving Over the Great Lakes.
(Courtesy Dan Ramsey, How to Forecast Weather, page 24.
© 1983 by TAB Books, Inc.: Blue Ridge Summit, PA)

A front is a boundary separating two different air masses. A frontal zone is a region of transition between two different air masses. The primary frontal zones of the Northern Hemisphere are the arctic and polar frontal zones. The most important zone affecting the United States is the polar front.

A cold air mass, being heavier or denser, tends to underrun a warm air mass. The slope of the frontal surface is usually between 1:50 (one mile vertical for 50 miles horizontal) for a cold front and 1:300 for a warm front (Fig. 39).

The slope of a front is of considerable importance in visualizing and understanding weather along the front. Certain weather conditions and characteristics are typical of cold fronts: (1) temperature and humidity decrease, (2) barometric pressure increases, and (3) winds shift (usually from southwest to northwest in Northern Hemisphere) with the passage of a cold front. Warm fronts likewise have certain weather conditions and characteristics typically associated with them. These include (1) colder temperatures ahead of the front and warmer temperatures after passage of the front, (2) average frontal slope of 1:150 (miles), and (3) wind shift from southeast to southwest or west, but the shift is not as pronounced as with the passage of a cold front (Ramsey, 1983).

A low pressure system is one with decreasing barometric pressure toward its center and windflow around the system is counterclockwise in the Northern Hemisphere. High pressure systems are those with increasing pressure toward their centers and windflow around these systems is

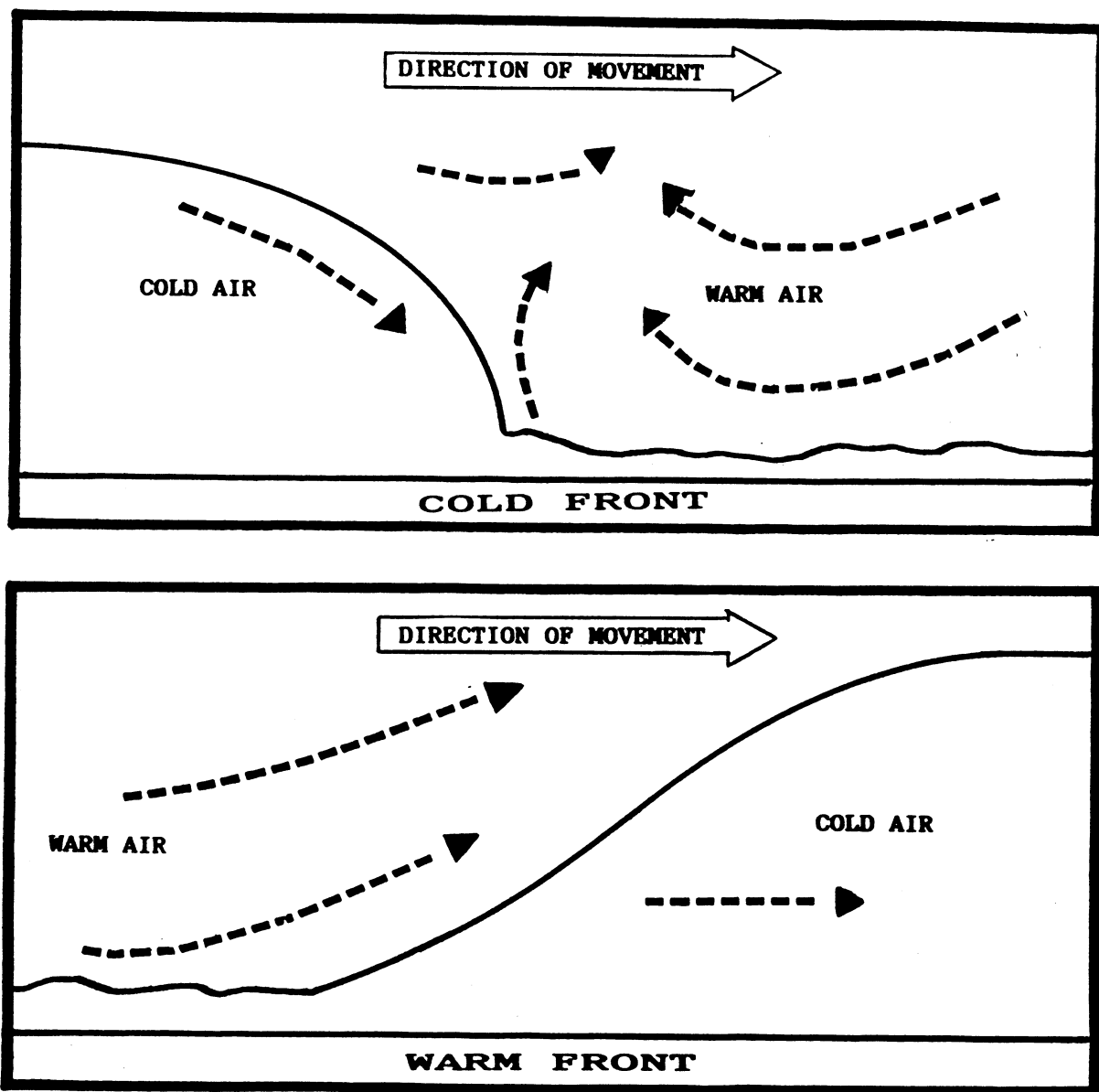


FIGURE 39: VERTICAL CROSS SECTIONS OF COLD AND WARM FRONTS (After Ramsey, 1983)

clockwise. The rate of change in barometric pressure in a direction perpendicular to the isobars is called the pressure gradient. The gradient or slope of pressure isobars is a good indicator of the strength and form of incoming weather. Barometric pressure that is changing can indicate whether the center of a pressure system is coming closer or moving away from your location. Barometric pressure > 30.5 inches of mercury (1016 millibars) and rising means a high pressure system is coming toward you while falling pressure indicates the system is moving away. Pressure < 30.5 inches of mercury (1016 millibars) and falling means a low pressure system is coming in and increasing pressure would indicate it has passed through the area (Ramsey, 1983).

Pressure gradients play a special part in analyzing and forecasting winds as well (Ramsey, 1983). Average surface winds will flow across isobars toward lower pressure at an angle of approximately 30° . Surface winds flow counterclockwise around and toward the center of low pressure and clockwise around and away from a center of high pressure in the Northern Hemisphere. Table 43 summarizes some general wind-barometric pressure relationships associated with certain weather patterns (Ramsey, 1983; Laird and Laird, 1955).

The jetstream is a concentration of relatively strong winds within a narrow stream in the atmosphere, usually at altitudes of 10,000 to 50,000 feet (3 to 15 km) or more. Winds in the jetstream have a strong westerly that meanders around the earth. The jetstream may range from 25 to 100 miles (40 to 160 km) in width and up to a mile or two in depth. Wind velocities range from 115 to 173 mph (52.3 to 78.6 m/s). The jetstream

TABLE 43: FORECASTING WITH WIND-BAROMETRIC PRESSURE RELATIONSHIPS
(After: Laird and Laird, 1955 and Ramsey, 1983)

Wind Direction	Barometer Reading Reduced to Sea Level (Inches of mercury)	Weather Forecast
SW to NW	30.10 - 30.20; steady	Fair, with slight temperature changes for 1 to 2 days
SW to NW	30.10 - 30.20; rising rapidly	Fair, followed within 2 days by rain
SW to NW	30.20 and above; steady	Continued fair, with no decided temperature change
SW to NW	30.20 and above; falling slowly	Slowly rising temperature and fair for 2 days
S to SE	30.10 - 30.20; falling slowly	Rain within 24 hours
S to SE	30.10 - 30.20; falling rapidly	Wind increasing in force, with rain within 12 to 24 hours
SE to NE	30.10 - 30.20; falling slowly	Rain in 12 to 18 hours
SE to NE	30.10 - 30.20; falling rapidly	Increasing wind, and rain within 12 hours
E to NE	30.10 and above; falling slowly	In summer, with light winds, rain may not fall for several days. In winter, rain with 24 hours
E to NE	30.10 and above; falling rapidly	In summer, rain probable within 12 to 24 hours. In winter, rain or snow, with increasing winds, often will set in when barometer begins to fall and wind sets in from NE
SE to NE	30.00 or below; falling slowly	Rain will continue 1 to 2 days
SE to NE	30.00 or below; falling rapidly	Rain, with high wind, followed within 36 hours by clearing, and in winter by colder temperatures
S to SW	30.00 or below; rising slowly	Clearing within a few hours, and fair for several days
S to E	29.80 or below; falling rapidly	Severe storm imminent, followed within 24 hours by clearing, and in winter by colder temperatures
E to N	29.80 or below; falling rapidly	Severe northeast gale and heavy precipitation; in winter, heavy snow followed by a cold wave
Going to W	29.80 or below; rising rapidly	Clearing and colder

is closely associated with migratory low pressure systems and polar fronts. Observation of the jetstream is therefore very important in forecasting weather relative to the development and movement of fronts and low pressure systems (Ramsey, 1983).

Most weather in the United States moves from west to east due to the rotation of the earth. Weather systems move at average speeds of 15 mph (6.8 m/s) in summer to 25 mph (11.4 m/s) in winter, carried along by air streams called the prevailing westerlies.

Dust Storms

Dust storms are the result of numerous coincidental factors including climate, physiography, vegetation and often the human element. Wind is the most important contributing element. Precipitation is the second climatic element involved, because dust in large quantity will form only if the soil is sufficiently dry. However, on some of the sandy and droughty soils of the Central Sands Area of Wisconsin, significant dust storms have been observed within 12 hours of rainfall amounts up to three inches (7.6 cm) or more. The main physiographic factor involved in the development of dust storms is the presence of an extensive plain, such as that found in the Great Plains states, and, to a lesser, more regional extent, the Central Sands Area of Wisconsin.

Dust storms may occur with all wind directions, although those which are associated with the highest velocities are the most significant. Table 44 summarizes some of the recorded dust storms in Portage County, Wisconsin.

TABLE 44: DUST STORMS OBSERVED IN PORTAGE COUNTY, WI (1948-1967)

DATE	TYPE ¹	DURATION	AVERAGE WIND VELOCITY (mph) [Range] & DIRECTION	AVERAGE VISIBILITY (miles) [Range]	ESTIMATED CONCENTRATION OF AIRBORNE DUST ² (mg/m ³)
4/10/48	BD	13:25-15:35	35; SW	5.5 [5-6]	6.5
	RN	15:35-16:35	35; SW	5.0	7.2
5/5/50	RN	15:25-19:25	47,G65 ^a [40-50]; S-SW	1.8 [1-3]	19.7
5/6/50	BN	10:25-12:25	37,G50 [35-40]; S-SW	10	3.6
11/5/52	BD	11:25-13:25	18,G30 [15-20]; NW-W	6	6.0
	BD	15:25-17:23	17,G30 [15-18]; NW-W	5.5 [5-6]	6.5
4/16/53	D	20:25-23:25	26,G40 [25-28]; W	4.7 [3-6]	7.6
11/3/53	BD	12:25-13:25	30,G40; NW	6	6.0
4/17/54	BD	20:27-21:27	18; W	5	7.2
4/18/54	D	07:25-11:25	15,G25 [10-18]; SW-W-NW	6	6.0
4/20/57	BD	14:25-15:25	27,G40 [25-29]; SW	15	2.4
4/30/58	BD	14:55-16:50	21,G46 [17-23]; W	8 [6-10]	4.5
5/18/58	D	11:50-18:57	18,G35 [12-23]; W-NW	7 [5-8]	5.1
5/19/58	D	06:50-13:55	13,G40 [7-23]; W-N-NW	6	6.0
4/7/59	D	11:52-15:52	17,G35 [14-23]; NW	6	6.0
	BD	21:50-23:50	17,G29; NW	4	8.9
4/29/59	D	04:50-07:50	16,G35 [12-17]; W	4.7 [4-6]	7.6
	D	13:55-14:55	25,G35 [23-26]; NW	7	5.1
3/30/63	D	08:50-12:50	1 [0-6]; SW	5.3 [5-6]	6.7
4/3/63	D	11:50-13:50	29,G46; SW	5	7.2

¹ Types of duststorms: BD = blowing dust
D = dust
BN = blowing sand

² Concentration, $C = 57.2/V$ (Hagen and Woodruff, 1973), where C is mg/m^3 and V is visibility in km.

^a G represents the maximum velocity of "gustiness" reported at the time of observation.

Idso (1976) observed the following mechanisms operating in the development of dust storms in China. (1) Dust was often lifted by winds behind a front. These storms were usually limited in size and dust was often confined below an altitude of 5000 feet (1.5 km). Strong winds of low humidity were observed blowing at the surface and at moderate heights above it. (2) Dust can also be lifted by the vertical motions of air ahead of a front, to be transported up to 1600 miles (2500 km) from the source.

Based on observations near Lubbock, Texas, during 1949 and 1950, Warn (1952) arrived at a classification of blowing dust. Although intended to be applicable only to that location, Table 45 may nevertheless be modified for the Central Sands Area if these events will be sufficiently observed and documented in the future.

TABLE 45: CLASSIFICATION OF BLOWING DUST (After Warn, 1952)

Intensity	Usual Duration	Maximum Horizontal Windspeed (mph)	Maximum Ht. of Dust (feet)	Horizontal Visibility (miles)
Light	5-30 min.	14-24	500	8 - 15
Effects of Dust Movement: Sporadic blows of dust and sand at or near ground level; occasional light yellowish haze of dust to 500'				
Mild	0.5-3 hr.	25-34	5000	2 - 7
Effects of Dust Movement: Light, yellowish brown haze; fine dust in continuous suspension to 2000-5000'; sunlight bluish gray; blowing dust and sand to 75'				
Moderate	1 - 6 hr.	35-44	12000	0.75-2
Effects of Dust Movement: Dense, brownish haze; occasional dust cloud effect; dust in suspension to 8000-12000'; lights and sun dimmed; sky obscured				
Strong	3-12 hr.	45-54	18000	0.25-0.75
Effects of Dust Movement: Dust usually approaches as a dark, churning wall; sun barely visible as a weak blue light; ground and air travel impeded				
Severe	6-24 hr.	55-65	30000	0 - 0.25
Effects of Dust Movement: May approach as a dense, dark cloud on frontal winds or build up gradually to intense dust cover; sun usually obscured				

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