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THE DOUGLAS POINT PROJECT - AN ANALYSIS OF SURFACE WIND DATA

BY

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1. INTRODUCTION

A nuclear-powered electric generating station, CANDU, is being constructed at Douglas Point, Ontario on the east shore of Lake Huron between the towns of Kincardine and Port Elgin. (Figure 1). At the request of Atomic Energy of Canada Ltd. and the Hydro-Electric Power Commission of Ontario the Meteorological Branch has undertaken several studies involving the climatology and micrometeorology of the immediate area.

A climatological station was first installed at the reactor site in late June 1961. Preliminary studies were commenced at that time and an analysis of data from a special five-day period has been published by Munn (1). More detailed meteorological investigations began in May 1962 and a Progress Report describing some features of the 1962 program was published by Munn and Richards (2). Several other studies based on Douglas Point data have also been published as Meteorological Branch Circulars or as contributions to the meteorological journals. (Ferland and Leahey (3), Leahey (4), Munn and Richards (5)).

This particular study involves the analysis of surface wind data for the two year period from July 1961 to June 1963. Analyses of other meteorological data collected during this period are in progress and will be published as subsequent Progress Reports or as separate contributions.

2. METHOD

Four separate analyses of the wind data by machine methods were required:

A. A frequency analysis of wind directions grouped according to wind speeds and subdivided by seasons and times of day.

B. A frequency analysis of wind directions during rain subdivided by seasons.

C. Duration of calms and light winds (0-3 mph).

D. Duration of winds 10 mph and higher

(a) from all directions

(b) from the south and southeast only.

At the time the study was initiated there were two years of wind data from Douglas Point available on punched cards (July 1961 to June 1963). In order to ensure as sound climatological conclusions as possible from the available data it was deemed necessary to link the Douglas Point data to those from a nearby climatological station with a similar exposure but possessing a greater length of record. Southampton, also located close to the Lake Huron shoreline and only 15 miles north of Douglas Point, appeared to be the most suitable for the purpose. For this reason, each study, with the exception of the frequency analysis of wind during rain, includes an analysis of

(i) two years of available data from Douglas Point

(ii) the same two years from Southampton, for comparison purposes,

(iii) five years data from Southampton.

3. INSTRUMENTATION

Standard M.S.C. (Meteorological Service of Canada) Type 45B three-cup anemometers were available at each site. The anemographs are twenty-four hour step-recording instruments with the wind speed integrated over the whole hour. Wind directions are recorded to eight points of the compass. Cup heights were almost the same: - 33 feet at Douglas Point, 35 feet at Southampton.

An indication of the relative exposure of the two stations may be obtained from the map (Figure 1). The exposure of the Douglas Point anemometer, located some 300 yards from the shoreline, is considered only fair. There is dense bush within one to two hundred yards to the north, east and south with casual clumps of trees and some buildings much closer. To the west, between the instrument site and the lake, the reactor and generator complex currently under construction continue to rise. The Southampton site is located about 3/4 of a mile east of the shoreline near the south bank of the Saugeen River. The instrument exposure is considered good, although the orientation of the river valley may introduce some funnel effect in winds from the north and northeast.

4. INSTRUMENT DIRECTION BIAS

Unfortunately the frequency analyses exhibit a very noticeable direction bias towards the between-, or non-cardinal points, i.e. NE, SE, SW, and NW. A preliminary investigation of the MSC 45-B anemometer system confirms that this bias does exist and that it is inherent in the recording part of the instrument. A comprehensive study of the problem has been started.

A simple method to help ameliorate the bias, and yet not affect the usefulness of the study, suggested itself in the combination of an equal number of cardinal and between-cardinal directions into off-lake, off-land, and shoreline segments. The location of the Douglas Point site (Figure 1) is such that the four directions SW, W, NW and N are off-lake, E and SE are off-land, and S and NE are parallel to the shoreline. Of the four directions considered off-lake, two, W and NW, may also be defined as on-land. Fortunately such a division evenly combines the cardinal and between-cardinal directions and yet presents the data in a form suitable for the overall study.

A. FREQUENCY ANALYSIS OF SURFACE WIND DIRECTIONS

1. THE DATA

The initial analyses showing the frequency of winds from eight directions grouped according to wind speed classes are presented in Table I through XXII. The data are presented as an Annual Summary in Table I, and are then divided into Seasonal Summaries: Winter, Table II; Spring, Table VI; Summer, Table X; and Fall, Table XIV. To illustrate the diurnal characteristics of the wind the seasonal data are further subdivided into three periods of the day: 0200-0900 EST, 1000-1700 EST, and 1800-0100 EST: Winter, Tables III, IV, V; Spring, Tables VII, VIII, IX; Summer, Tables XI, XII, XIII; and Fall, Tables XV, XVI and XVII.

To relate the data more directly to the Douglas Point shoreline and to help reduce the direction bias discussed earlier, Table XVIII presents the Annual and Season Summaries by off-lake, on-land, off-land and shoreline segments. The seasonal data showing diurnal variations are displayed in the next four tables; Table XIV, Winter; Table XX, Spring; Table XXI, Summer; Table XXII, Fall. Figures 2 to 7 illustrate the same data superimposed on the Douglas Point shoreline and will be referred to in discussions to follow.

2. ANALYSIS

Annual Summaries

A comparison of the annual summaries for Douglas Point and Southampton, Tables I and XVIII and Figure 2, reveals a marked degree of similarity particularly when considering wind directions as related to the Douglas Point shoreline. Both stations show a slight tendency for more frequent winds from the off-lake segment. Although the mean wind speed is somewhat higher at Douglas Point (7.6 to 6.6 mph) the mean speeds from each direction are reasonably comparable. The stronger wind from the northwest at Douglas Point is presumably due to the open exposure to Lake Huron; the stronger northeast wind at Southampton would appear to be due to the exposure to the Saugeen River valley (see Figure 1). Table I indicates fewer light winds and calms (0-3 mph) at Douglas Point. Again this appears to be a matter of proximity to the lake. Winds of 25 mph and higher occur only 0.1% of the time at each station.

Seasonal Summaries

A comparison of the Seasonal Summaries for the two stations, (Tables II, VI, X, XIV and XVIII, and Figures 3 and 4) reveals a fair degree of similarity. The exceptions again point to the closer proximity of the Douglas Point site to the lake. Apparent in Table XVIII and Figures 3 and 4 is the marked decrease in the off-lake winds and the corresponding increase in off-land winds in the fall. This is physically consistent with a mean lake temperature higher than the mean over-land air temperature, as is the case at this time of year.

Wind speeds are highest in the winter and lowest in the summer and in all cases Douglas Point mean speeds exceed those of Southampton; winter 10.1 to 8.9, fall 8.0 to 6.4, spring 6.8 to 6.5, summer 5.8 to 4.0. Winds at Douglas Point reached 25 mph and higher 0.3% of the time in winter, 0.1% in the spring and not at all in the summer and fall. Conversely, calms and light winds (0-3 mph) are greatest in the summer. However, in this regard light winds are much less prevalent at Douglas Point. (24.8% to 51.3%).

Diurnal Summaries

The diurnal variation in wind frequencies are tabulated in detail for each station in Tables III, IV, V, Winter; VII, VIII, IX, Spring; XI, XII, XIII, Summer; XV, XVI, XVII, Fall; and are illustrated more generally for Douglas Point in Figures 5 and 6.

In each season there is an increase in off-lake winds during the daytime - a function of daytime heating over land. As might be expected this effect is much greater during the spring and summer, reaching a maximum of 79.8% off-lake winds during the daytime in the summer as compared to only 4.1% off-land winds. Conversely, off-land winds are greatest during the night in the fall. Calms are most frequent during the evening in the spring (3.3% of the time).

B. THE ASSOCIATION OF RAIN WITH WIND

1. INTRODUCTION

In a study such as this, precipitation is of importance because of its scavenging effect upon gases and particles suspended in the air. This scavenging may be desirable or not depending upon the direction of the wind during periods of precipitation.

Table XXIII shows the association of rain with wind at Douglas Point for the three seasons, spring, summer and fall. The data are for the two-year period of July 1961 to June 1963: the wind data from the standard MSC Type 45-B anemometer with cups at 33 feet, the rain data as recorded by a standard MSC Recording Rain Gauge (tipping-bucket) measuring increments of 1/100 inch. Since there was no recording snow gauge the study was limited to cases of rain only, hence the winter season has been omitted. The table shows, for each of 8 directions and for each of 3 seasons:

- the number of hours that measurable rain occurred,
- the hours of rain as a percentage of the total number of hours of rain,
- the hours of rain as a percentage of the total number of hours each season.

As in the earlier frequency study, because of the shoreline location of the Douglas Point site and because of the direction bias of the instrument, Table XXIV was produced to present the data in off-lake, off-land and shoreline segments. Figure 7 illustrates the same data graphically.

2. ANALYSIS

The Association of Wind Direction with Rain

The association of wind direction with rain is shown by seasons in Table XXIII. A statistical study (outlined in Appendix I) comparing these conditional frequencies to simple frequencies of the previous study (Tables VI, X, XIV) indicates that in each season the occurrence of rain is related to, or dependent upon, wind directions.

For reasons indicated earlier, the directions have again been grouped in Table XXIV into off-lake, off-land, and shoreline segments. The noticeably greater frequency of winds in the combined off-land and shoreline directions (NE, E, SE and S) is presumably associated with the fact that these are wind directions associated with pre-warm front, and therefore rain-producing, situations. Appendix I also indicates more than average rain associated with West winds in the Fall. These would be shower conditions resulting from colder air passing over the relatively warm water, - a fall and winter phenomenon.

The Association of Wind Speed with Rain

In general, rain is associated with above average wind speeds. For the period of record the average wind speed in rain was 8.1 mph as compared to the overall average of 7.6 mph.

Seasonal Variation in the Frequency of Rain

In both Tables XXIII and XXIV it may be seen that during the spring it rained 3.3% of the time, during the summer 3.8%, and during the fall 7.2%. However, a much greater length of record would be required before these figures could be considered significant. The record at the nearby climatological station at Southampton for the same period showed precipitation amounts 4.7% below normal in the spring, 24.5% below normal in the summer and 0.7% below normal in the fall.

C. DURATION OF CALMS AND LIGHT WINDS (0-3 mph)

1. INTRODUCTION

In order to estimate the frequency and duration of periods of calms and winds of 1 to 3 mph, (hereafter referred to as light winds (0-3 mph)), at Douglas Point three separate machine analyses were undertaken. Table XXV tabulates the average number of occurrences of light winds arrayed by months and hour classes for -

(a) Douglas Point for 2 years (July 1961-June 1963)

(b) Southampton for same 2 years

(c) Southampton for 5 years

As in the previous studies this was done so that a comparison of Douglas Point and Southampton winds during the same 2 year period would assist in the intelligent use of the greater depth of record of the Southampton data.

2. ANALYSIS

A comparison of arrays (a), (b) and (c) in Table XXV and reference to figures 8 and 9 reveals the same general pattern of occurrences and duration of light winds at both stations. In each of the three analyses light winds are more frequent and of shortest duration during the winter months.

A comparison of Douglas Point and Southampton for the same 2 year period produces the definite indication that periods of light winds at Douglas Point are fewer and of shorter duration than that at Southampton. The longest duration of light winds at Douglas Point was one period in two years that reached the 25-30 hour class (in June) as compared with two occurrences of light winds during the same time at Southampton and these reached the 49-54 hour class (July, October). The difference is presumably due to the respective locations of the anemometers, i.e. Douglas Point only 300 yards from the shoreline, Southampton 3/4 of a mile.

It is apparent that the use of the 5 year record from Southampton would represent the general seasonal pattern of light winds at Douglas Point but would over-estimate the number of occurrences and the length of duration.

D. DURATION OF WINDS 10 M.P.H. OR GREATER - ALL DIRECTIONS

1. INTRODUCTION

Essentially the same machine methods were employed to analyse the occurrences and duration of winds 10 mph and greater hereafter referred to as strong winds. Tables XXVI tabulates the average number of occurrences of strong winds arrayed by months and hour classes for -

(a) Douglas Point for 2 years,

(b) Southampton for the same 2 years,

(c) Southampton for 5 years.

2. ANALYSIS

A comparison of arrays (a), (b) and (c) and reference to figures 10 and 11 reveals the same general pattern at both Douglas Point and Southampton. In each case strong winds are least frequent and of shortest duration during the summer and most frequent and of longest durations during the late fall and winter (November to February).

A comparison of Douglas Point and Southampton for the same two years indicates somewhat longer durations of strong winds at Douglas Point; once in two years strong winds persisted longer than 120 hours (December) and twice in the same period the longest duration at Southampton was in the 73-84 hour range, - three times in two years (December and January). This is presumably because the Douglas Point site is closer to the lake and hence has a more open exposure.

It is apparent that the five year climatological record for Southampton may be used as an indication of the general monthly pattern of duration of strong winds. However, at Douglas Point winds 10 mph and higher tend to occur a little more frequently and persist a little longer than at Southampton.

E. DURATION OF WINDS 10 M.P.H. OR GREATER - SOUTH AND SOUTHEAST

1. INTRODUCTION

To assist in the solution of a problem unique to the Douglas Point site a similar analysis was undertaken restricted to winds of 10 m.p.h. or more from the South and Southeast. Table XXVII tabulates the average number of occurrences of winds at this strength from these directions again arrayed by month and hour classes for:

III (a) Douglas Point for 2 years

III (b) Southampton for the same 2 years

III (c) Southampton for 5 years

2. ANALYSIS

There appears to be little similarity between occurrences and durations of South and Southeast winds at Douglas Point and Southampton. However, it may be concluded that occurrences of South and Southeast winds at either site are infrequent and of relatively short durations, - not exceeding 24 hours during the period of study.

5. GENERAL SUMMARY

1. The annual, seasonal and diurnal variations in wind, and the durations of light and strong winds at Douglas Point and Southampton are physically consistent with the location of the observing sites near the shore of a large lake. The differences that do occur between winds at the two stations may be explained in terms of exposure.

2. The use of the longer record from Southampton as an indication of the wind regime at Douglas Point appears justified particularily if due regard is given to the difference in exposures. A study is currently being undertaken to produce a quantitative evaluation of the differences between Douglas Point and Southampton winds employing a technique introduced by Untersteiner (6).

3. A further study comparing winds at a shoreline station (Douglas Point) to winds at a station 12 miles inland (Paisley) will be commenced as soon as sufficient data from the inland station are available.

6. ACKNOWLEDGEMENTS

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APPROVED,

J. R. H. Noble,
Director.

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APPENDIX 1

A Statistical Comparison of Conditional Wind Frequencies (with rain) to Simple Frequencies

In order to show that the conditional wind frequencies with rain (Table XXIII) are independent of the simple wind frequencies (Tables VI, X, XIV) the following analysis was employed:

We assume that there is the same probability of rain for each direction.

An estimate of the common probability p is the number of observed occurrences of rain divided by the total number of observations.

From the hypothesis the expected number of occurrences of rain in a sample of n is n.p and the standard deviation of the number of occurrences in the sample is $n.p.q.$ where $q = 1-p.$

Then 95% limits are given by $np \pm 2 \quad n.p.q.$

If the observed occurrences of rain with some directions (first column, Table 1) fall within the 95% limits (last column) and for other directions fall outside the limits the hypothesis is not sustained and we conclude that rain is more or less likely with some wind directions than others.

Table I (Appendix 1) shows the results of this test for the Spring, Summer and Fall. The conditional wind frequencies (with rain) are taken from Table XXIII the simple frequencies from Tables VI (Spring), X (Summer) and XIV (Fall).

During the Spring the number of observations with rain are significantly larger than the 95% limits with wind directions NE and SE and less for NW and Calm.

During the Summer the number of observations with rain are significantly larger than the 95% limits with wind directions NE and SE and less for NW.

During the Fall the number of observations with rain are significantly larger than the 95% limits with wind directions E, SE and W.

Therefore for these directions the hypothesis is not sustained and it must be concluded that rain is more likely with winds from certain directions.

TABLE 1

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

ANNUAL SUMMARY

Wind Direction	Speed, mph 0-3	4-10	11-17	18-24	≥ 25	Total Observations %	No.	Mean Speed mph	% of Overall Mean
(a) Douglas Point - 2 years									
N	1.4	3.9	0.6	0.0		5.9	833	5.8	76
NE	1.9	7.5	1.5	0.1	0.0	11.0	1560	7.0	92
E	3.3	3.6	0.6	0.1		7.6	1089	5.2	68
SE	2.6	9.6	1.4	0.0		13.6	1921	6.3	83
S	2.6	10.3	1.2	0.1		14.2	2019	6.2	82
SW	1.7	13.2	6.2	1.0		22.1	3111	9.1	120
W	1.2	4.3	1.5	0.3	0.0	7.3	1042	7.8	103
NW	1.2	7.6	5.6	2.1	0.1	16.6	2346	10.5	138
Calm	1.4					1.4	199		
Totals	17.3	60.0	18.6	3.7	0.1	99.7	14120	7.6 (Mean)	
(b) Southampton - same 2 years									
N	2.1	3.5	0.7	0.1		6.4	1023	5.9	89
NE	1.5	6.4	3.2	0.4	0.0	11.5	1830	8.6	130
E	5.1	4.5	0.8	0.0		10.4	1673	4.6	70
SE	3.7	4.7	0.4	0.0		8.8	1411	4.8	73
S	6.1	7.7	0.5			14.3	2281	4.4	67
SW	3.7	13.1	5.4	1.1	0.1	23.4	3756	8.3	126
W	1.7	3.1	1.5	0.1		6.4	1025	7.0	106
NW	2.9	9.8	3.9	0.3		16.9	2695	7.6	115
Calm	2.1					2.1	329		
Totals	28.9	52.8	16.4	2.0	0.1	100.2	16023	6.6 (Mean)	
(c) Southampton - 5 years									
N	1.7	3.3	0.8	0.1		5.9	2459	6.4	91
NE	1.2	6.2	3.4	0.4	0.0	11.2	4633	8.9	127
E	4.6	4.8	0.9	0.1	0.0	10.4	4284	5.0	71
SE	3.7	5.7	0.7	0.0		10.1	4180	5.1	73
S	5.7	6.8	0.4			12.9	5302	4.4	63
SW	3.2	14.1	6.5	1.3	0.1	25.2	10400	8.8	126
W	1.3	2.4	1.2	0.2		5.1	2082	7.4	106
NW	2.4	10.1	5.1	0.4		18.0	7407	8.3	119
Calm	1.3					1.3	523		
Totals	25.1	53.4	19.0	2.5	0.1	100.1	41269	7.0 (Mean)	

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TABLE II

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

WINTER (Dec., Jan., Feb.): All Hours

Wind Direction	Speed, mph					Total Observations		Mean Speed	
	0-3	4-10	11-17	18-24	≥ 25	%	No.	mph	% of Overall Mean
(a) Douglas Point 2 years									
N	0.2	0.2				0.4	14	3.8	38
NE	1.0	9.4	2.3	0.2		12.9	457	8.0	79
E	2.0	1.7	0.7	0.3		4.7	164	6.5	64
SE	1.9	11.9	2.7	0.1		16.6	586	7.1	70
S	1.2	4.7	0.3	0.1		6.3	220	5.9	58
SW	0.5	11.6	13.2	3.2		28.5	1006	11.7	116
W	0.3	3.9	3.6	0.8	0.0	8.6	303	10.8	107
NW	0.3	5.2	10.1	5.6	0.3	21.5	760	13.9	138
Calm	0.7					0.7	26		
Totals	8.1	48.6	32.9	10.3	0.3	100.2	3536	Mean 10.1	
(b) Southampton - same 2 years									
N	0.5	2.2	0.7	0.2		3.6	153	8.3	93
NE	0.8	6.5	5.0	0.4		12.7	550	9.8	110
E	3.3	4.7	1.3	0.1		9.4	406	5.9	66
SE	1.9	5.0	0.6	0.0		7.5	323	5.9	66
S	3.1	11.2	0.6			14.9	645	5.5	62
SW	0.8	12.0	9.2	3.1	0.2	25.3	1096	11.3	127
W	1.0	4.1	4.6	0.3		10.0	433	10.0	112
NW	0.9	6.7	7.4	0.7		15.7	679	10.6	119
Calm	0.8					0.8	35		
Totals	13.1	52.4	29.4	4.8	0.2	99.9	4320	Mean 8.9	
(c) Southampton - 5 years									
N	0.4	2.1	1.4	0.2		4.1	447	9.3	103
NE	0.7	6.8	5.4	0.7		13.6	1470	10.2	113
E	3.3	6.3	1.6	0.1		11.3	1229	6.3	70
SE	2.3	6.5	0.6	0.0		9.4	1019	5.6	62
S	3.3	9.6	0.4			13.3	1434	5.3	59
SW	0.6	11.9	8.7	2.7	0.2	24.1	2606	11.1	123
W	0.6	2.8	3.3	0.5		7.2	785	10.5	117
NW	0.6	6.3	8.7	0.9		16.5	1786	11.2	124
Calm	0.4					0.4	48		
Totals	12.2	52.3	30.1	5.1	0.2	99.9	10824	Mean 9.0	

TABLE III

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

WINTER: 0200-0900 EST

Wind Direction	Speed, mph 0-3	4-10	11-17	18-24	≥25	Total Observations %	No.
(a) Douglas Point 2 years							
N	0.2	0.2				0.5	6
NE	1.3	8.1	2.5			11.9	140
E	2.0	1.9	1.2	0.3		5.4	63
SE	1.8	14.6	2.7	0.1		19.2	226
S	1.9	5.8	0.3	0.2		8.2	98
SW	0.3	9.3	13.1	2.1		24.8	293
W	0.4	3.5	4.1	0.4		8.4	99
NW	0.3	6.4	7.8	5.4	0.3	20.2	239
Calm	1.4					1.4	16
Totals	9.7	49.8	31.7	8.5	0.3	100.0	1180
(b) Southampton - same 2 years							
N	0.6	1.5	0.5	0.4		3.0	42
NE	0.4	7.9	6.4	0.3		15.0	216
E	5.1	4.9	1.0			11.0	159
SE	2.3	5.1	0.6	0.1		8.1	116
S	3.9	11.9	0.8			16.6	238
SW	1.2	11.2	8.1	1.7		22.2	320
W	0.6	3.8	4.4	0.6		9.4	136
NW	0.8	5.8	6.7	0.7		14.0	202
Calm	0.8					0.8	11
Totals	15.7	52.1	28.5	3.8		100.1	1440
(c) Southampton - 5 years							
N	0.4	1.4	1.5	0.2		3.5	126
NE	0.4	8.5	6.5	0.4		15.7	572
E	4.6	7.1	1.1	0.1		13.0	467
SE	2.9	6.7	0.5	0.0		10.1	367
S	4.0	10.0	0.4			14.4	519
SW	0.7	10.8	7.9	1.8	0.1	21.3	769
W	0.3	2.4	3.4	0.9		7.0	254
NW	0.4	5.2	8.0	0.7		14.3	516
Calm	0.5					0.5	18
Totals	14.2	52.1	29.3	4.1	0.1	99.8	3608

TABLE IV

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

WINTER: 1000-1700 EST

Wind Direction	Speed, mph					Total Observations	
	0-3	4-10	11-17	18-24	≥25	%	No.
(a) Douglas Point 2 years							
N	0.3	0.3				0.6	7
NE	0.9	11.8	2.3	0.3		15.3	179
E	0.4	2.1	0.2			2.7	32
SE	0.9	11.1	1.4	0.1		13.5	158
S	0.6	3.2	0.1			3.9	45
SW	0.5	13.9	15.3	3.8		33.5	392
W	0.5	5.2	3.2	0.9	0.1	9.9	116
NW	0.1	5.0	10.8	4.7		20.6	242
Calm	0.2					0.2	2
Totals	4.4	52.6	33.3	9.8	0.1	100.2	1173
(b) Southampton - same 2 years							
N	0.5	3.5	1.3	0.1		5.4	77
NE	0.4	5.4	4.0	0.2		10.0	144
E	0.5	5.3	2.2			8.0	115
SE	1.3	4.7	0.3			6.3	91
S	3.1	10.3	0.3			13.7	198
SW	0.6	12.6	12.0	3.9	0.3	29.4	423
W	1.5	4.3	4.0	0.1		9.9	143
NW	1.4	7.6	6.9	0.8		16.7	241
Calm	0.6					0.6	8
Totals	9.9	53.7	31.0	5.1	0.3	100.0	1440
(c) Southampton - 5 years							
N	0.5	3.4	1.7	0.2		5.8	206
NE	0.4	6.1	4.8	0.9		12.2	442
E	0.7	6.2	2.5	0.1		9.5	340
SE	1.5	6.9	0.6			9.0	325
S	2.8	8.8	0.4			12.0	431
SW	0.6	12.4	10.2	3.2	0.2	26.6	958
W	0.9	3.4	2.9	0.2		7.4	268
NW	0.8	7.2	8.4	1.0		17.4	627
Calm	0.3					0.3	11
Totals	8.5	54.4	31.5	5.6	0.2	100.2	3608

TABLE V

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

WINTER: 1800-0100 EST

Wind Direction	Speed, mph 0-3	4-10	11-17	18-24	≥25	Total Observations %	No.
(a) Douglas Point 2 years							
N	—	0.1				0.1	1
NE	0.8	8.3	2.4	0.3		11.8	138
E	3.5	1.0	0.8	0.6		5.9	69
SE	3.0	10.1	3.8	0.2		17.1	202
S	1.2	5.0	0.3			6.5	77
SW	0.7	11.5	11.2	3.7		27.1	321
W	—	3.0	3.4	1.0		7.4	88
NW	0.4	4.2	11.7	6.8	0.4	23.5	279
Calm	0.7					0.7	8
Totals	10.3	43.2	33.6	12.6	0.4	100.1	1183
(b) Southampton - same 2 years							
N	0.3	1.6	0.4			2.3	34
NE	1.5	6.2	4.8	0.7		13.2	190
E	4.2	4.0	0.8	0.3		9.3	132
SE	2.0	5.1	0.9			8.0	116
S	2.4	11.4	0.7			14.5	209
SW	0.7	12.3	7.6	3.6	0.3	24.5	353
W	0.8	4.2	5.4	0.2		10.6	154
NW	0.3	6.7	8.7	0.7		16.4	236
Calm	1.1					1.1	16
Totals	13.3	51.5	29.3	5.5	0.3	99.9	1440
(c) Southampton - 5 years							
N	0.5	1.6	1.0	0.1		3.2	115
NE	1.3	5.7	5.0	0.6		12.6	456
E	4.6	5.8	1.0	0.2		11.6	422
SE	2.5	5.9	0.7			9.1	327
S	3.0	10.1	0.4			13.5	484
SW	0.5	12.3	8.1	3.2	0.3	24.4	879
W	0.7	2.6	3.6	0.4		7.3	263
NW	0.5	6.5	9.8	1.1		17.9	643
Calm	0.5					0.5	19
Totals	14.1	50.5	29.6	5.6	0.3	100.1	3608

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TABLE VI

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS
GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

SPRING (March, April, May): All Hours

Wind Direction	Speed, mph					Total Observations		Mean Speed	
	0-3	4-10	11-17	18-24	≥ 25	%	No.	mph	% of Overall Mean
(a) Douglas Point 2 years									
N	1.6	5.5	0.6			7.7	262	6.0	88
NE	2.6	10.1	2.5	0.4	0.1	15.7	540	7.3	107
E	3.7	3.3				7.0	239	3.7	54
SE	1.7	8.3	1.5			11.5	394	6.9	101
S	1.9	8.5	1.7			12.1	414	6.4	94
SW	2.5	15.3	5.9			23.7	816	7.9	116
W	1.7	3.9	0.3			5.9	204	5.2	76
NW	1.5	8.8	3.5	0.6	0.0	14.4	495	8.5	125
Calm	2.1					2.1	72		
Totals	19.3	63.7	16.0	1.0	0.1	100.1	3436	Mean 6.8	
(b) Southampton - same 2 years									
N	3.2	5.9	0.7	0.1		9.9	433	5.5	85
NE	1.7	4.8	2.6	0.5	0.1	9.7	427	8.7	134
E	4.7	5.5	1.2	0.0		11.4	507	5.3	82
SE	1.9	6.0	0.8	0.0		8.7	383	6.1	94
S	4.3	8.4	0.6			13.3	589	5.0	77
SW	2.4	12.1	6.5	0.8		21.8	961	8.9	137
W	2.3	5.3	0.2			7.8	345	5.0	77
NW	3.3	10.6	1.6	0.3		15.8	698	6.3	97
Calm	1.7					1.7	73		
Totals	25.5	58.6	14.2	1.7	0.1	100.1	4416	Mean 6.5	
(c) Southampton - 5 years									
N	2.4	4.9	0.8	0.1		8.2	899	5.9	83
NE	1.4	5.7	3.5	0.5	0.0	11.1	1233	9.2	130
E	3.9	6.1	1.4	0.1		11.5	1277	6.0	85
SE	2.2	7.2	1.5	0.0		10.9	1215	6.6	93
S	3.9	8.0	0.7			12.6	1399	5.2	73
SW	2.1	11.3	6.7	0.9	0.1	21.1	2342	9.3	131
W	1.7	3.9	0.4			6.0	667	5.4	76
NW	2.9	11.4	2.9	0.2		17.4	1910	7.1	100
Calm	0.9					0.9	98		
Totals	21.4	58.5	17.9	1.8	0.1	99.7	11040	Mean 7.1	

TABLE VII

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

SPRING: 0200-0900 EST

Wind Direction	Speed, mph 0-3	4-10	11-17	18-24	≥25	Total Observations %	No.
(a) Douglas Point 2 years							
N	1.0	1.9	0.3			3.2	35
NE	2.2	9.5	2.6	0.4	0.1	14.8	167
E	5.2	3.1				8.3	94
SE	2.2	11.4	2.0			15.6	177
S	2.0	13.0	0.6			15.6	177
SW	3.1	15.4	5.3			23.8	269
W	1.9	2.3	0.3			4.5	51
NW	1.4	6.3	3.0	0.7		11.4	129
Calm	2.7					2.7	30
Totals	21.7	62.9	14.1	1.1	0.1	99.9	1129
(b) Southampton -same 2 years							
N	2.1	3.5	0.4	0.1		6.1	89
NE	1.9	5.8	2.7	0.5		10.9	161
E	7.2	6.7	0.9			14.8	217
SE	3.0	8.4	1.1			12.5	184
S	6.6	9.6	0.3			16.5	243
SW	2.9	12.6	5.1	0.4		21.0	309
W	2.6	4.6	0.1			7.3	108
NW	2.1	5.9	1.0	0.1		9.1	134
Calm	1.8					1.8	27
Totals	30.2	57.1	11.6	1.1		100.0	1472
(c) Southampton - 5 years							
N	2.1	3.6	0.5	0.0		6.2	229
NE	1.5	7.0	3.9	0.4		12.8	473
E	5.8	6.6	1.4			13.8	509
SE	3.6	10.1	1.3	0.0		15.0	552
S	5.1	10.1	0.5			15.7	576
SW	2.3	10.8	4.9	0.8	0.0	18.8	699
W	1.7	2.7	0.5			4.9	179
NW	2.0	7.4	2.1	0.1		11.6	426
Calm	1.0					1.0	37
Totals	25.1	58.3	15.1	1.3	0.0	99.8	3680

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TABLE VIII

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

SPRING: 1000-1700 EST

Wind Direction	Speed, mph 0-3	4-10	11-17	18-24	≥ 25	Total Observations %	No.
(a) Douglas Point 2 years							
N	1.2	11.3	1.1			13.6	156
NE	0.2	10.0	3.4	0.3	0.2	14.1	161
E	0.7	2.6				3.3	38
SE	0.2	6.3	1.4			7.9	90
S	0.1	2.4	1.5			4.0	46
SW	0.6	19.0	8.5			28.1	322
W	1.8	7.1	0.6			9.5	109
NW	1.7	13.6	3.5	0.3		19.1	219
Calm	0.3					0.3	4
Totals	6.8	72.3	20.0	0.6	0.2	99.9	1145
(b) Southampton - same 2 years							
N	2.0	9.2	1.0			12.2	181
NE	0.1	2.6	3.1	0.5	0.1	6.4	95
E	0.7	4.1	2.0	0.1		6.9	103
SE	0.3	4.8	0.3			5.4	79
S	1.4	7.5	1.2			10.1	147
SW	0.7	11.0	10.5	1.2		23.4	344
W	1.5	8.1	0.5			10.1	149
NW	4.7	18.2	1.9	0.4		25.2	371
Calm	0.2					0.2	3
Totals	11.6	65.5	20.5	2.2	0.1	99.9	1472
(c) Southampton - 5 years							
N	1.4	7.0	1.2	0.0		9.6	353
NE	0.2	4.0	3.8	0.7	0.1	8.8	322
E	0.4	4.8	2.0	0.2	0.1	7.5	273
SE	0.3	5.7	1.8	0.0		7.8	289
S	1.2	5.7	0.9			7.8	287
SW	0.7	11.0	11.5	1.2		24.4	895
W	1.1	6.1	0.7			7.9	290
NW	3.7	19.0	3.3	0.2		26.2	966
Calm	0.1					0.1	5
Totals	9.1	63.3	25.2	2.3	0.2	100.1	3680

TABLE IX

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

SPRING: 1800-0100 EST

Wind Direction	Speed, mph 0-3	4-10	11-17	18-24	≥25	Total Observations %	No.
(a) Douglas Point 2 years							
N	2.5	3.4	0.3			6.2	71
NE	5.2	10.9	1.5	0.4	0.2	18.2	212
E	5.2	4.0				9.2	107
SE	2.7	7.3	0.9			10.9	127
S	3.6	10.0	2.8			16.4	191
SW	3.9	11.4	4.0			19.3	225
W	1.4	2.2	0.2			3.8	44
NW	1.4	6.5	4.0	0.7	0.1	12.7	147
Calm	3.3					3.3	38
Totals	29.2	55.7	13.7	1.1	0.3	100.0	1162
(b) Southampton - same 2 years							
N	5.4	5.0	0.5	0.1		11.0	163
NE	3.1	6.0	2.1	0.3	0.1	11.6	171
E	6.3	5.8	0.7			12.8	187
SE	2.2	4.7	1.2	0.1		8.2	120
S	5.0	8.0	0.5			13.5	199
SW	3.6	12.6	3.9	0.7		20.8	308
W	2.9	3.1				6.0	88
NW	3.1	7.7	2.0	0.3		13.1	193
Calm	2.9					2.9	43
Totals	34.5	52.9	10.9	1.5	0.1	99.9	1472
(c) Southampton - 5 years							
N	3.6	4.1	0.7	0.2		8.6	317
NE	2.5	6.0	2.9	0.5	0.0	11.9	438
E	5.6	6.9	0.8	0.1		13.4	495
SE	2.8	5.9	1.4	0.1		10.2	374
S	5.6	8.3	0.7			14.6	536
SW	3.4	12.2	3.8	0.8	0.2	20.4	748
W	2.3	3.0	0.1			5.4	198
NW	3.0	7.7	3.2	0.2		14.1	518
Calm	1.5					1.5	56
Totals	30.3	54.1	13.6	1.9	0.2	100.1	3680

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TABLE X

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

SUMMER (June, July, Aug.): All Hours

Wind Direction	Speed, mph 0-3	4-10	11-17	18-24	≥25	Total Observations %	No.	Mean Speed mph	% of Overall Mean
(a) Douglas Point 2 years									
N	2.9	6.8	0.8	0.0		10.5	452	5.5	95
NE	2.9	7.9	0.6			11.4	491	5.7	98
E	3.3	1.6				4.9	208	2.9	50
SE	3.2	6.9	0.3			10.4	448	5.0	86
S	4.6	13.3	0.7			18.6	796	5.3	91
SW	2.5	15.7	2.0			20.2	868	6.8	117
W	1.4	4.9	0.3			6.6	287	5.6	97
NW	2.3	10.1	2.8	0.4		15.6	671	7.3	126
Calm	1.7					1.7	74		
Totals	24.8	67.2	7.5	0.4		99.9	4295	Mean 5.8	
(b) Southampton - same 2 years									
N	3.3	3.5	0.1			6.9	256	3.9	98
NE	2.2	6.6	1.0			9.8	367	6.3	158
E	6.7	2.8	0.1			9.6	357	3.0	75
SE	7.1	2.3	0.0			9.4	352	2.9	73
S	9.6	1.1				10.7	403	2.1	53
SW	9.2	16.2	1.0	0.0		26.4	990	4.9	123
W	2.6	0.8				3.4	127	2.4	60
NW	5.8	12.0	1.2			19.0	714	5.1	128
Calm	4.8					4.8	178		
Totals	51.3	45.3	3.4	0.0		100.0	3744	Mean 4.0	
(c) Southampton - 5 years									
N	2.9	4.0	0.1			7.0	705	4.2	89
NE	1.8	5.6	1.0			8.4	845	6.4	136
E	6.5	2.4	0.1			9.0	906	3.0	64
SE	6.3	2.7	0.1			9.1	906	3.0	64
S	9.2	1.1				10.3	1025	2.2	47
SW	7.7	19.6	3.3	0.0		30.6	3071	6.1	130
W	2.0	1.0				3.0	304	2.9	62
NW	4.9	12.8	1.7			19.4	1957	5.6	119
Calm	3.1					3.1	313		
Totals	44.4	49.2	6.3	0.0		99.9	10032	Mean 4.7	

TABLE XI

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

SUMMER: 0200-0900 EST

Wind Direction	Speed, mph 0-3	4-10	11-17	18-24	≥25	Total Observations %	No.
(a) Douglas Point 2 years							
N	2.2	2.8	0.5			5.5	78
NE	2.4	7.2	0.4			10.0	143
E	4.2	2.4				6.6	94
SE	5.4	10.8	0.3			16.5	237
S	6.4	19.5	0.3			26.8	375
SW	3.1	10.3	1.2			14.6	209
W	1.3	3.1				4.4	64
NW	2.7	7.8	2.7	0.4		13.6	194
Calm	2.7					2.7	38
Totals	30.4	63.9	5.4	0.4		100.1	1432
(b) Southampton - same 2 years							
N	1.8	2.2	0.2			4.2	53
NE	1.4	6.9	0.2			8.5	107
E	9.9	2.4				12.3	153
SE	12.7	2.6				15.3	191
S	15.7	1.3				17.0	212
SW	10.5	11.1	1.3			22.9	285
W	3.3	0.3				3.6	45
NW	3.4	7.0	1.0			11.4	141
Calm	4.9					4.9	61
Totals	63.6	33.8	2.7			100.1	1248
(c) Southampton - 5 years							
N	1.7	2.2	0.2			4.1	140
NE	1.4	5.6	0.4			7.4	248
E	8.5	2.4	0.1			11.0	367
SE	10.4	4.1				14.5	485
S	15.1	1.3				16.4	549
SW	9.2	15.6	3.0	0.0		27.8	929
W	2.5	0.8				3.3	111
NW	3.2	7.4	1.4			12.0	405
Calm	3.3					3.3	110
Totals	55.3	39.4	5.1	0.0		99.8	3344

TABLE XII

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

SUMMER: 1000-1700 EST

Wind Direction	Speed, mph 0-3	4-10	11-17	18-24	≥25	Total Observations %	No.
(a) Douglas Point 2 years							
N	1.8	12.5	1.2			15.5	222
NE	0.4	8.9	1.1			10.4	149
E	0.3	0.8				1.1	16
SE	0.1	2.6	0.3			3.0	43
S	0.3	4.7	0.7			5.7	81
SW	0.7	27.7	2.9			31.3	448
W	0.7	9.2	0.8			10.7	154
NW	1.9	17.0	2.9	0.5		22.3	318
Calm	0.1					0.1	1
Totals	6.3	83.4	9.9	0.5		100.1	1432
(b) Southampton - same 2 years							
N	2.8	4.8				7.6	95
NE	0.5	6.7	2.2			9.4	118
E	0.6	3.2	0.2			4.0	51
SE	1.3	2.0	0.1			3.4	42
S	2.6	1.0				3.6	45
SW	3.8	26.8	1.4	0.1		32.1	400
W	1.4	1.8				3.2	39
NW	8.7	23.1	1.3			33.1	413
Calm	3.6					3.6	45
Totals	25.3	69.4	5.2	0.1		100.0	1248
(c) Southampton - 5 years							
N	2.1	6.0	0.1			8.2	271
NE	0.4	5.8	2.0			8.2	272
E	0.6	2.0	0.1			2.7	90
SE	1.2	1.3	0.2			2.7	91
S	1.6	0.7				2.3	78
SW	3.0	29.5	5.2	0.1		37.8	1265
W	0.9	1.8				2.7	92
NW	7.1	24.3	2.1			33.5	1120
Calm	1.9					1.9	65
Totals	18.8	71.4	9.7	0.1		100.0	3344

TABLE XIII

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

SUMMER: 1800-0100 EST

Wind Direction	Speed, mph 0-3	4-10	11-17	18-24	≥25	Total Observations %	No.
(a) Douglas Point 2 years							
N	4.7	5.0	0.8	0.1		10.6	152
NE	6.0	7.6	0.3			13.9	199
E	5.3	1.5				6.8	98
SE	4.1	7.2	0.4			11.7	168
S	7.1	15.7	1.0			23.8	340
SW	3.7	9.2	1.9			14.8	211
W	2.3	2.3	0.2			4.8	69
NW	2.3	5.7	2.8	0.3		11.1	159
Calm	2.4					2.4	35
Totals	37.9	54.2	7.4	0.4		99.9	1431
(b) Southampton - same 2 years							
N	5.1	3.5				8.6	108
NE	4.6	6.2	0.6			11.4	142
E	9.5	2.7				12.2	153
SE	7.4	2.2				9.6	119
S	10.5	1.2				11.7	146
SW	13.4	10.7	0.3			24.4	305
W	3.2	0.2				3.4	43
NW	5.3	6.1	1.4			12.8	160
Calm	5.8					5.8	72
Totals	64.8	32.8	2.3			99.9	1248
(c) Southampton - 5 years							
N	5.0	3.7	0.1			8.8	294
NE	3.7	5.4	0.6			9.7	325
E	10.5	2.9	0.0			13.4	449
SE	7.3	2.5				9.8	330
S	10.8	1.1				11.9	398
SW	10.9	13.8	1.6			26.3	877
W	2.7	0.3				3.0	101
NW	4.5	6.7	1.7			12.9	432
Calm	4.1					4.1	138
Totals	59.5	36.4	4.0			99.9	3344

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TABLE XIV

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

FALL (Sept., Oct., Nov.): All Hours

Wind Direction	Speed, mph 0-3	4-10	11-17	18-24	≥25	Total Observations %	No.	Mean Speed mph	% of Overall Mean
(a) Douglas Point 2 years									
N	0.6	2.3	0.8			3.7	105	7.2	90
NE	0.5	1.5	0.5			2.5	72	7.0	88
E	4.7	9.5	2.3	0.3		16.8	478	6.5	81
SE	3.5	12.5	1.2	0.1		17.3	493	5.9	74
S	2.3	15.1	2.8	0.4		20.6	589	7.2	90
SW	0.8	8.8	4.4	0.7		14.7	421	9.6	120
W	1.3	4.7	2.1	0.6		8.7	248	8.9	111
NW	0.6	5.3	6.7	2.1		14.7	420	12.0	150
Calm	0.9					0.9	27		
Totals	15.2	59.7	20.8	4.2		99.9	2853	Mean 8.0	
(b) Southampton - same 2 years									
N	1.4	2.3	1.4			5.1	181	7.4	116
NE	1.2	8.0	4.0	0.5		13.7	486	8.8	138
E	6.0	5.0	0.4			11.4	403	3.9	61
SE	4.6	5.2	0.2			10.0	353	4.2	66
S	8.3	9.3	0.6			18.2	644	4.1	64
SW	2.9	12.5	4.2	0.3		19.9	709	7.6	119
W	0.8	1.8	0.8			3.4	120	6.9	108
NW	1.6	10.0	5.3	0.1		17.0	603	8.6	134
Calm	1.2					1.2	43		
Totals	28.0	54.1	16.9	0.9		99.9	3542	Mean 6.4	
(c) Southampton - 5 years									
N	1.0	2.2	1.1	0.1		4.4	408	7.8	107
NE	0.9	7.0	3.4	0.3		11.6	1085	8.7	119
E	4.8	4.2	0.4			9.4	872	4.1	56
SE	4.3	6.3	0.4	0.0		11.0	1040	4.6	63
S	6.9	8.0	0.5			15.4	1444	4.3	59
SW	2.7	14.0	7.1	1.5	0.2	25.5	2381	9.1	125
W	0.8	1.5	1.0	0.2		3.5	326	8.3	114
NW	1.1	10.1	7.0	0.5	0.1	18.8	1753	9.6	132
Calm	0.7					0.7	64		
Totals	23.2	53.3	20.9	2.6	0.3	100.3	9373	Mean 7.3	

TABLE XV

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

FALL: 0200-0900 EST

Wind Direction	Speed, mph 0-3	4-10	11-17	18-24	≥25	Total Observations %	No.
(a) Douglas Point 2 years							
N	0.3	2.3	1.0			3.6	34
NE	0.1	0.5	0.2			0.8	8
E	5.2	10.2	2.2			17.6	166
SE	4.0	18.1	1.4	0.2		23.7	224
S	3.3	18.0	2.4	0.4		24.1	228
SW	0.3	3.4	2.4	0.5		6.6	63
W	0.8	2.1	3.3	0.3		6.5	62
NW	0.4	5.5	7.6	2.5		16.0	152
Calm	0.8					0.8	8
Totals	15.2	60.1	20.5	3.9		99.7	945
(b) Southampton - same 2 years							
N	0.2	1.4	2.0			3.6	43
NE	1.1	7.7	3.7	0.3		12.8	152
E	7.9	5.7				13.6	160
SE	6.7	6.4	0.4			13.5	159
S	10.2	12.2	0.7			23.1	272
SW	2.7	8.3	2.7			13.7	162
W	0.3	1.4	0.8			2.5	29
NW	0.2	9.1	6.1			15.4	181
Calm	1.5					1.5	
Totals	30.8	52.2	16.4	0.3		99.7	1176
(c) Southampton - 5 years							
N	0.6	1.7	1.3	0.0		3.6	116
NE	1.2	6.8	3.2	0.3		11.5	359
E	6.3	4.9	0.2			11.4	357
SE	6.0	8.0	0.2			14.2	443
S	9.2	10.0	0.3			19.5	607
SW	2.3	11.0	5.8	1.2	0.4	20.7	642
W	0.3	1.1	0.8	0.2		2.4	74
NW	0.4	8.0	7.0	0.4		15.8	494
Calm	0.9					0.9	28
Totals	27.2	51.5	18.8	2.1	0.4	100.0	3120

TABLE XVI

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

FALL: 1000-1700 EST

Wind Direction	Speed, mph 0-3	4-10	11-17	18-24	≥25	Total Observations %	No.
(a) Douglas Point 2 years							
N	0.3	2.8	0.4			3.5	34
NE	0.5	2.0	0.5			3.0	29
E	2.1	8.6	3.6	0.3		14.6	139
SE	1.8	7.8	1.4			11.0	104
S	0.9	9.0	4.0	0.4		14.3	137
SW	1.3	18.6	6.6	0.2		26.7	254
W	1.2	8.0	1.4	0.6		11.2	106
NW	0.7	7.5	5.8	1.5		15.5	147
Calm	0.3					0.3	3
Totals	9.1	64.3	23.7	3.0		100.1	953
(b) Southampton - same 2 years							
N	3.0	3.0	1.0			7.0	83
NE	1.3	6.6	4.5	0.8		13.2	155
E	2.1	4.2	1.0			7.3	87
SE	1.9	4.4	0.3			6.6	77
S	3.0	6.3	0.6			9.9	118
SW	2.1	20.9	5.7	0.4		29.1	345
W	1.0	2.5	0.3			3.8	46
NW	4.0	14.1	4.5	0.1		22.7	268
Calm	0.4					0.4	5
Totals	18.8	62.0	17.9	1.3		100.0	1184
(c) Southampton - 5 years							
N	1.5	3.1	1.0	0.1		5.7	180
NE	0.6	6.5	4.0	0.3		11.4	356
E	1.2	3.6	0.6			5.4	168
SE	1.5	5.0	0.8			7.3	230
S	2.2	5.8	0.6			8.6	270
SW	2.0	20.7	9.1	1.6	0.2	33.6	1050
W	0.9	2.4	0.9	0.2		4.4	138
NW	2.4	14.1	6.6	0.2	0.1	23.4	730
Calm	0.2					0.2	6
Totals	12.5	61.2	23.6	2.4	0.3	100.0	3128

TABLE XVII

PERCENTAGE FREQUENCY OF OCCURRENCES OF WINDS IN EIGHT DIRECTIONS GROUPED ACCORDING TO WIND SPEEDS

Douglas Point at 33 feet, Southampton at 35 feet

FALL: 1800-0100 EST

Wind Direction	Speed, mph 0-3	4-10	11-17	18-24	≥25	Total Observations %	No.
(a) Douglas Point 2 years							
N	1.0	1.8	1.0			3.8	37
NE	0.9	2.0	0.7			3.6	35
E	6.7	9.7	1.0	0.6		18.0	173
SE	4.6	11.7	0.8	0.1		17.2	165
S	2.6	18.4	2.0	0.4		23.4	224
SW	0.7	4.4	4.2	1.6		10.9	104
W	1.9	3.9	1.7	0.9		8.4	80
NW	0.5	3.0	6.8	2.3		12.6	121
Calm	1.7					1.7	16
Totals	20.6	54.9	18.2	5.9		99.6	955
(b) Southampton - same 2 years							
N	1.1	2.4	1.2			4.7	55
NE	1.2	9.8	3.6	0.5		15.1	179
E	8.0	5.1	0.1			13.2	156
SE	5.2	4.7				9.9	117
S	11.6	9.4	0.5			21.5	254
SW	4.0	8.3	4.2	0.6		17.1	202
W	1.3	1.4	1.2			3.9	45
NW	0.8	6.8	5.2	0.3		13.1	154
Calm	1.7					1.7	20
Totals	34.9	47.9	16.0	1.4		100.2	1183
(c) Southampton - 5 years							
N	0.7	1.7	0.9	0.2		3.5	112
NE	1.0	7.7	2.8	0.3		11.8	370
E	6.8	4.0	0.4			11.2	347
SE	5.5	6.0	0.2	0.1		11.8	367
S	9.3	8.3	0.5			18.1	567
SW	3.8	10.2	6.3	1.7	0.2	22.2	689
W	1.2	1.0	1.2	0.3		3.7	114
NW	0.6	8.1	7.4	0.7	0.1	16.9	529
Calm	1.0					1.0	30
Totals	29.9	47.0	19.7	3.3	0.3	100.2	3126

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TABLE XVIII

PERCENTAGE FREQUENCY OF WIND DIRECTIONS AT DOUGLAS POINT AND SOUTHAMPTON AS RELATED TO THE SHORELINE AT DOUGLAS POINT

Annual and Season Summaries

Location	Period	Off-lake SW, W, NW, N	On-land W, NW	Off-land E, SE	Shoreline NE, S	Calm
Annual Summary						
Douglas Point	2 years	51.9	23.9	21.2	25.2	1.4
Southampton	same 2 years	53.1	23.3	19.2	25.8	2.1
Southampton	5 years	54.2	23.1	20.5	24.1	1.3
Winter (Dec., Jan., Feb.)						
Douglas Point	2 years	59.0	30.1	21.3	19.2	0.7
Southampton	same 2 years	54.6	25.7	16.9	27.6	0.8
Southampton	5 years	51.9	23.7	20.7	26.9	0.4
Spring (Mar., Apr., May)						
Douglas Point	2 years	51.7	20.3	18.5	27.8	2.1
Southampton	same 2 years	55.3	23.6	20.1	23.0	1.7
Southampton	5 years	52.7	23.4	22.4	23.7	0.9
Summer (June, July, Aug.)						
Douglas Point	2 years	52.9	22.2	15.3	30.0	1.7
Southampton	same 2 years	55.7	22.4	19.0	20.5	4.8
Southampton	5 years	60.0	22.4	18.1	18.7	3.1
Fall (Sept., Oct., Nov.)						
Douglas Point	2 years	41.8	23.4	34.1	23.1	0.9
Southampton	same 2 years	45.4	20.4	21.4	31.9	1.2
Southampton	5 years	52.2	22.3	20.4	27.0	0.7

TABLE XIX

PERCENTAGE FREQUENCY OF WIND DIRECTIONS AT DOUGLAS POINT AND SOUTHAMPTON AS RELATED TO SHORELINE AT DOUGLAS POINT

Season: Winter

Location	Period	Off-lake SW, W, NW, N	On-Land W, NW	Off-land E, SE	Shoreline NE, S	Calm
Time: Whole Day						
Douglas Point	2 years	59.0	30.1	21.3	19.2	0.7
Southampton	same 2 years	54.6	25.7	16.9	27.6	0.8
Southampton	5 years	51.9	23.7	20.7	26.9	0.4
Time: 0200-0900 EST						
Douglas Point	2 years	53.9	28.6	24.6	20.1	1.4
Southampton	same 2 years	48.6	23.4	19.1	31.6	0.8
Southampton	5 years	46.1	21.3	23.1	30.1	0.5
Time: 1000-1700 EST						
Douglas Point	2 years	64.6	30.5	16.2	19.2	0.2
Southampton	same 2 years	61.4	26.6	14.3	23.7	0.6
Southampton	5 years	57.2	24.8	18.5	24.2	0.3
Time: 1800-0100 EST						
Douglas Point	2 years	58.1	30.9	23.0	18.3	0.7
Southampton	same 2 years	53.8	27.0	17.3	27.7	1.1
Southampton	5 years	52.8	25.2	20.7	26.1	0.5

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TABLE XX

PERCENTAGE FREQUENCY OF WIND DIRECTIONS AT DOUGLAS POINT AND SOUTHAMPTON AS RELATED TO SHORELINE AT DOUGLAS POINT

Season: Spring

Location	Period	Off-lake SW, W, NW, N	On-land W, NW	Off-land E, SE	Shoreline NE, S	Calm
Time: Whole Day						
Douglas Point	2 years	51.7	20.3	18.5	27.8	2.1
Southampton	same 2 years	55.3	23.6	20.1	23.0	1.7
Southampton	5 years	52.7	23.4	22.4	23.7	0.9
Time: 0200-0900 EST						
Douglas Point	2 years	42.9	15.9	23.9	30.4	2.7
Southampton	same 2 years	43.5	16.4	27.3	27.4	1.8
Southampton	5 years	41.5	16.5	28.8	28.5	1.0
Time: 100-1700 EST						
Douglas Point	2 years	70.3	28.6	11.2	18.1	0.3
Southampton	same 2 years	70.9	35.3	12.3	16.5	0.2
Southampton	5 years	68.1	34.1	15.3	16.6	0.1
Time: 1800-0100 EST						
Douglas Point	2 years	42.0	16.5	20.1	34.6	3.3
Southampton	same 2 years	50.9	19.1	21.0	25.1	2.9
Southampton	5 years	48.5	19.5	23.6	26.5	1.5

TABLE XXI

PERCENTAGE FREQUENCY OF WIND DIRECTIONS AT DOUGLAS POINT AND SOUTHAMPTON AS RELATED TO THE SHORELINE AT DOUGLAS POINT

Season: Summer

Location	Period	Off-lake SW, W, NW, N	On-land W, NW	Off-land E, SE	Shoreline NE, S	Calm
Time: Whole Day						
Douglas Point	2 years	52.9	22.2	15.3	30.0	1.7
Southampton	same 2 years	55.7	22.4	19.0	20.5	4.8
Southampton	5 years	60.0	22.4	18.1	18.7	3.1
Time: 0200-0900 EST						
Douglas Point	2 years	38.1	18.0	23.1	36.2	2.7
Southampton	same 2 years	42.1	15.0	27.6	25.5	4.9
Southampton	5 years	47.2	15.3	25.6	23.8	3.3
Time: 1000-1700 EST						
Douglas Point	2 years	79.8	33.0	4.1	16.2	0.1
Southampton	same 2 years	76.0	36.3	7.4	13.0	3.6
Southampton	5 years	82.2	36.2	5.4	10.5	1.9
Time: 1800-0100 EST						
Douglas Point	2 years	41.3	15.9	18.5	37.7	2.4
Southampton	same 2 years	49.2	16.2	21.8	23.1	5.8
Southampton	5 years	51.0	15.9	23.2	21.6	4.1

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TABLE XXII

PERCENTAGE FREQUENCY OF WIND DIRECTIONS AT DOUGLAS POINT AND SOUTHAMPTON AS RELATED TO THE SHORELINE AT DOUGLAS POINT

Season: Fall

Location	Period	Off-lake SW, W, NW, N	On-Land W, NW	Off-land E, SE	Shoreline NE, S	Calm
Time: Whole Day						
Douglas Point	2 years	41.8	23.4	34.1	23.1	0.9
Southampton	same 2 years	45.4	20.4	21.4	31.9	1.2
Southampton	5 years	52.2	22.3	20.4	27.0	0.7
Time: 0200-0900 EST						
Douglas Point	2 years	32.7	22.5	41.3	24.9	0.8
Southampton	same 2 years	35.2	17.9	27.1	36.1	1.5
Southampton	5 years	42.5	18.2	25.6	31.0	0.9
Time: 1000-1700 EST						
Douglas Point	2 years	56.9	26.7	25.6	17.3	0.3
Southampton	same 2 years	62.6	26.5	13.9	23.1	0.4
Southampton	5 years	67.1	27.8	12.7	20.0	0.2
Time: 1800-0100 EST						
Douglas Point	2 years	35.7	21.0	35.2	27.0	1.7
Southampton	same 2 years	38.8	17.0	23.1	36.6	1.7
Southampton	5 years	46.3	20.6	23.0	29.9	1.0

TABLE XXIII

THE ASSOCIATION OF WIND WITH RAIN AT DOUGLAS POINT

(2 years, July 1961 - June 1963)

Direction	Average Wind Speed, mph	Average Wind Speed During Rain	No. of Observations During Rain	Hours of Rain as % of Total Hours of Rain	Hours of Rain as % of Total Hours
(a) Spring (March, April, May)					
N	6.0	4.0	3	2.6	0.1
NE	7.3	8.8	33	28.7	1.0
E	3.7	5.6	5	4.3	0.1
SE	6.9	8.5	29	25.2	0.8
S	6.4	7.2	15	13.0	0.4
SW	7.9	7.4	19	16.5	0.6
W	5.2	7.0	3	2.6	0.1
NW	8.5	9.1	8	7.0	0.2
Calm	0.0	0.0	0	0.0	0.0
Totals			115	99.9	3.3
Averages	6.8	8.0			
(b) Summer (June, July, August)					
N	5.5	4.5	11	6.7	0.3
NE	5.7	5.7	34	20.9	0.8
E	2.9	5.0	8	4.9	0.2
SE	5.0	3.5	28	17.2	0.6
S	5.3	6.3	31	19.0	0.7
SW	6.8	7.8	29	17.8	0.7
W	5.6	6.9	7	4.3	0.2
NW	7.3	7.9	15	9.2	0.3
Calm	0.0	0.0	0	0.0	0.0
Totals			163	100.0	3.8
Averages	5.8	6.3			
(c) Fall (Sept., Oct., Nov.)					
N	7.2	13.0	3	1.5	0.1
NE	7.0	14.0	1	0.5	0.0
E	6.5	8.5	46	22.4	1.6
SE	5.9	5.4	37	18.0	1.3
S	7.2	7.9	40	19.5	1.4
SW	9.6	12.1	27	13.2	1.0
W	8.9	10.3	21	10.2	0.7
NW	12.0	13.0	27	13.2	1.0
Calm	0.0	0.0	3	1.5	0.1
Totals			205	100.0	7.2
Averages	8.0	9.0			

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TABLE XXIV

THE ASSOCIATION OF WIND WITH RAIN AT DOUGLAS POINT
AS RELATED TO THE SHORELINE

(2 years, July 1961 - June 1963)

Season	Off-lake SW, W, NW, N		Off-land E, SE		Shoreline NE, S		Calm	
	Hours of Rain as % of		Hours of Rain as % of		Hours of Rain as % of		Hours of Rain as % of	
	Total Hours of Rain	Total Hours	Total Hours of Rain	Total Hours	Total Hours of Rain	Total Hours	Total Hours of Rain	Total Hours
Spring	28.7	1.0	29.7	0.9	41.7	1.4	0	0
Summer	38.0	1.5	22.1	0.8	39.9	1.5	0	0
Fall	38.1	2.8	40.4	2.9	20.0	1.4	1.5	1

TABLE XXV

DURATION OF CALMS AND LIGHT WINDS (0-3 mph)

Average Number of Occurrences Each Month Arrayed by Hour Classes

Months	Hour Classes									
	5-8	9-12	13-16	17-20	21-24	25-30	31-36	37-42	43-48	49-54
(a) Douglas Point - 2 years										
January	1.0									
February	5.5	1.0	1.0							
March	7.0	3.0	3.0	1.0						
April	5.5	1.5	1.5							
May	5.5	3.0	3.0	0.5						
June	9.0	4.0	2.0	2.0	0.5	0.5				
July	8.5	3.0	4.5							
August	5.5	3.0	2.0	0.5						
September	2.0	2.5	0.5	1.0						
October	2.5	3.0	0.5		0.5					
November	4.5	1.5	1.0							
December	2.5	1.0								
(b) Southampton - same 2 years										
January	2.0	2.0								
February	4.5	1.5	0.5	1.0	0.5			1.0		
March	6.0	3.5	3.5			0.5	0.5			
April	5.0	3.5	2.5	0.5						
May	8.5	4.0	3.0	3.0	0.5					
June	8.0	6.0	6.0	5.0	1.0			1.0		
July	8.0	8.0	5.5	3.5	0.5		1.0			0.5
August	6.5	3.0	6.5	4.5	1.0	0.5	0.5	0.5		
September	4.0	3.0	5.0	4.0		1.0	1.0			
October	5.0	6.0	3.5	1.0	0.5			0.5		0.5
November	6.5	2.0	0.5	0.5	1.0					
December	5.0	2.0	1.0	0.5			0.5			
(c) Southampton - 5 years										
January	4.2	1.0	0.6	0.2	0.2					
February	5.0	1.4	0.8	0.8	0.2	0.2		0.4		
March	5.2	3.4	2.4	0.6		0.2	0.2			
April	6.6	2.6	2.0	0.2						
May	7.4	3.2	3.0	2.4	0.2	0.2				
June	6.5	5.0	4.5	3.5	0.5	0.5		0.3		
July	7.4	8.0	7.2	3.2	0.4		0.4			0.2
August	7.8	4.0	5.8	2.8	0.8	0.6	0.4	0.2		
September	8.0	2.7	5.3	3.3	0.3	0.7	0.3			
October	5.0	4.2	2.4	1.6	0.4			0.2		0.2
November	4.4	1.2	0.6	0.2	0.4					
December	3.6	1.4	0.8	0.4			0.4			

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TABLE XXVI

DURATION OF WINDS 10 MPH OR GREATER
ALL DIRECTIONS
Average Number of Occurrences Each Month Arrayed by Hour Classes

Months	Hour Classes												
	7-12	13-18	19-24	25-30	31-36	37-42	43-48	49-60	61-72	73-84	85-96	97-120	>120
(a) Douglas Point 2 years													
Jan.	1.0		1.0	3.0	1.0		1.0	1.0		1.0	1.0	1.0	
Feb.	5.5	3.0	2.0	1.5	0.5			0.5					
Mar.	3.0		1.0										
Apr.	3.5	1.0	3.5	2.5									
May	4.5	3.5	0.5										
June	1.5	0.5	0.5		0.5								
July	3.0		1.0				0.5						
Aug.	2.5	0.5	1.5										
Sept.	3.5	1.5	1.0	1.0	0.5	0.5				0.5			
Oct.	5.0	2.0	2.0				1.0						
Nov.	2.5	1.0			0.5	0.5	0.5	1.0		0.5			
Dec.	2.5	1.0	2.0	0.5	0.5		1.5	1.0		0.5			0.5
(b) Southampton - same 2 years													
Jan.	2.0	1.5	0.5	1.5	1.5	0.5	2.5			1.0			
Feb.	5.0	3.0	2.0	0.5		0.5							
Mar.	3.5	2.0	2.5	0.5									
Apr.	6.5	3.0	1.0	2.0									
May	4.0	0.5	1.0										
June	3.0												
July	1.0	0.5	0.5										
Aug.	1.0	1.0											
Sept.	2.0	0.5	0.5	0.5									
Oct.	3.5	1.5	0.5	1.0		0.5							
Nov.	1.0	2.0		0.5		0.5	0.5	1.5					
Dec.	4.5	2.5		2.0			0.5	1.0	0.5	0.5			
(c) Southampton - 5 years													
Jan.	2.4	1.6	1.6	1.0	1.0	0.6	1.4	0.2	0.2	0.4		0.2	
Feb.	4.6	2.2	2.2	1.0	0.4	0.8	0.2						
Mar.	4.4	1.6	2.0	0.8	0.2		0.2	0.6	0.2				
Apr.	6.8	2.8	1.2	1.0	0.6	0.2							
May	4.2	1.4	0.6	0.6	0.2								
June	2.5	0.8	0.8		0.3								
July	2.2	0.2	0.4										
Aug.	2.8	0.8		0.2									
Sept.	2.4	0.4	0.2	0.2	0.4								
Oct.	3.8	1.4	0.8	0.6		0.4		0.8					
Nov.	3.4	2.6	1.0	1.0	0.2	0.2	1.0	0.8			0.2	0.4	
Dec.	3.8	2.6	0.8	1.6	1.2	0.2	0.2	0.6	0.6	0.2		0.2	

TABLE XXVII

DURATIONS OF WINDS 10 MPH OR GREATER
SOUTH AND SOUTHEAST DIRECTIONS ONLY

Average Number of Occurrences Each Month Arrayed by Hour Classes

	(a) Douglas Point - 2 years			(b) Southampton - same 2 years			(c) Southampton - 5 years		
Months	Hour Classes								
	7-12	13-18	18-24	7-12	13-18	18-24	7-12	13-18	18-24
Jan.				0.5			0.2		
Feb.				0.5			0.2		
Mar.	0.5			0.5			0.6		
Apr.	0.5	0.5		0.5			0.2		
May	0.5								
June									
July									
Aug.									
Sept.	1.0	0.5	0.5						
Oct.									
Nov.	1.0					0.5			0.2
Dec.	0.5			0.5			0.2		

TABLE 1 (Appendix 1)

COMPARISON OF CONDITIONAL WIND FREQUENCIES (WITH RAIN)
TO SIMPLE FREQUENCIES
Douglas Point;- 2 years, July 1961-June 1963

Direction	No. of Observations During Rain	Total No. of Observations	95% limits ($np \pm 2$ n.p.q.)
(a) Spring (March, April, May)			
N	3	262	3.0 to 14.6
NE	33	540	9.8 to 26.4
E	5	239	2.5 to 13.5
SE	29	394	6.1 to 20.3
S	15	414	6.5 to 21.1
SW	19	816	14.9 to 39.7
W	3	204	1.7 to 11.9
NW	8	495	8.6 to 24.6
Calm	0	72	1.4 to 3.4
Totals	115	3436	
(b) Summer (June, July, August)			
N	11	452	9.0 to 25.3
NE	34	491	10.2 to 27.2
E	8	208	2.4 to 13.4
SE	28	448	9.0 to 25.2
S	31	796	20.1 to 42.0
SW	29	868	21.7 to 44.3
W	7	287	3.4 to 17.4
NW	15	671	15.6 to 35.4
Calm	0	74	0 to 6.2
Totals	163	4295	
(c) Fall (Sept. Oct., Nov.)			
N	3	105	1.0 to 10.2
NE	1	72	0 to 7.6
E	46	478	15.6 to 35.2
SE	37	493	16.3 to 36.2
S	40	589	20.3 to 42.5
SW	27	421	13.2 to 31.6
W	21	248	6.1 to 20.3
NW	27	420	13.2 to 31.5
Calm	3	27	0 to 3.8
Totals	205	3853	

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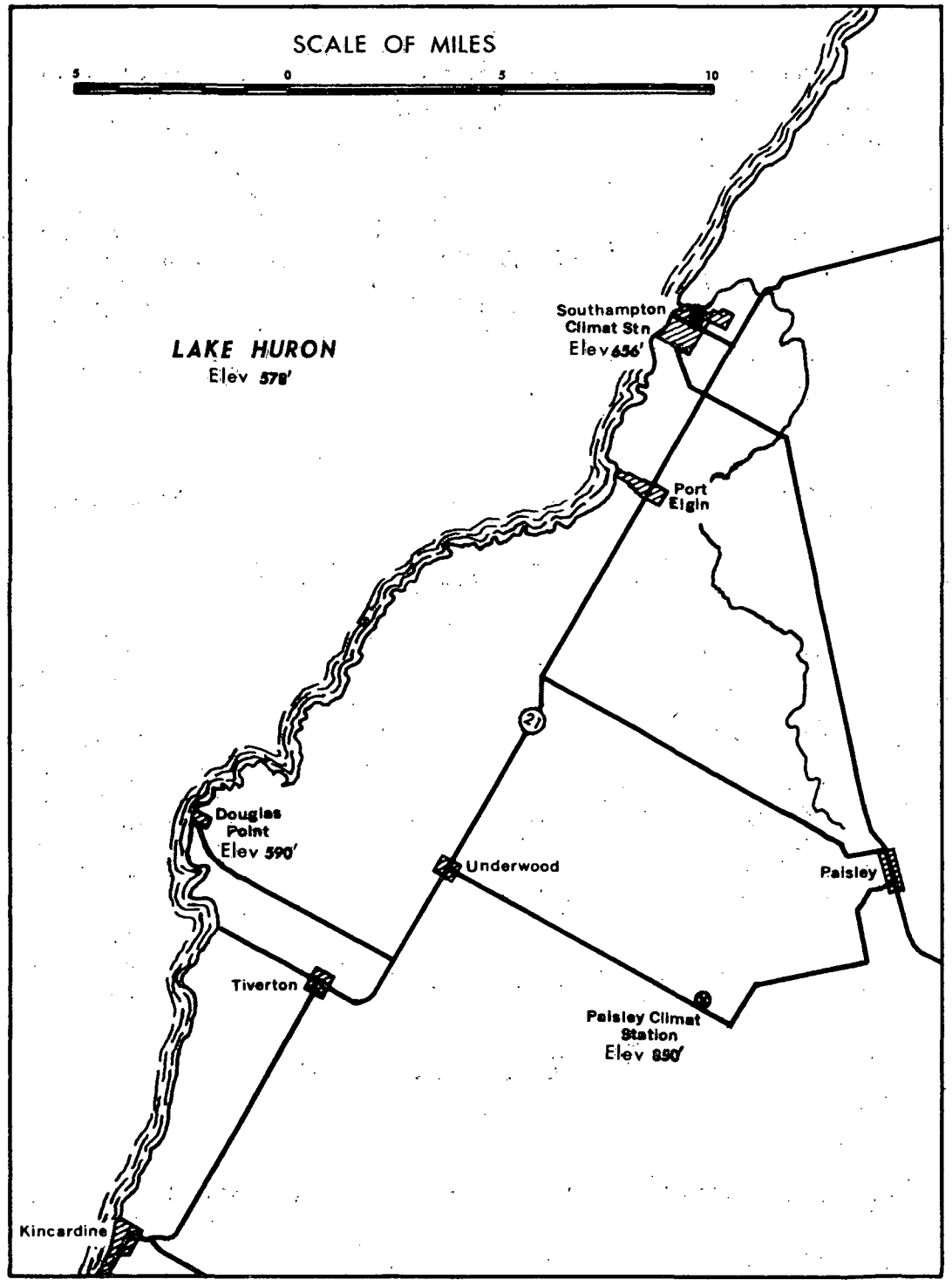

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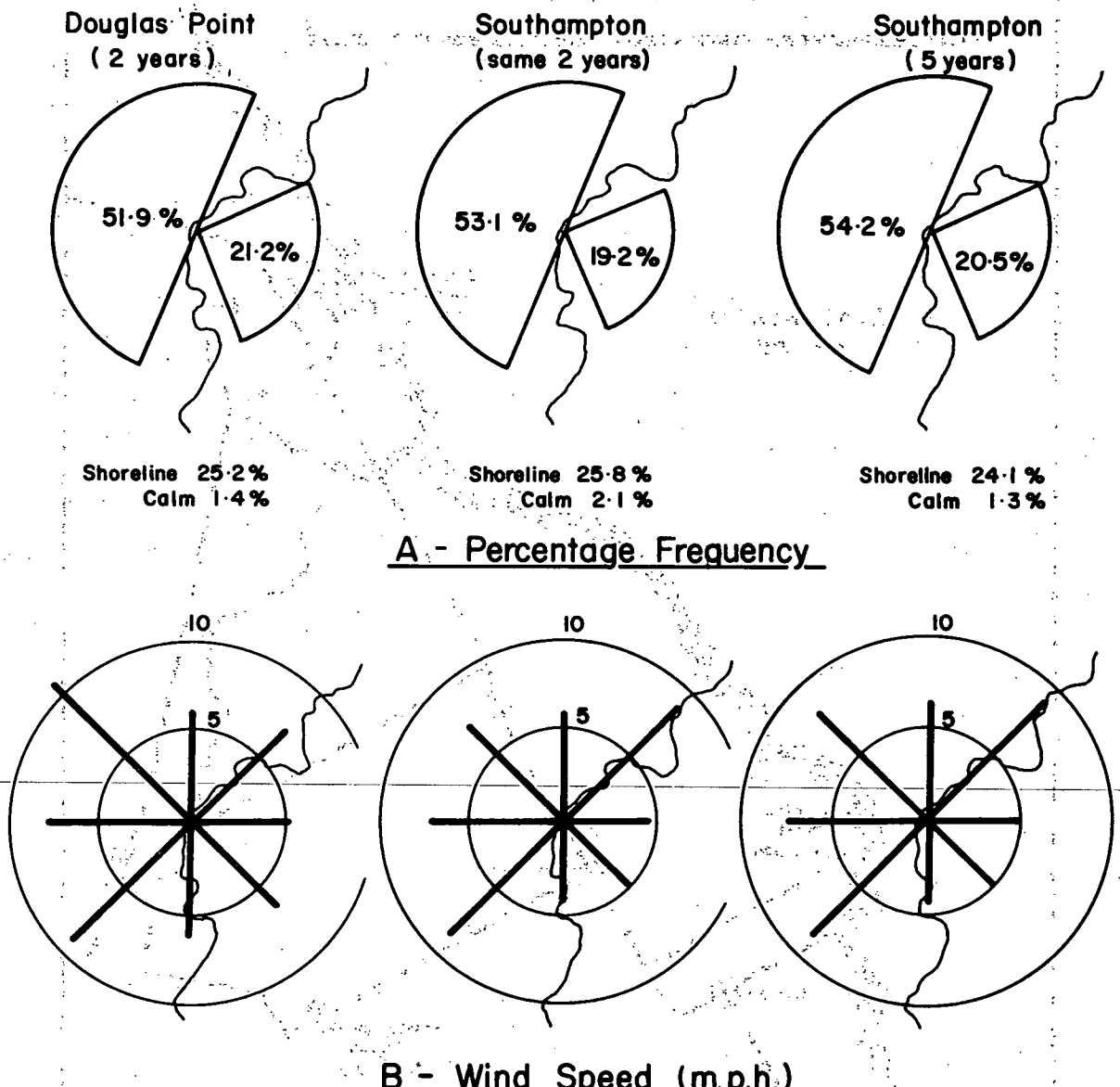

Figure 2. Comparison of mean annual Wind.

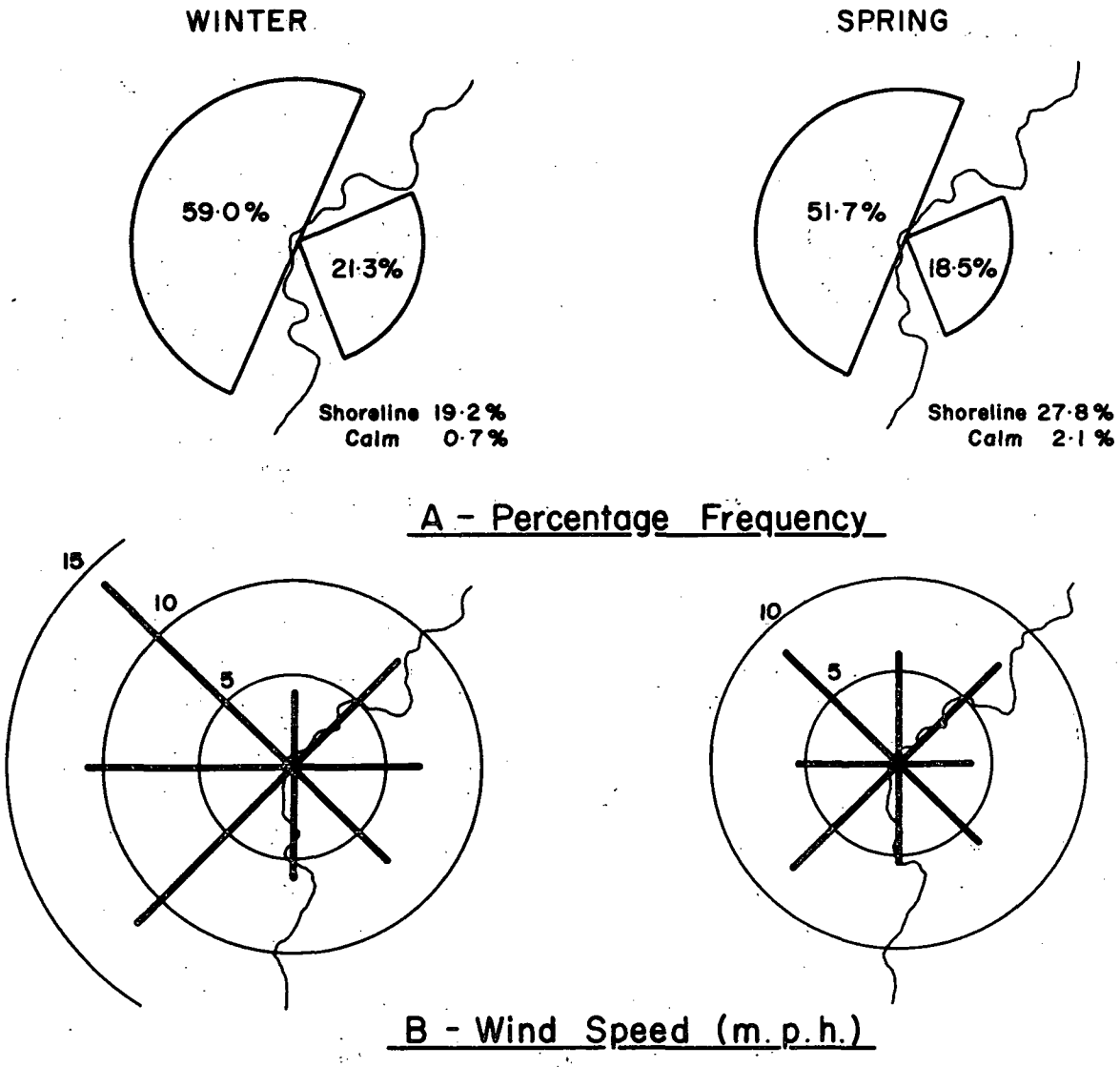

Figure 3. Winds at Douglas Point (2 years) by Seasons.

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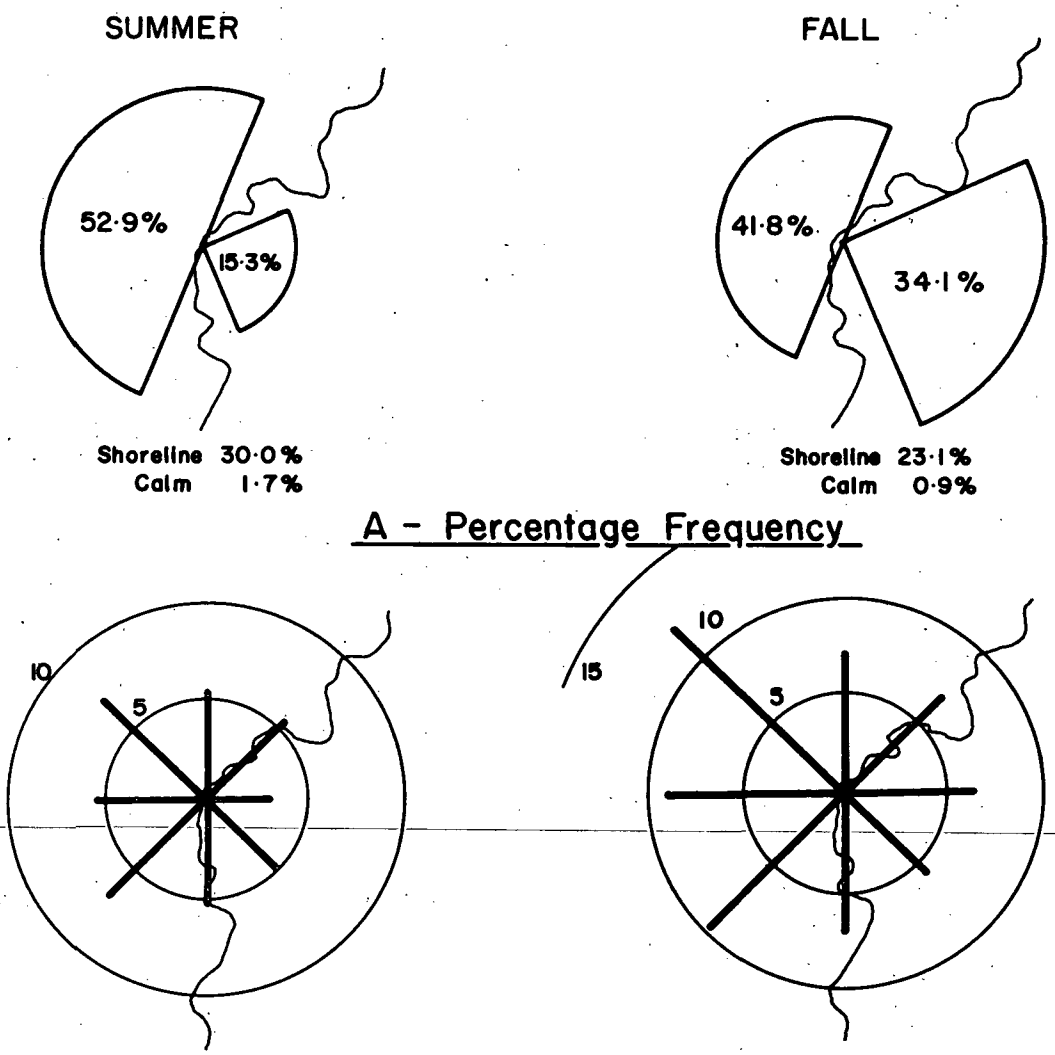

Figure 4. Winds at Douglas Point (2 years) by Season.

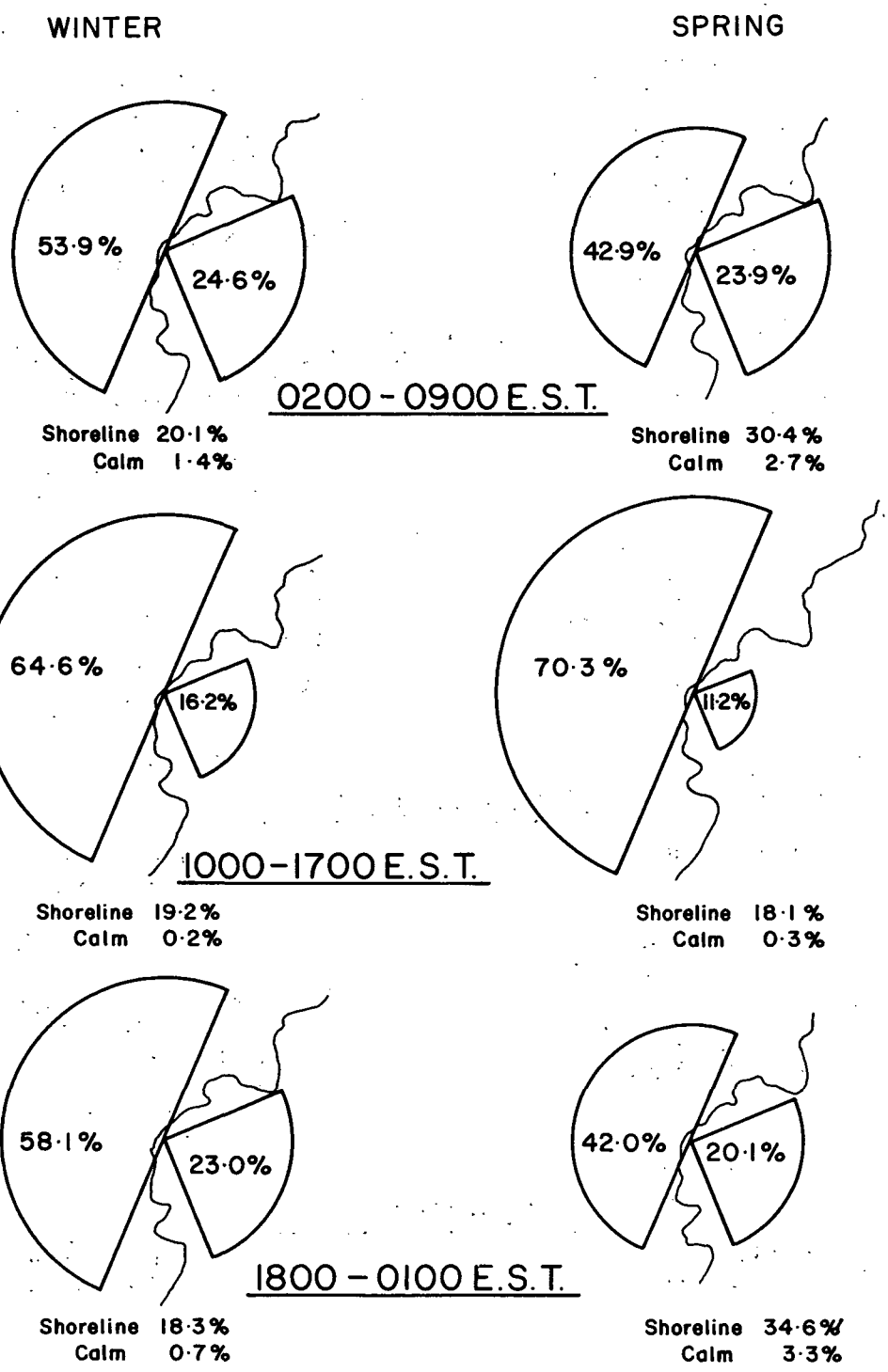

Figure 5. Diurnal Variation of Wind Frequencies at Douglas Point.

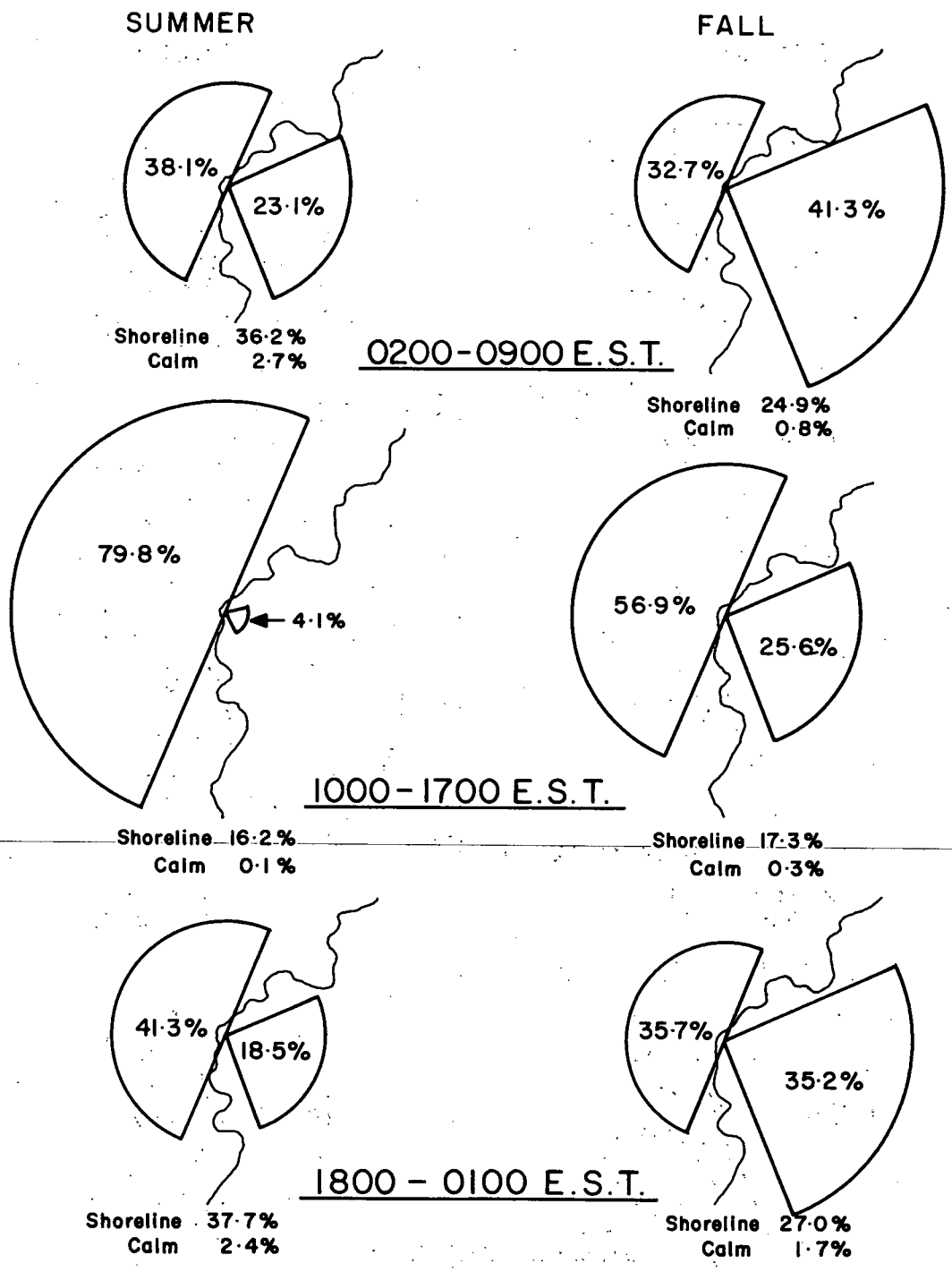

Figure 6. Diurnal Variation of Wind Frequencies at Douglas Point.

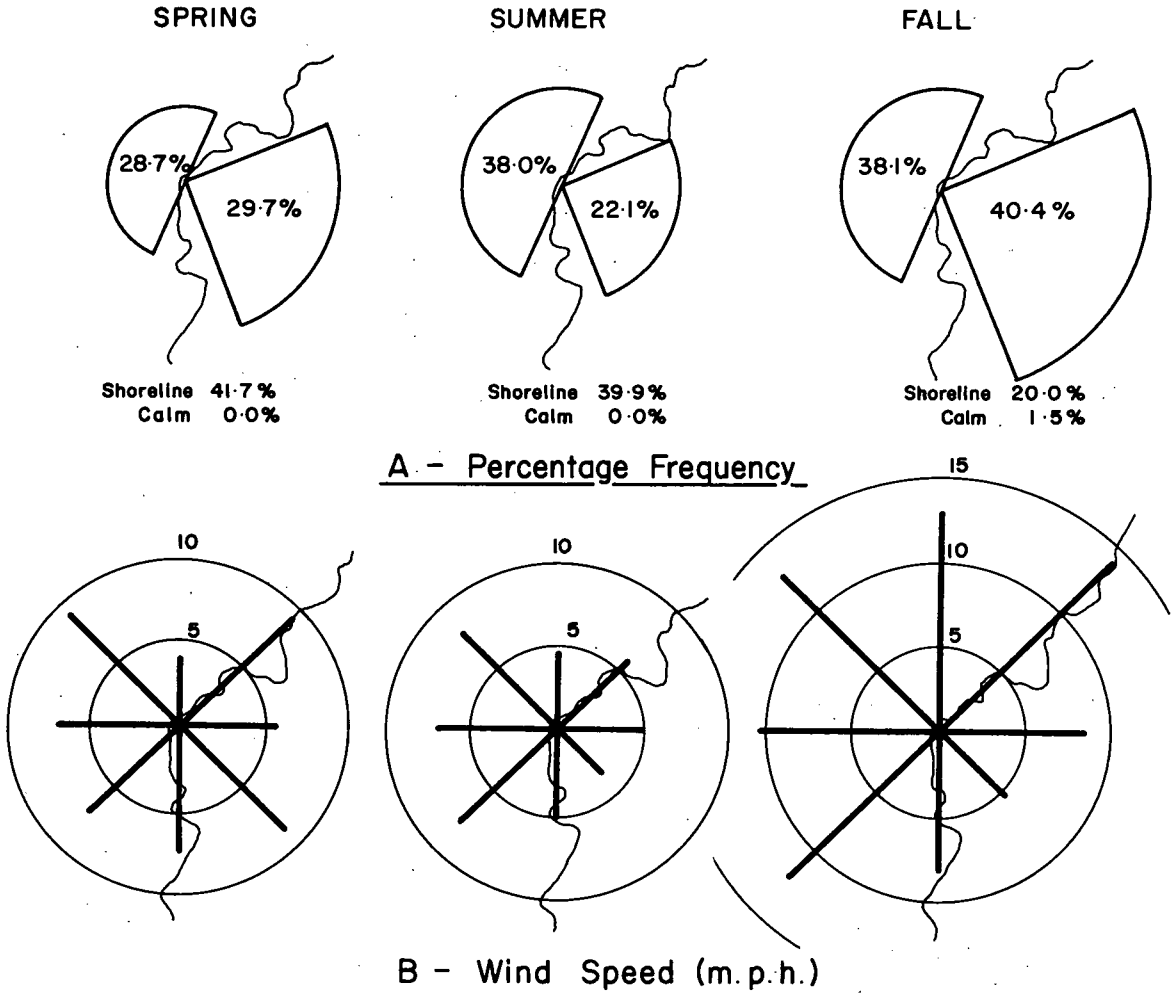

Figure 7. Association of Wind with Rain at Douglas Point.

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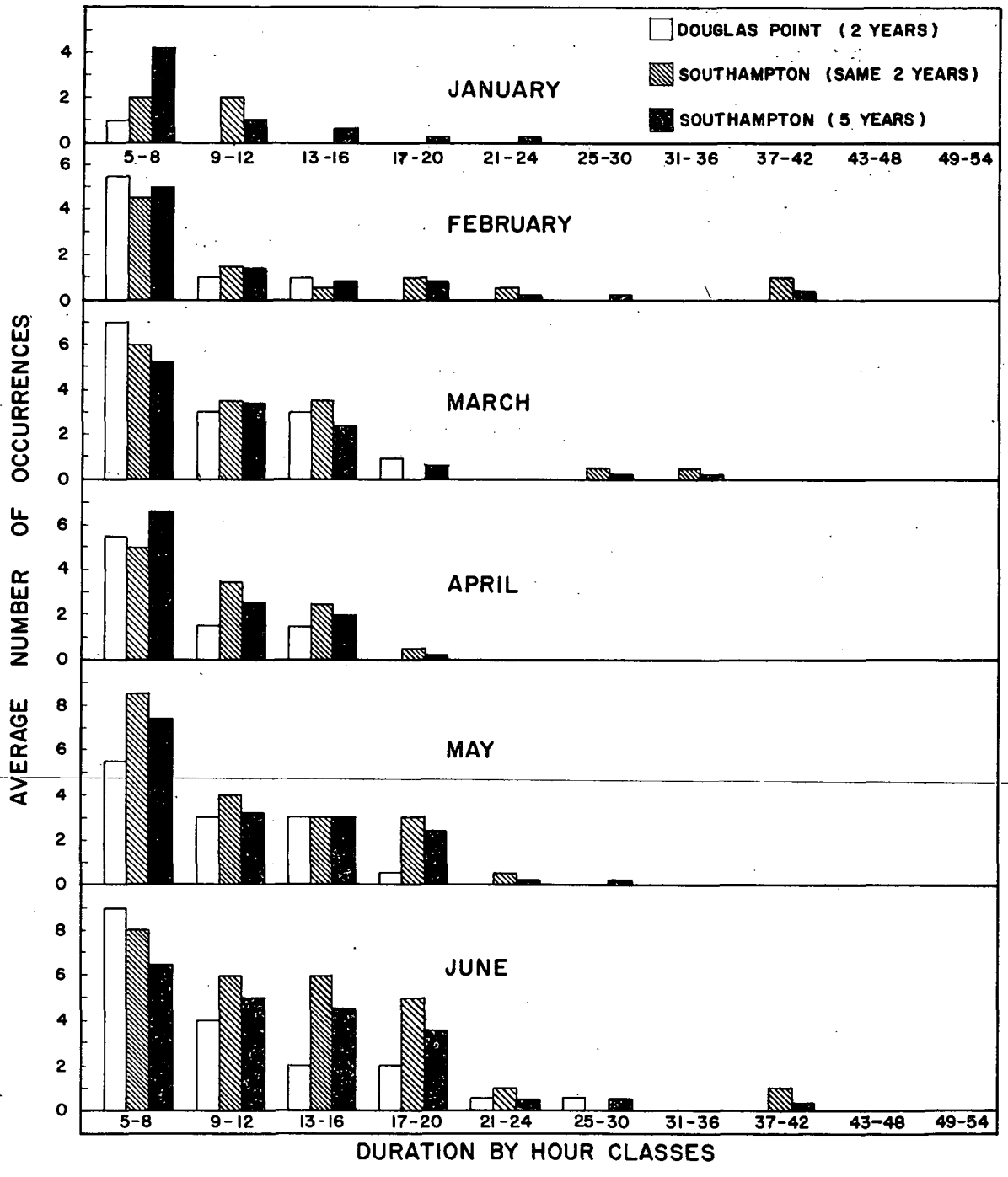

Figure 8. Duration of calms and light winds (0 - 3 M. P. H.) Douglas Point and Southampton.

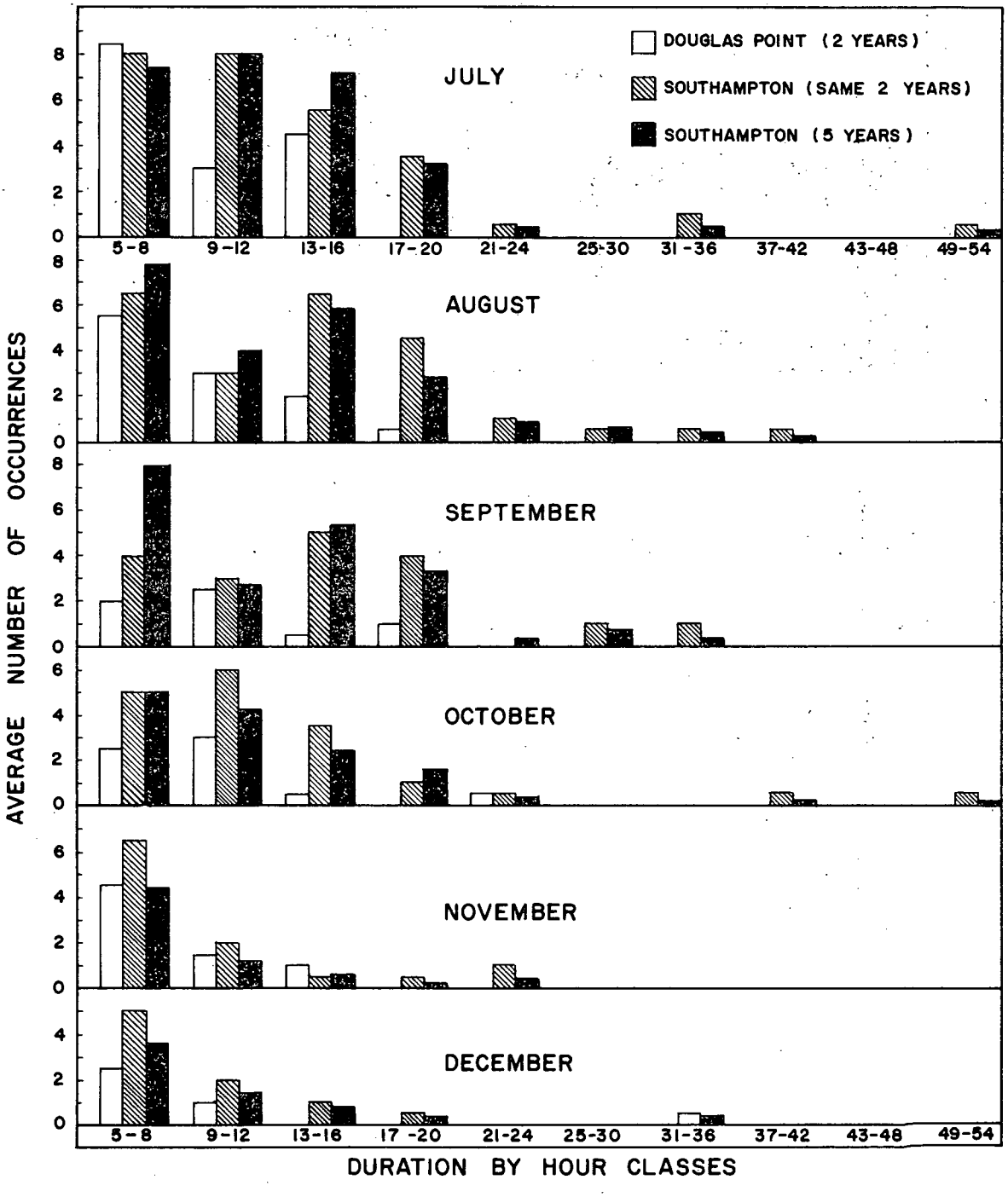

Figure 9. Duration of calms and light winds (0-3 M.P.H.) Douglas Point and Southampton.

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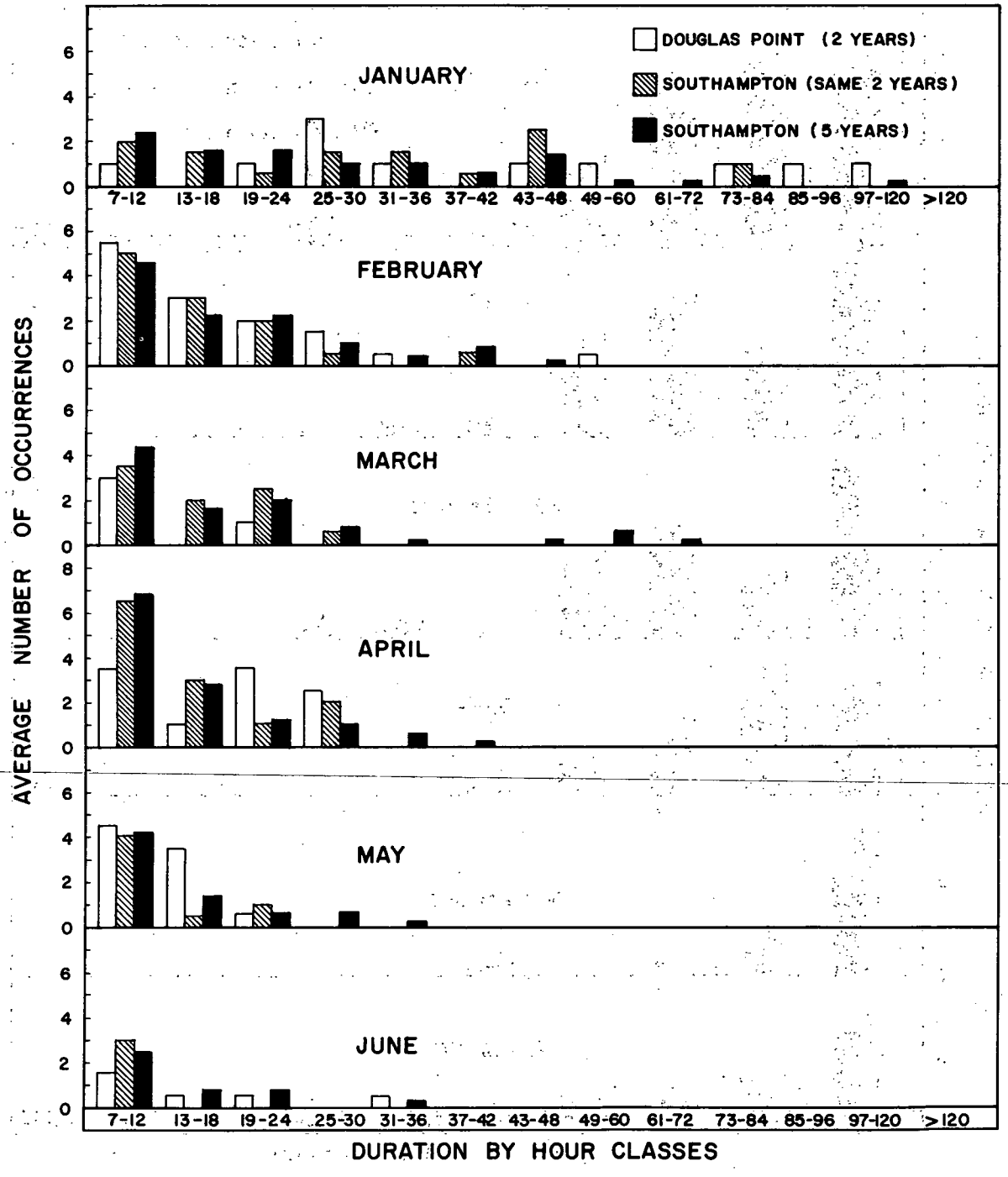

Figure 10. Duration of winds ≥10 M.P.H. at Douglas Point and Southampton.

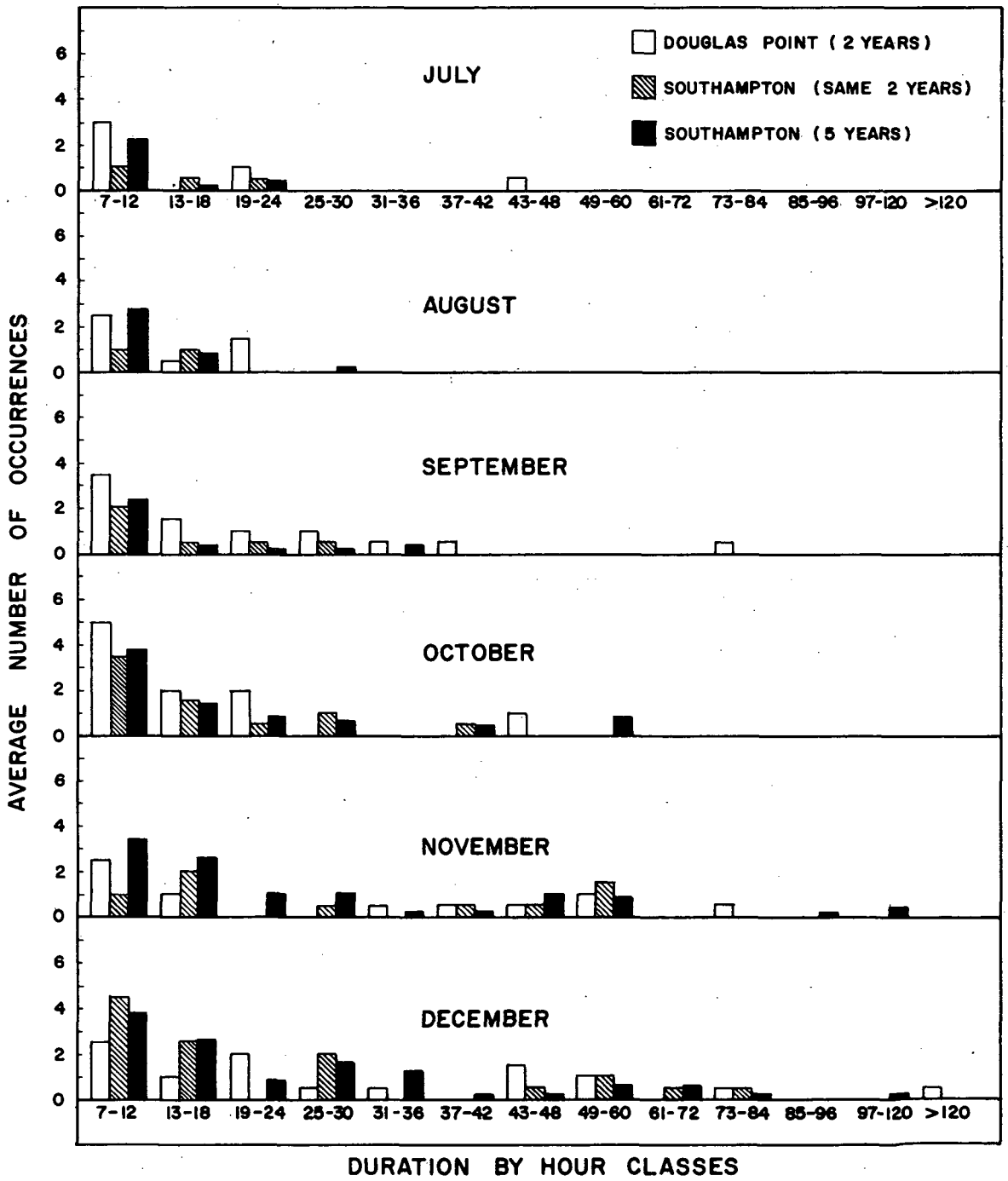

Figure 11. Duration of winds ⩾10 M.P.H. at Douglas Point and Southampton.

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An Analysis of Surface Wind Data
by T. L. Richards

12 pps. 11 figs. 28 tables.

Subject reference: Surface Wind; Douglas Point, Ontario.

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