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A STUDY OF WINDS IN THE LAKE MEAD RECREATION AREA

R. P. AUGULIS

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*Revised November 1967

A western Indian symbol for rain. It also symbolizes man's dependence on weather and environment in the West.

U. S. DEPARTMENT OF COMMERCE
ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
WEATHER BUREAU

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A STUDY OF WINDS IN THE LAKE MEAD RECREATION AREA

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WESTERN REGION
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TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

A STUDY OF WINDS IN THE LAKE MEAD RECREATION AREA

I. INTRODUCTION

The year around use by the public of the Lake Mead recreation facilities makes the issuance of accurate and up-to-date wind forecasts for recreational activities an important function of WBAS Las Vegas. However, because of the variability of the terrain features in the recreational area, wind conditions observed at Las Vegas are frequently quite different from those on or in the vicinity of the lake.

It was the purpose of this study to determine if objective techniques employing sea-level pressure and pressure differences as predictors could be developed to facilitate improved daily wind forecasts in the recreation area.

II. TOPOGRAPHY

The topography of the recreation area is best divided into two separate regions, the first being Lake Mead itself and the second, the Colorado River-Black Canyon and Lake Mohave area to the south. Lake Mead is protected from macroscale windflow from the northwest through east by the Black, Muddy and Sheep Mountain Ranges. See Figure 1. These mountains shelter much of the lake from the full effects of strong winds with any northerly component. The Virgin River Valley northeast of the lake does allow a more unhindered airflow to enter through the Overton Arm. Southerly winds are more easily channeled into the lake through the relatively flat Eldorado and Detrital Valleys to the south. Thus, Lake Mead is more susceptible to strong winds with a southerly component than those with a northerly one. This comment does not consider localized small-scale wind regimes which might be quite different than their large-scale counterpart.

The Colorado River in the Black Canyon and the Lake Mohave water recreation areas are well protected from east-west airflow. The Colorado River lies at approximately 800 feet above sea level with the topography rising to over 5,000 feet in the Eldorado, and Black Mountains paralleling the canyon. These changes in height occur over distances on the order of ten miles in some places. The rise along most of the canyon averages approximately 2,000 feet in five miles. The canyon itself is generally from a half to one and a half miles wide with the widest sector being three and a half miles at Lake Mohave.

This topography protects the canyon bottoms from winds with any easterly or westerly component, but favors channeling of north or south airflow, resulting in higher north-south airspeeds than would be expected under the given pressure gradients. With a gradual slope of terrain from the higher Lake Mead to the lower Lake Mohave, a natural nocturnal wind from a northerly direction can be expected.

III. LOCATION AND TYPE OF WIND EQUIPMENT

There are nine wind-recording stations in the Lake Mead Recreation area; however, for this study data from only seven stations were used because of either lack of observations (Boulder City) or poor exposure and correspondingly unrepresentative wind measurements (Willow Beach). The seven installations used are shown in Figure 1.

Observations were taken twice daily by National Recreation Area personnel at approximately 0800 local time, and again sometime between 1200 and 1400. This information was then telephoned to the Weather Bureau airport station at Las Vegas.

Wind equipment consisted of a vane for determining direction and cup anemometer with associated meter for determination of wind speed. The equipment was usually located on the roof of the recreation site headquarters or visitor center. The time period for which data were available covered December 1965 to July 1967, with the exception of May 1966 and September to November 1966.

Many deficiencies in the quality of the observations exist and should be mentioned. Some of these are as follows:

1) Time errors. Although the morning observations are considered to be synchronous, i.e., all observations taken near or at 0800 local time, the afternoon observations were taken at the discretion of the Ranger anytime between 1200 and 1400 hours.

2) Observing errors. These consist of failure to obtain a representative one-minute or longer wind direction or speed.

3) Unrepresentative wind measurements due to relatively poor exposure of the instruments. All stations are protected to some degree by higher terrain and are not located near the water.

4) Improper operating condition of the wind instrument.

5) Frequency of reports. Some stations did not send in observations faithfully every day.

6) Transcribing errors by Weather Bureau personnel when data were received.

In order to evaluate deficiencies 2) and 3), scatter diagrams of the Las Vegas WBAS wind speed against the speed at an observing site were constructed. These are shown in Figures 2 to 13. Notice the large number of 4- to 10-miles per-hour speeds recorded at Las Vegas while at the same time calm was observed at a recreation site. Also note how the number of the above phenomena varies for the two observation times and among stations, with the larger proportion of the recreation site calms occurring in the morning, and the canyon stations having a lesser number of calms. Compare Figures 2-3 and 4-5 as examples of the former and Figures 3 and 5 with 9 and 11 as examples of the latter. These diagrams indicate a smaller than expected number of very light winds at recreation sites due either to observer carelessness, poor instrument exposure or a combination of both. Figure 13 is a composite chart for all four lake sites and definitely shows this 4- to 10-m.p.h. difference between Las Vegas WBAS and recreational site wind speeds under light wind conditions. Also note that all these diagrams were plotted using data for the winter season only. However, a few similar diagrams were plotted for the warm season and the same pattern also occurred.

Even with knowledge of possible deficiencies in the observations, it is difficult to give a definite quantitative estimate of the difference in wind speeds between land station sites and lake speeds. Ranger personnel point out that speeds over the open water are usually greater and, at times, significantly greater than at land sites. Conservatively, this difference could be put in a 5- to 10-m.p.h. range.

The above discussion points out that any one or a combination of these deficiencies can be associated with any given observation and must be considered in evaluating an observation as a representative wind measurement.

IV. PROCEDURE

Since the Lake Mead Recreation Area was divided into two distinct topographic regions, any objective technique would have to treat each region separately. The first region considered was the Black Canyon south of Lake Mead. It was also decided to divide the two years of data into winter and spring seasons with the data from December to February comprising winter and March to June spring. This study made no use of July through November data. The objective technique developed is only for the winter season.

Because of the canyon topography, it would seem likely that wind flow in this region would be quite sensitive to pressure-gradient values, especially the gradient in a north-south direction. Using this as a guide, the first two variables selected were the 0400 PST pressure differences, Las Vegas minus Yuma and Daggett minus Prescott. These stations were chosen because of their geometric orientation, i.e., lines connecting the two related stations intersecting at approximately right angles and secondly their geographical locations which should give a representative pressure distribution over the region of interest. See Figure 14. In Figure 15 these two pressure differences were used as coordinates of a scatter diagram with the highest afternoon wind speed reported at one of the three stations in the canyon being plotted in the body of the chart. Using a relationship of morning pressure differences and afternoon wind speeds eliminates the need of forecasting these differences and using the highest observed at any one of three stations gives a more representative area wind than if only one location is used. Since most people using the waterway will be changing their location, their interest in wind conditions would be over the area rather than at one specific location.

For easier analysis of Figure 15, wind speeds equal to or greater than fifteen miles per hour are circled. At first inspection it can be seen that a large majority of the ⩾ 15 m.p.h. speeds are concentrated in the upper right quadrant of the plot. Another smaller concentration of higher values are in the lower left. The midsection of the diagram contains the majority of speeds less than 15 m.p.h. with some higher values mixed in. The data were then categorized as shown with the number of occurrences of speeds ⩾ 15 m.p.h. compared to the total number of observations in each category. The greater percentage of higher wind speeds occur in categories 3, 4 and 5 with much less in in 1 and 2.

A number of other pressure differences, pressures and 12-hour pressure changes were tried as predictor variables, but only the 0400 PST sea-level pressure at Las Vegas showed a useful relationship to the afternoon canyon winds. Above normal pressure at Las Vegas, usually the result of a well developed Basin high is associated with above average northerly winds, while much below normal pressure at Las Vegas is associated with above average southerly winds through the canyon. This is reflected in Table 1 where the Las Vegas sea-level pressure has been categorized according to the percent frequency of winds ⩾ 15 m.p.h. in each category.

TABLE I

	Las Vegas SLP (mbs)	No. of Cases	No. of Winds ⩾15 MPH	%
Category 1	1006-1020	76	25	33
Category 2	1021-1025	38	22	58
Category 3	1026-1030 or ⩽1005	32	24	75
Category 4	⩾1031	2	2	100

Each observation was categorized from Figure 15 and Table 1 and replotted as a combination of these two figures. This third diagram is shown in Figure 16. The number of cases with wind speed ⩾ 15 m.p.h. divided by the total number of cases were entered at the points determined by the two coordinates. Again lines were drawn dividing the diagram into sections of various percentages of wind speeds equal to or greater than 15 m.p.h. These percentages range from about 5% in Category 1 to 100% in Category 5. Figure 16 indicates a good separation of speeds.

In order to obtain an estimate of the expected wind speed in the Black Canyon and Lake Mohave area for the afternoon hours, the following procedure should be used:

1) Calculate the 0400 PST Las Vegas minus Yuma and Daggett minus Prescott sea-level pressure differences. Enter Figure 17 with these values and note the category in which the point falls.

2) Determine the category of the 0400 PST Las Vegas sea-level pressure from Table 1 in upper right of Figure 18.

3) Enter Figure 18 with these two categories and read off the expected wind speed associated with the category in which the point lies.

Ranges of speed are given to each forecast category in 10 m.p.h. increments with a 5 m.p.h. overlap. This is done to facilitate forecasting wind speeds from this diagram.

This should give a good first approximation of expected afternoon wind speeds in the canyon. Modification of this forecast may be made based on expected or forecast weather changes and personal experience.

"Forecasts" from the developmental data were made from Figure 18 for wind < 15 or ⩾ 15 m.p.h. using Categories 1 and 2 for < 15 m.p.h. and Categories 3, 4 and 5 for ⩾ 15 m.p.h. The contingency table for these "forecasts" is given in Figure 19 and shows a skill score of .59 with 80 percent correct. Thus even with deficiencies in the developmental data as discussed previously, this technique for wind-speed forecasts using sea-level pressure and pressure differences shows definite utility so that a similar method could be developed for the months March through June. As more wind data become available, the objective technique can be updated and an estimate of the value of the technique on independent data could be ascertained.

The second topographic region selected was Lake Mead, with four stations being used for obtaining wind measurements around the lake. See Figure 1. Employing an approach similar to that used in the canyon wind study, various combinations of sea-level pressure differences, pressures and pressure changes were plotted against observed afternoon wind speeds at these stations. Organized patterns did not materialize as well as in the canyon study. Any success using this approach for Lake Mead seemed unlikely. A probable reason for this was that the strong topographic influence which affected the canyon wind observations was not present or not as influential on lake winds, i.e., channeling was not the major factor contributing to the wind regime on the lake.

It was then decided to use the method developed by Williams [1] for forecasting winds of 20 knots or greater at Las Vegas McCarren Field as the basic tool for wind-speed forecasts on the lake. Wind speeds of approximately this speed or greater are significant to boating interests, for it is at these speeds that the water begins forming whitecaps and becomes choppy enough to cause concern to the average Lake Mead boater. Wind speeds under this speed should in general not be of as much concern.

The approach taken was to develop a conditional climatology in terms of the probability of a given wind speed at each of the four observing stations and for a combination of all four stations, based on the condition of a 20-knot or greater afternoon wind speed forecast at Las Vegas. It should be noted here that the conditional climatology developed is based on a 20-knot wind speed at Las Vegas and a 20 m.p.h. speed on the lake. This slight difference in speed scales should not be considered a factor affecting the technique's usefulness.

Cumulative frequency diagrams were constructed based upon the wind speed at the given station in the afternoon versus a 20-knot or greater afternoon speed at Las Vegas between 1200 and 1400 local time. A 20 m.p.h. or greater speed observed at any one of these three hours was used because it was not known when the Ranger personnel took their observations. Frequency distributions of speeds for the four stations and a combination of the four were computed for December through June from two years of data. Increments of 5 m.p.h. were used in the distribution. These distributions were plotted in Figures 20 to 24. In the combination diagram, Figure 24, the highest wind observed at any one of the four stations was used. This again gives a better estimate of the average speeds over the lake, thus smoothing local effects.

To determine the expected afternoon wind on the lake, use the Williams' method [1] for forecasting the afternoon wind at Las Vegas airport. If this forecast wind is expected to reach 20 knots or higher, use the appropriate diagram, Figures 19-23, to determine the probabilities of various wind speeds at the stations. In simple terms, given a wind forecast of 20 knots or higher in the afternoon at Las Vegas, the probability of a wind speed equal to or greater than a given value at a particular station is read off the curve. Remember that this climatology can still be used independently of the Williams' method. To do this, it must be expected that 20 knots or greater winds at Las Vegas will occur in the afternoon.

Since no test data is available, it is recommended that a continuous verification score be kept current on independent data as they become available.

available. It is also suggested that each station's conditional climatology, i.e., station curves, should be updated as sufficient data are available.

V. STATION WIND CLIMATOLOGY

The station wind climatology for all data are given in Tables II to V. The sites are divided into three categories, the first three being canyon stations, the next four lake sites, and the last two being the stations not used in the study. The total number of observations from each station and the percentage frequency of a given wind direction or speed range are listed. Note the high frequency of north or south directions for the canyon sites and also their higher speeds as compared to the Lake Mead locations. This emphasizes the importance of the channeling effect on the wind regime in the canyon.

Although the period of record is short, i.e., approximately two years, this climatology indicates local differences in wind regimes in the recreation area, and allows comparisons among stations.

VI. CONCLUSIONS

The following are some conclusions drawn from this study:

1) Additional local climatological data from sources such as electric power facilities and forestry or recreation areas available to Weather Bureau personnel can be quite valuable in solving local meteorological problems.

2) Useful information can be obtained for both climatological and forecast studies from data with limited deficiencies in reliability and accuracy.

3) Previous forecast studies combined together with additional new data can be adapted to develop useful forecast schemes to solve local problems.

VII. REFERENCE

[1] Williams, Philip - Forecasting Strong Winds at Las Vegas, Nevada U.S.W.B. Manuscript, February 1959.

VIII. ACKNOWLEDGMENTS

The writer is indebted to Mr. Reed Gardener and his staff at the Weather Bureau Airport Station, Las Vegas, for their work in supplying the data and information needed for this study. Helpful ideas and comments by Mr. W. W. Dickey of the Weather Bureau Western Region Headquarters Scientific Services Division during the preparation of this paper were very much appreciated.

TABLE II

PERCENTAGE FREQUENCY OF MORNING WIND DIRECTIONS FOR THE PERIOD
DECEMBER 1965 TO JULY 1967*

	Total No. Obs.	340-030° %	040-090° %	100-150° %	160-210° %	220-270° %	280-330° %
Cottonwood Cove	283	43	2	1	50	4	0
Katherine	297	38	10	2	40	9	1
Eldorado Canyon	150	52	0	0	39	4	1
Echo Bay	154	37	4	0	41	14	4
Temple Bar	209	27	5	2	40	20	7
Boulder Beach	221	22	12	4	43	13	7
Las Vegas Bay	259	20	4	5	17	25	30
Willow Beach	98	24	4	10	45	10	6
Boulder City	113	21	19	4	39	14	3

*Excluding May and September to November 1966.

TABLE III

PERCENTAGE FREQUENCY OF MORNING WIND SPEEDS FOR THE PERIOD DECEMBER 1965 TO JULY 1967*

	Total # Obs. when a speed was observed	01-05 mph %	06-10 mph %	11-15 mph %	16-20 mph %	21-25 mph %	26-30 mph %	31-35 mph %	36-40 mph %	Calm % Total # Obs.
Cottonwood Cove	283	14	43	19	20	3	1	0	0	36
Katherine	297	19	34	31	15	0	1	0	0	38
Eldorado Canyon	150	33	32	25	9	1	0	0	0	42
Echo Bay	154	28	25	19	15	6	4	3	0	63
Temple Bar	209	36	30	21	7	3	2	0	0	52
Boulder Beach	221	22	33	28	12	2	2	0	0	48
Las Vegas Bay	259	26	50	18	3	0	1	0	0	47
Willow Beach	98	54	31	13	2	0	0	0	0	76
Boulder City	113	20	42	29	6	0	2	0	0	65

*Excluding May and September to November 1966.

TABLE IV

PERCENTAGE FREQUENCY OF AFTERNOON WIND DIRECTIONS FOR THE PERIOD
DECEMBER 1965 TO JULY 1967*

	Total No. Obs.	340-030° %	040-090° %	100-150° %	160-210° %	220-270° %	280-330° %
Cottonwood Cove	364	34	2	4	52	4	2
Katherine	364	38	2	0	38	18	4
Eldorado Canyon	172	44	0	0	51	3	1
Echo Bay	188	20	2	3	49	20	6
Temple Bar	291	43	4	1	27	14	10
Boulder Beach	221	26	14	7	39	12	3
Las Vegas Bay	192	15	5	17	36	11	16
Willow Beach	206	28	2	4	44	12	11
Boulder City	20	15	20	20	35	5	0

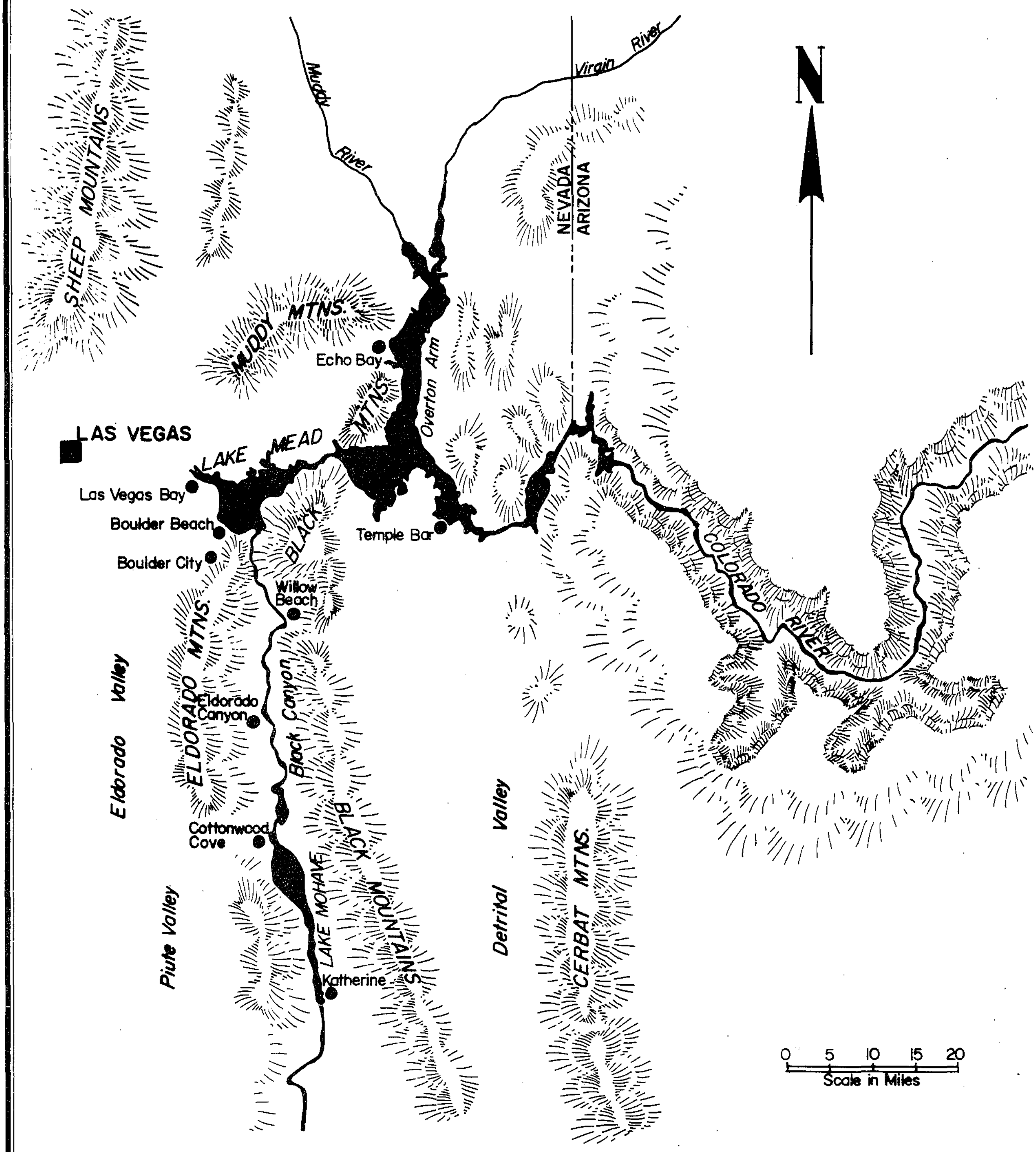
*Excluding May and September to November 1966.

TABLE V

PERCENTAGE FREQUENCY OF AFTERNOON WIND SPEEDS FOR THE PERIOD
DECEMBER 1965 TO JULY 1967

	Total # Obs. when a speed was observed	01-05 mph %	06-10 mph %	11-15 mph %	16-20 mph %	21-25 mph %	26-30 mph %	31-35 mph %	36-40 mph %	Calm % Total # Obs.
Cottonwood Cove	364	9	20	23	41	6	1	0	0	10
Katherine	364	9	30	34	23	3	1	0	0	6
Eldorado Canyon	172	20	33	27	17	3	0	0	0	9
Echo Bay	188	16	36	21	16	9	2	0	0	40
Temple Bar	291	23	31	25	13	5	1	1	0	25
Boulder Beach	221	14	34	31	13	6	2	0	0	28
Las Vegas Bay	192	21	41	18	15	4	1	0	0	27
Willow Beach	206	49	38	9	4	0	0	0	0	38
Boulder City	20	15	45	20	15	5	0	0	0	14

*Excluding May and September to November 1966.



LAS VEGAS
SHEEP MOUNTAINS
MUDDY MTNS.
Muddy River
Virgin River
NEVADA
ARIZONA
N
Echo Bay
MTNS.
Overton Arm
LAKE MEAD
Las Vegas Bay
Boulder Beach
Boulder City
Temple Bar
BLACK
Willow Beach
COLORADO RIVER
ELDORADO MTNS.
Eldorado Valley
Eldorado Canyon
Black Canyon
Cottonwood Cove
BLACK MOUNTAINS
LAKE MOHAVE
Katherine
Piute Valley
Detrital Valley
CERBAT MTNS.
0 5 10 15 20
Scale in Miles

FIG. 1

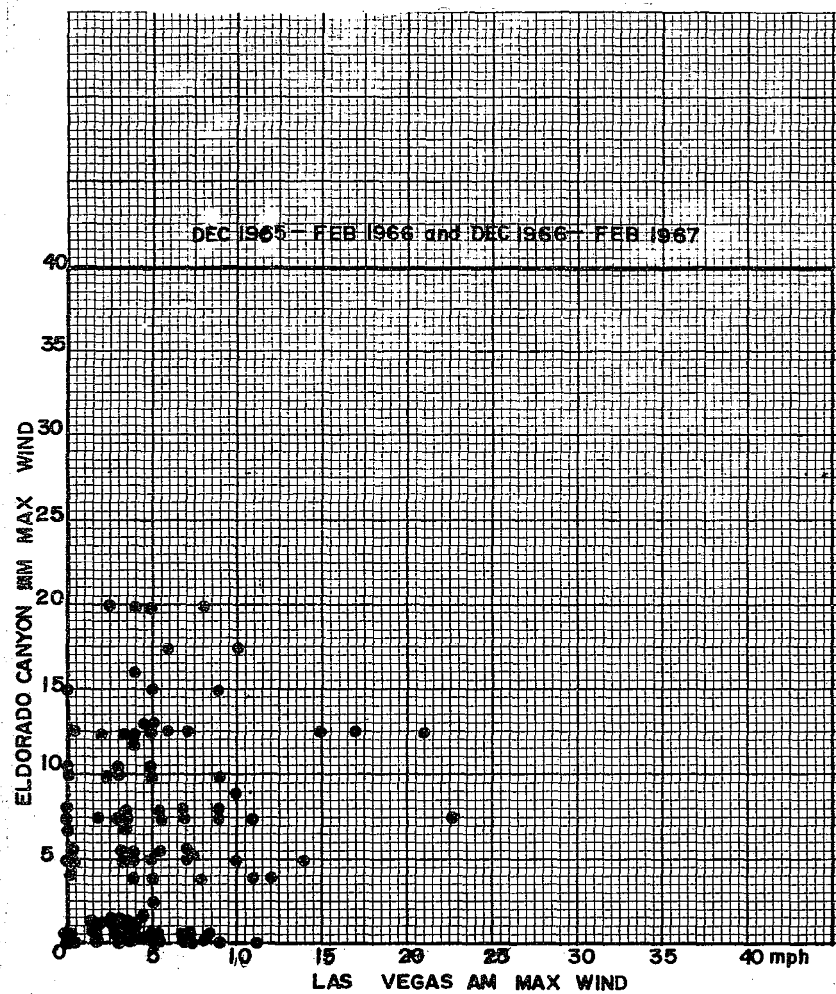

DEC 1965 – FEB 1966 and DEC 1966 – FEB 1967
ELDORADO CANYON AM MAX WIND
0
5
10
15
20
25
30
35
40
LAS VEGAS AM MAX WIND
40 mph

FIG. 2

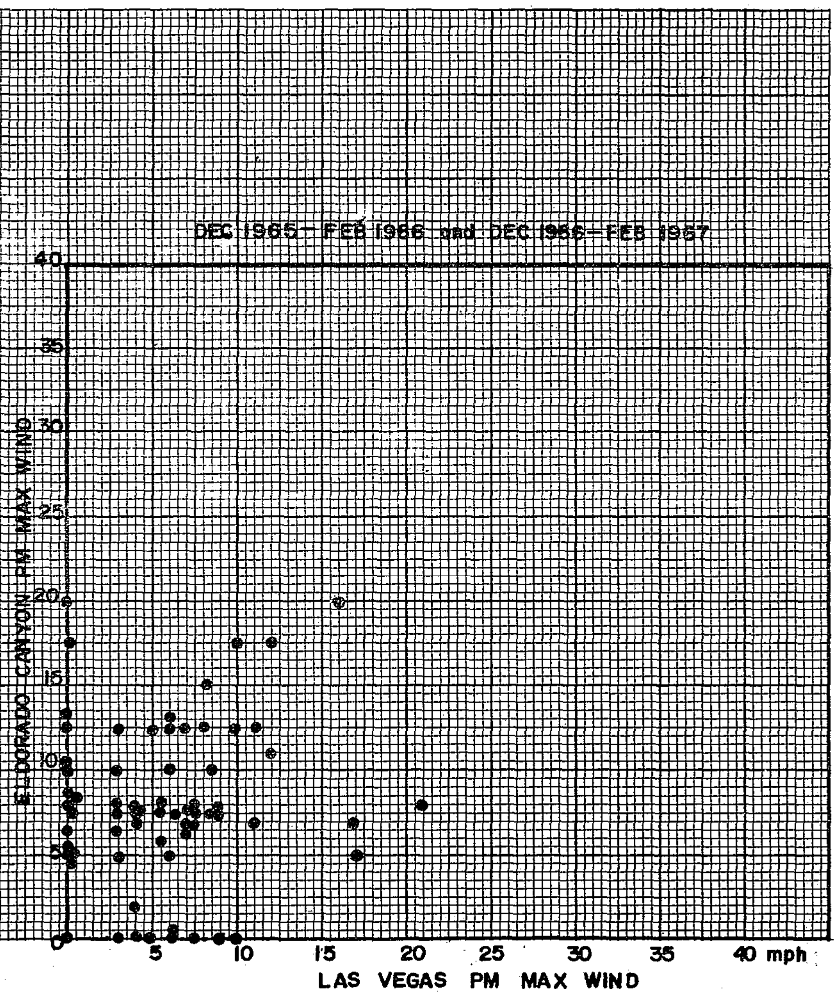

DEC 1965 – FEB 1966 and DEC 1966 – FEB 1967
ELDORADO CANYON PM MAX WIND
0
5
10
15
20
25
30
35
40
LAS VEGAS PM MAX WIND
40 mph

FIG. 3

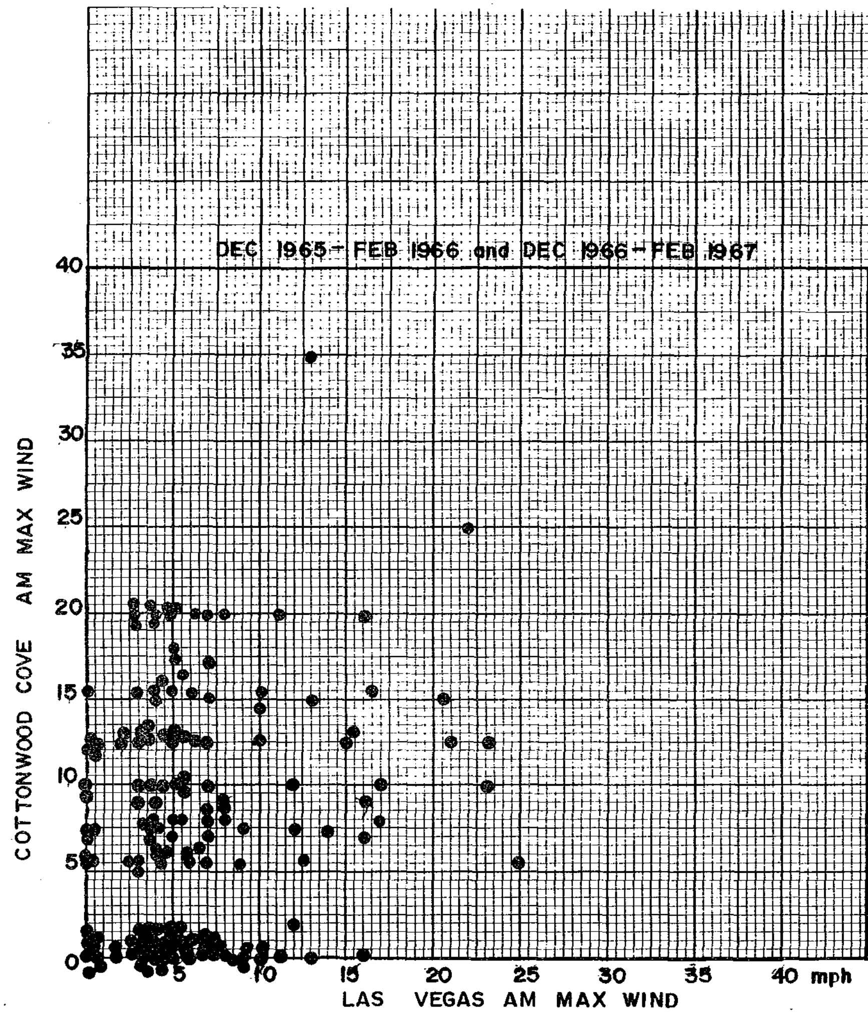

DEC 1965 – FEB 1966 and DEC 1966 – FEB 1967
COTTONWOOD COVE AM MAX WIND
0
5
10
15
20
25
30
35
40
LAS VEGAS AM MAX WIND
40 mph

FIG. 4

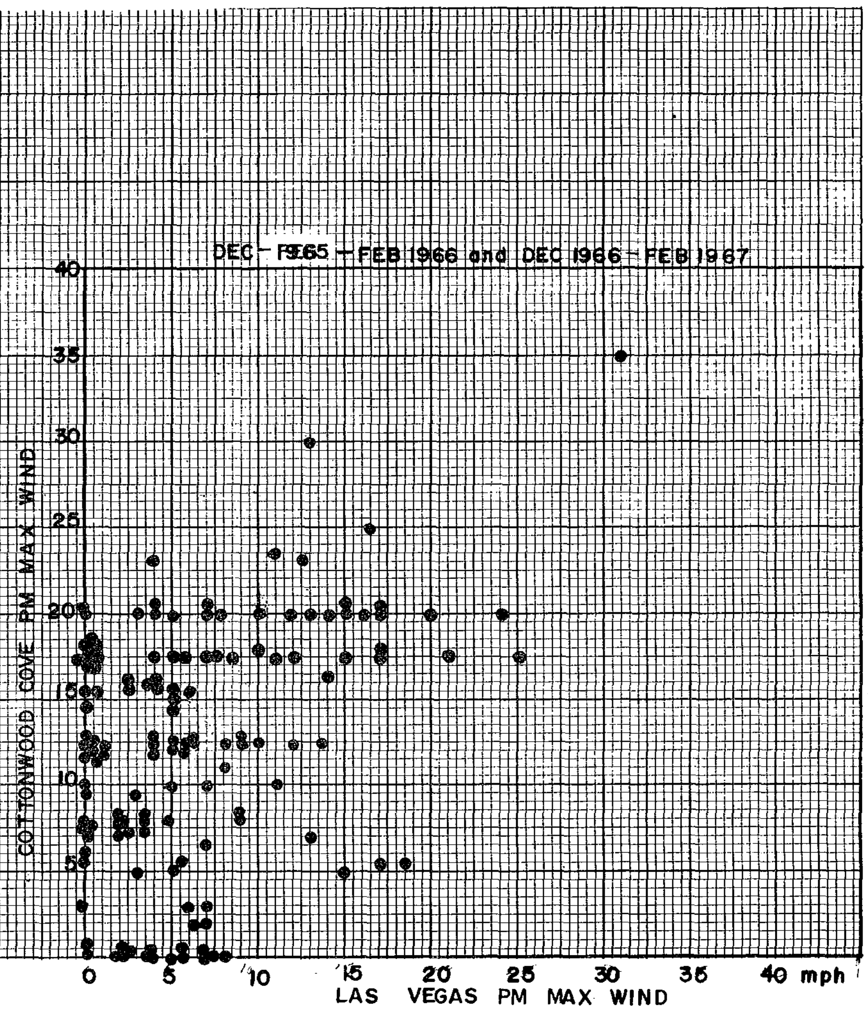

DEC 1965 – FEB 1966 and DEC 1966 – FEB 1967
COTTONWOOD COVE PM MAX WIND
0
5
10
15
20
25
30
35
40
LAS VEGAS PM MAX WIND
40 mph

FIG. 5

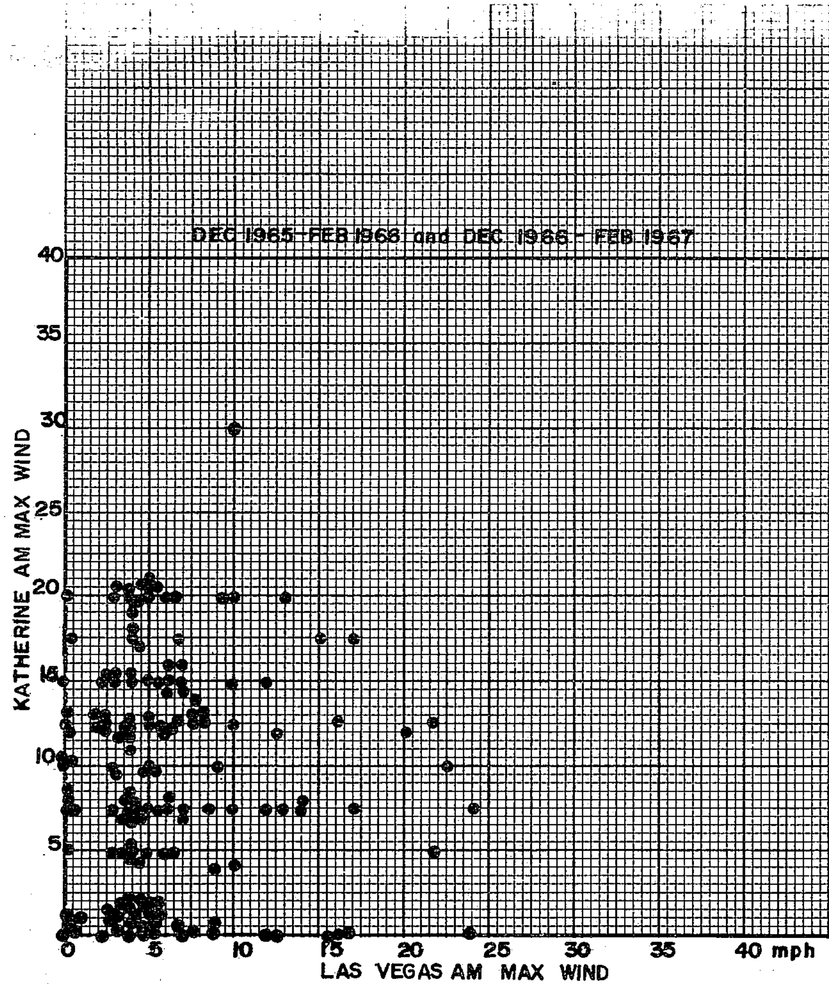

DEC 1965-FEB 1966 and DEC 1966-FEB 1967
KATHERINE AM MAX WIND
0 5 10 15 20 25 30 35 40
0 5 10 15 20 25 30 35 40 mph
LAS VEGAS AM MAX WIND

FIG. 6

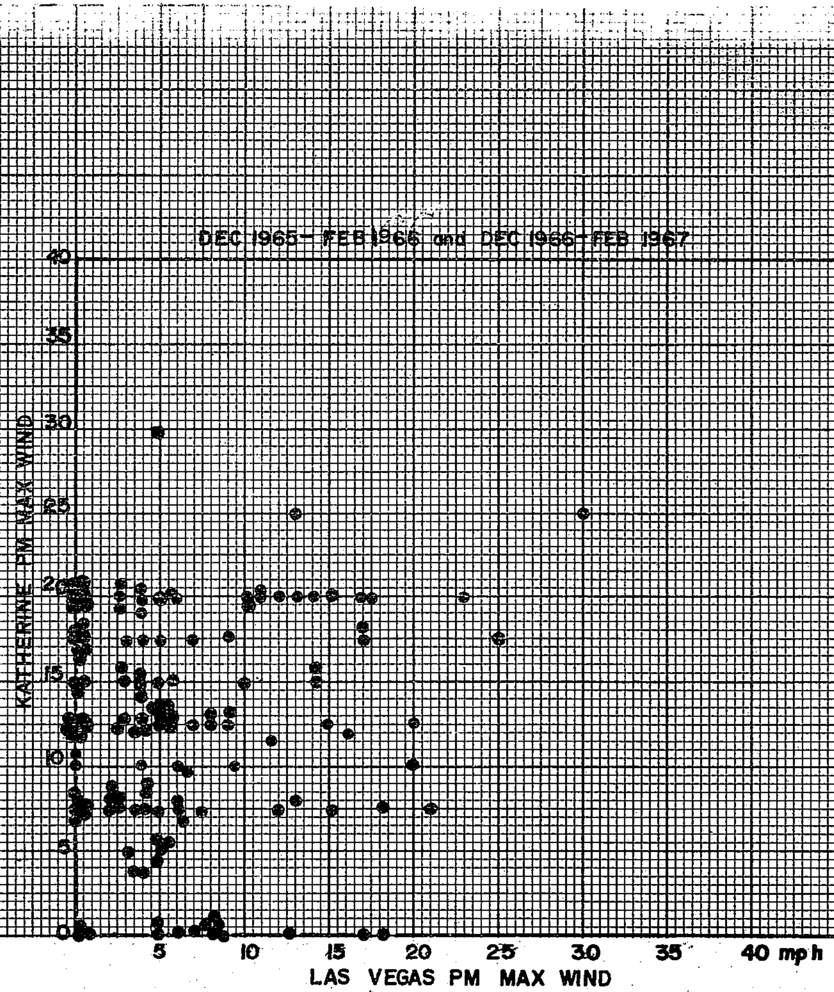

DEC 1965-FEB 1966 and DEC 1966-FEB 1967
KATHERINE PM MAX WIND
0 5 10 15 20 25 30 35 40
5 10 15 20 25 30 35 40 mph
LAS VEGAS PM MAX WIND

FIG. 7

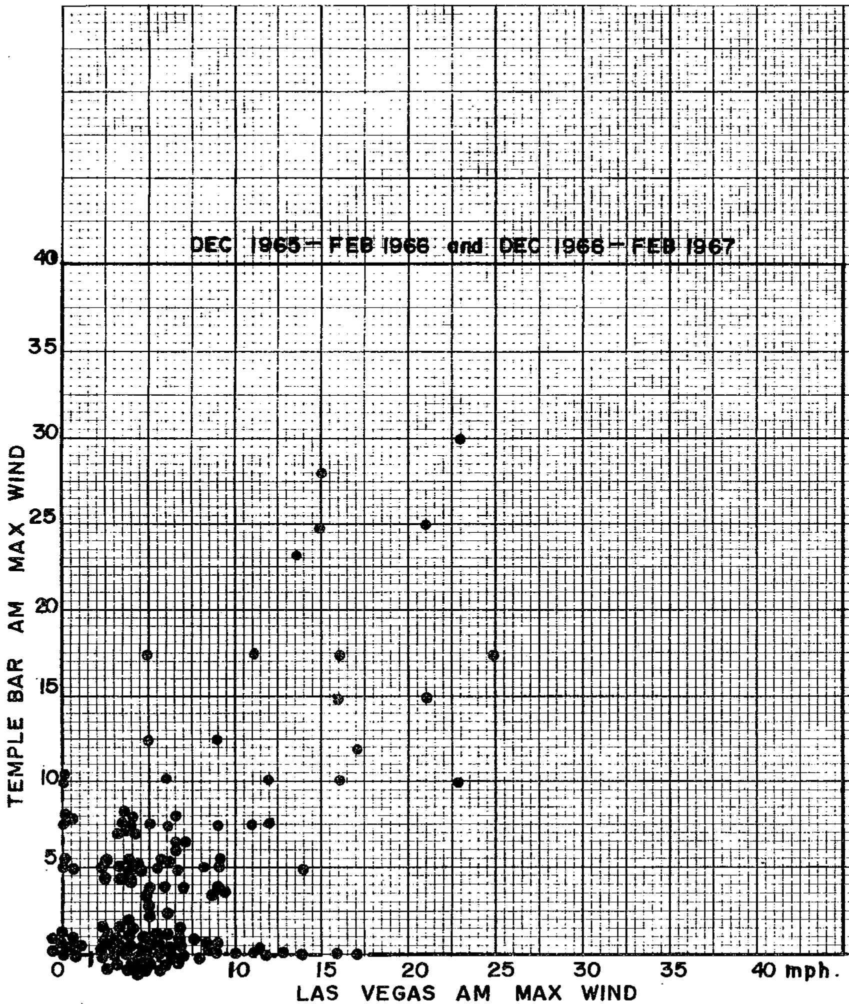

DEC 1965 – FEB 1966 and DEC 1966 – FEB 1967
TEMPLE BAR AM MAX WIND
LAS VEGAS AM MAX WIND
0 5 10 15 20 25 30 35 40 mph.

FIG. 8

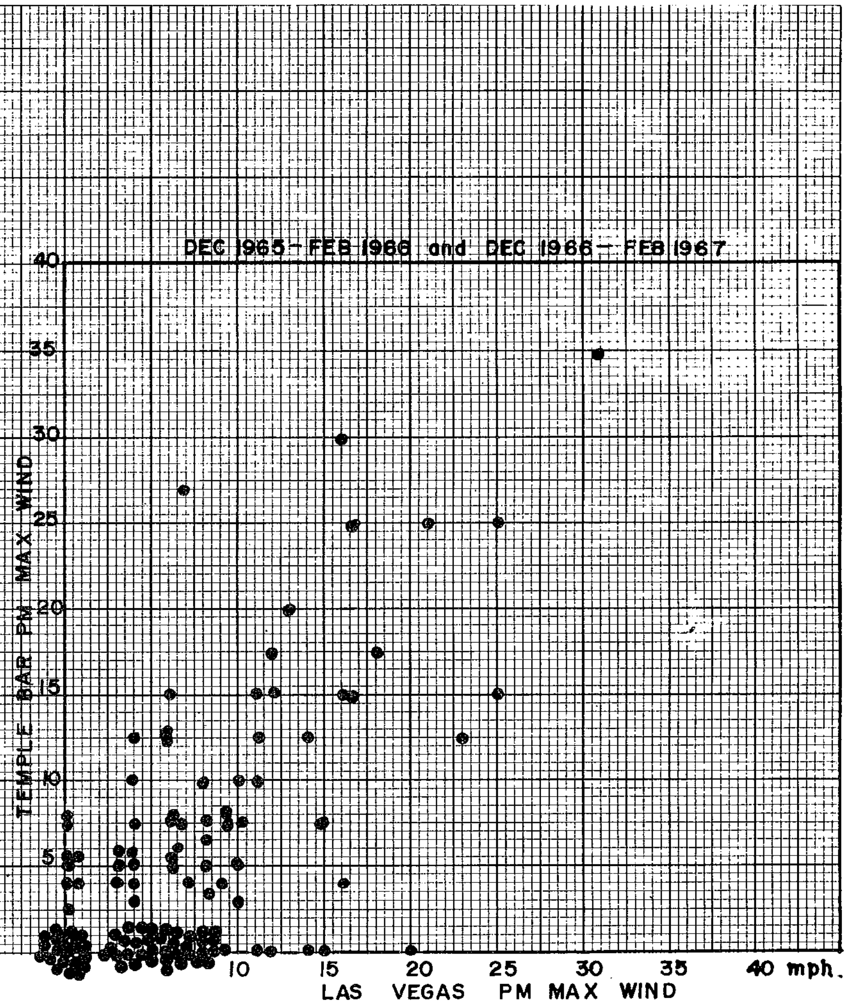

DEC 1965 – FEB 1966 and DEC 1966 – FEB 1967
TEMPLE BAR PM MAX WIND
LAS VEGAS PM MAX WIND
5 10 15 20 25 30 35 40 mph.

FIG. 9

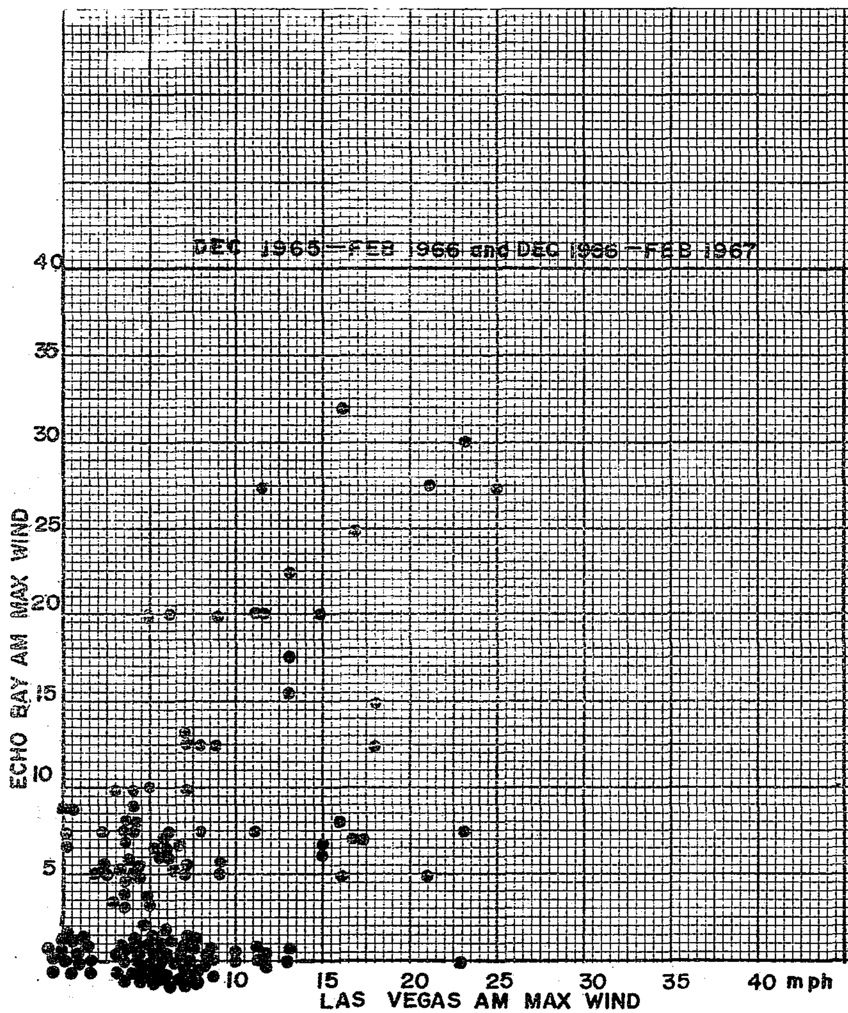

DEC 1965 — FEB 1966 and DEC 1966 — FEB 1967
ECHO BAY AM MAX WIND
5 10 15 20 25 30 35 40
LAS VEGAS AM MAX WIND
10 15 20 25 30 35 40 mph

FIG. 10

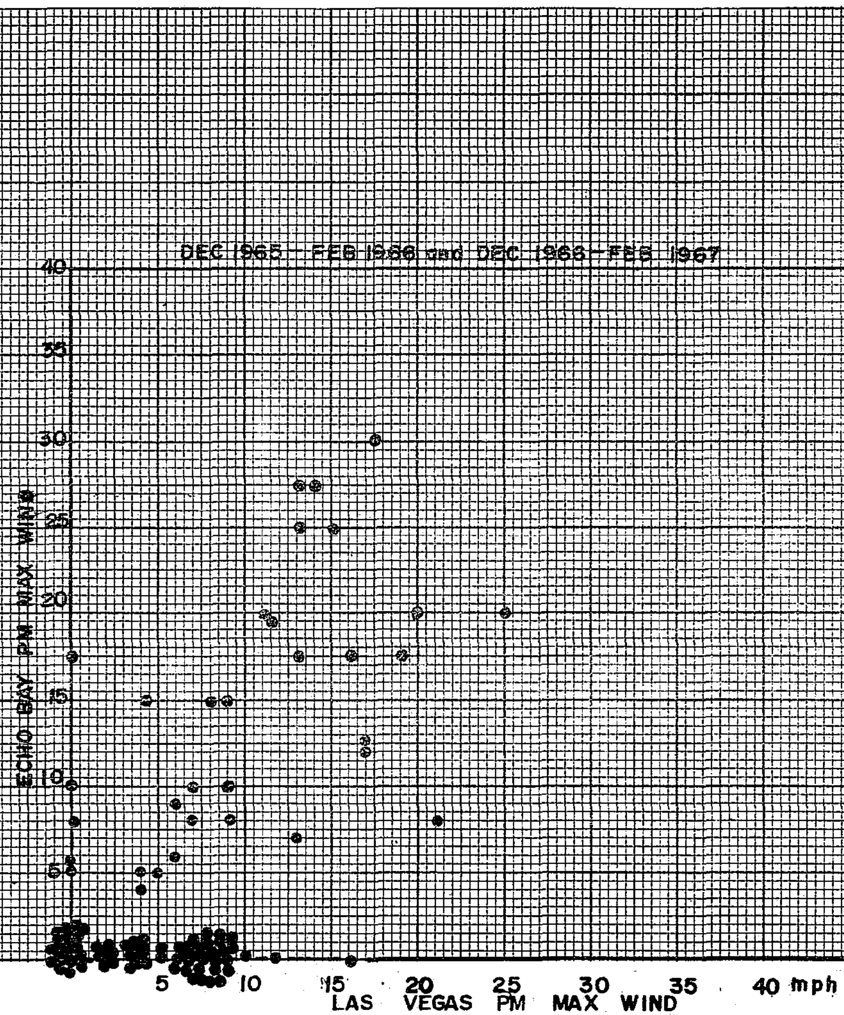

DEC 1965 — FEB 1966 and DEC 1966 — FEB 1967
ECHO BAY PM MAX WIND
5 10 15 20 25 30 35 40
LAS VEGAS PM MAX WIND
5 10 15 20 25 30 35 40 mph

FIG. 11

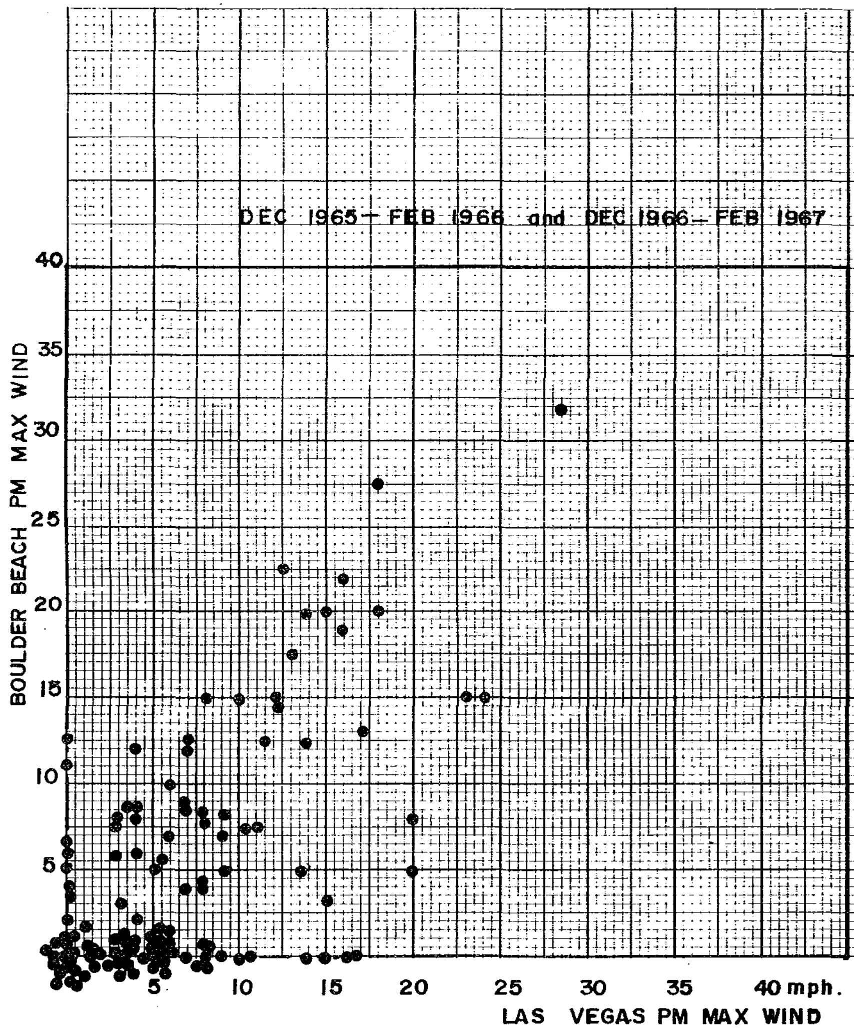

DEC 1965 – FEB 1966 and DEC 1966 – FEB 1967
BOULDER BEACH PM MAX WIND
40
35
30
25
20
15
10
5
5
10
15
20
25
30
35
40 mph.
LAS VEGAS PM MAX WIND

FIG. 12

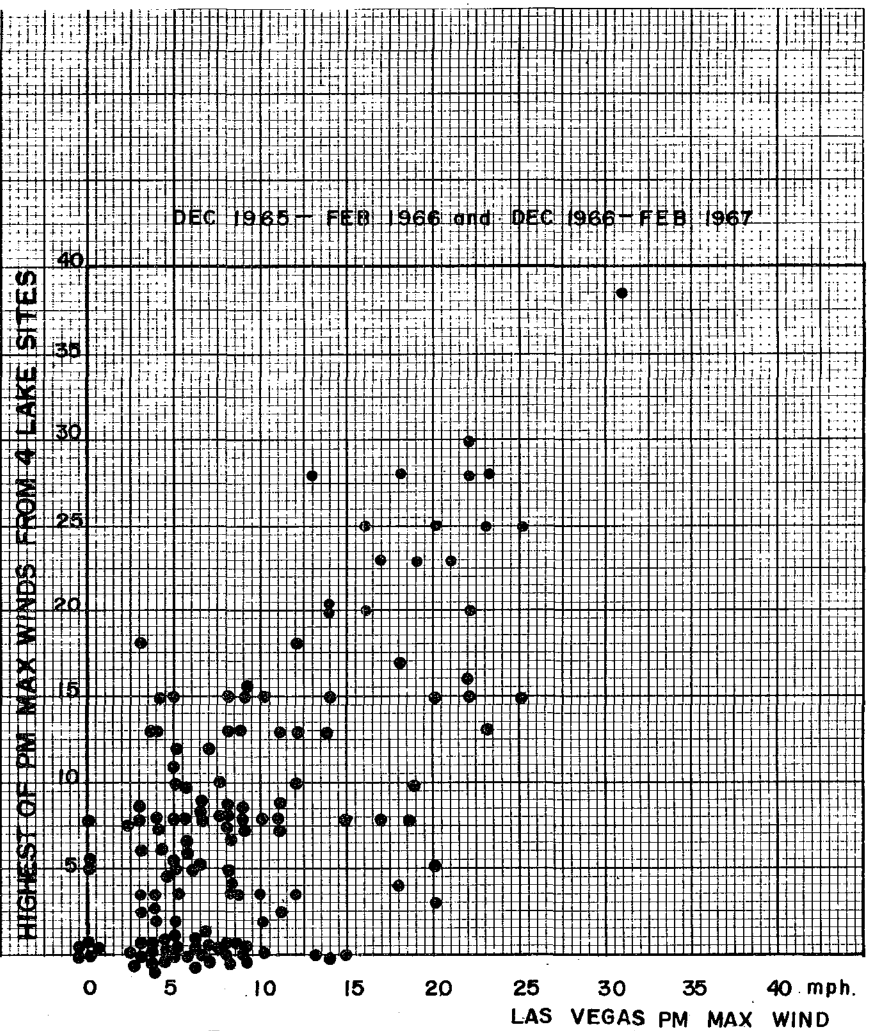

DEC 1965 – FEB 1966 and DEC 1966 – FEB 1967
HIGHEST OF PM MAX WINDS FROM 4 LAKE SITES
40
35
30
25
20
15
10
5
0
5
10
15
20
25
30
35
40 mph.
LAS VEGAS PM MAX WIND

FIG. 13

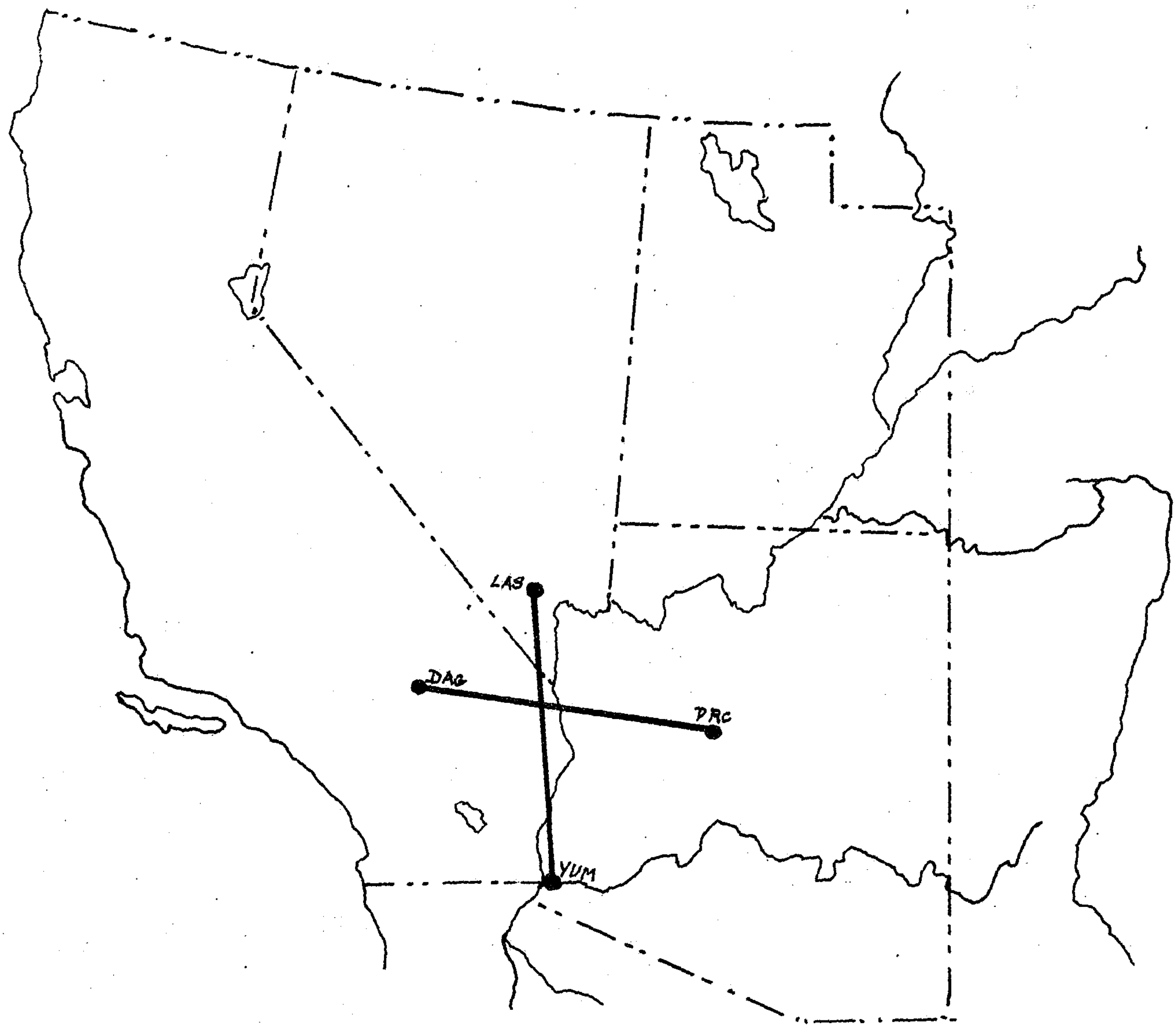
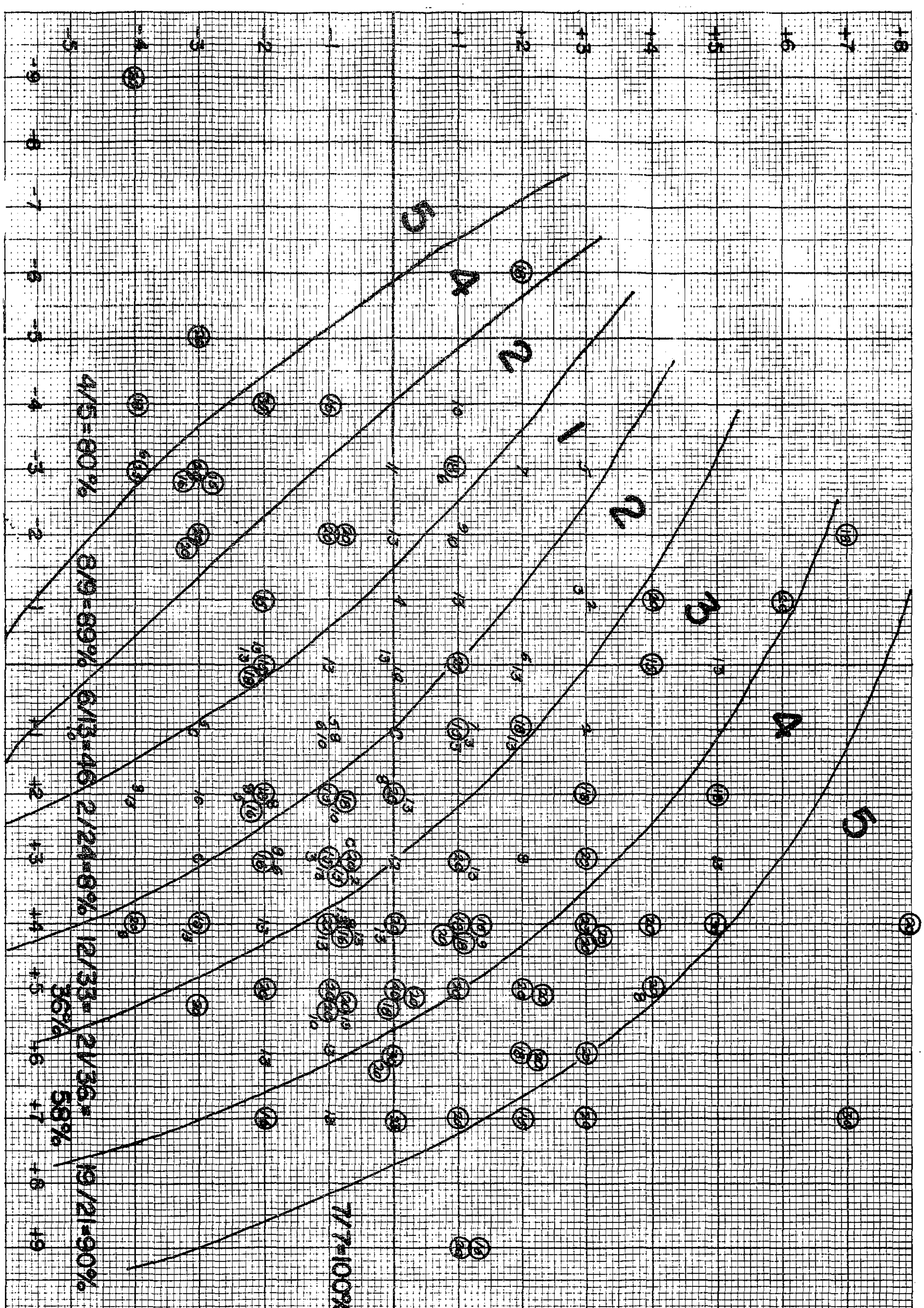


FIG. 14

FIG 15

0400 PST DAGGETT-PRESCOTT PRESSURE DIFFERENCE (MB)



0400 PST LAS VEGAS - YUMA PRESSURE DIFFERENCE (MB)

TABLE I

CATEGORY	LAS VEGAS 0400 PST SLP
1	1006 - 1020 mb
2	1021 - 1025 mb
3	1026 - 1030 mb or less than or equal to 1005 mb
4	greater than or equal to 1031 mb

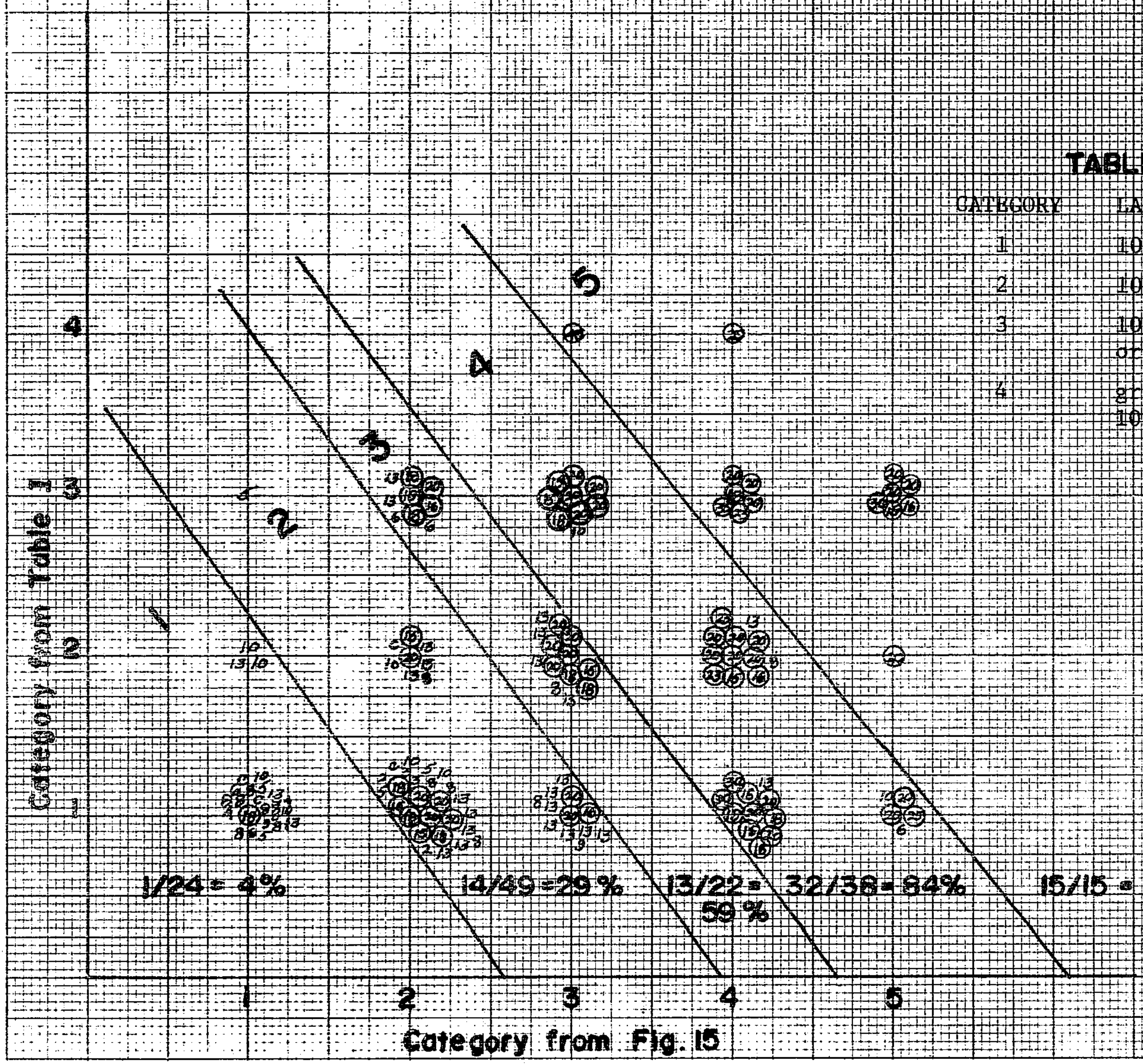
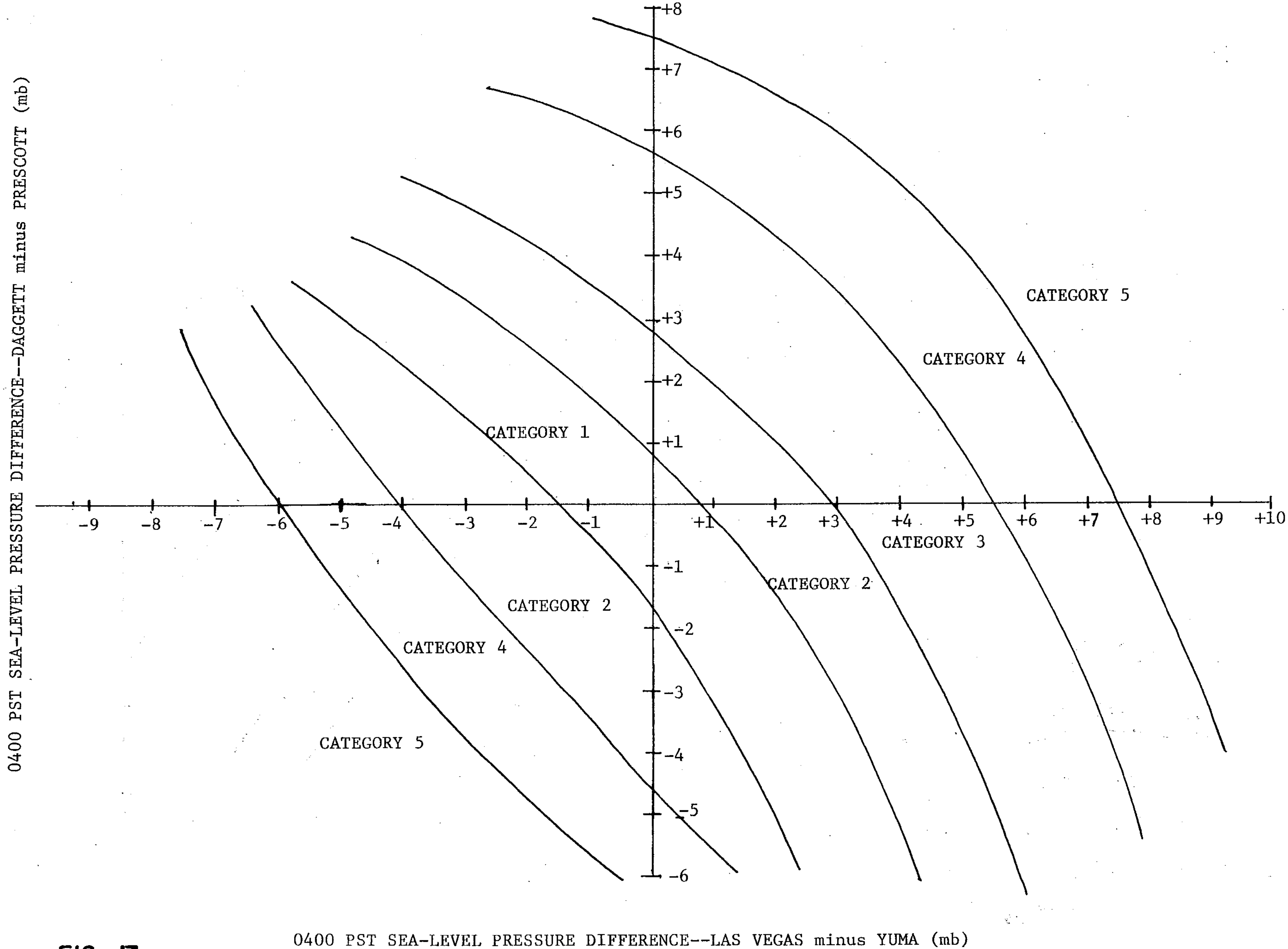


FIG. 16



0400 PST SEA-LEVEL PRESSURE DIFFERENCE--DAGGETT minus PRESCOTT (mb)
+8
+7
+6
+5
+4
+3
+2
+1
-1
-2
-3
-4
-5
-6
-9
-8
-7
-6
-5
-4
-3
-2
-1
+1
+2
+3
+4
+5
+6
+7
+8
+9
+10
CATEGORY 5
CATEGORY 4
CATEGORY 1
CATEGORY 3
CATEGORY 2
CATEGORY 2
CATEGORY 4
CATEGORY 5
0400 PST SEA-LEVEL PRESSURE DIFFERENCE--LAS VEGAS minus YUMA (mb)

FIG. 17

AFTERNOON WIND SPEEDS IN THE COLORADO RIVER-LAKE MOHAVE CANYON AREA

DECEMBER-FEBRUARY

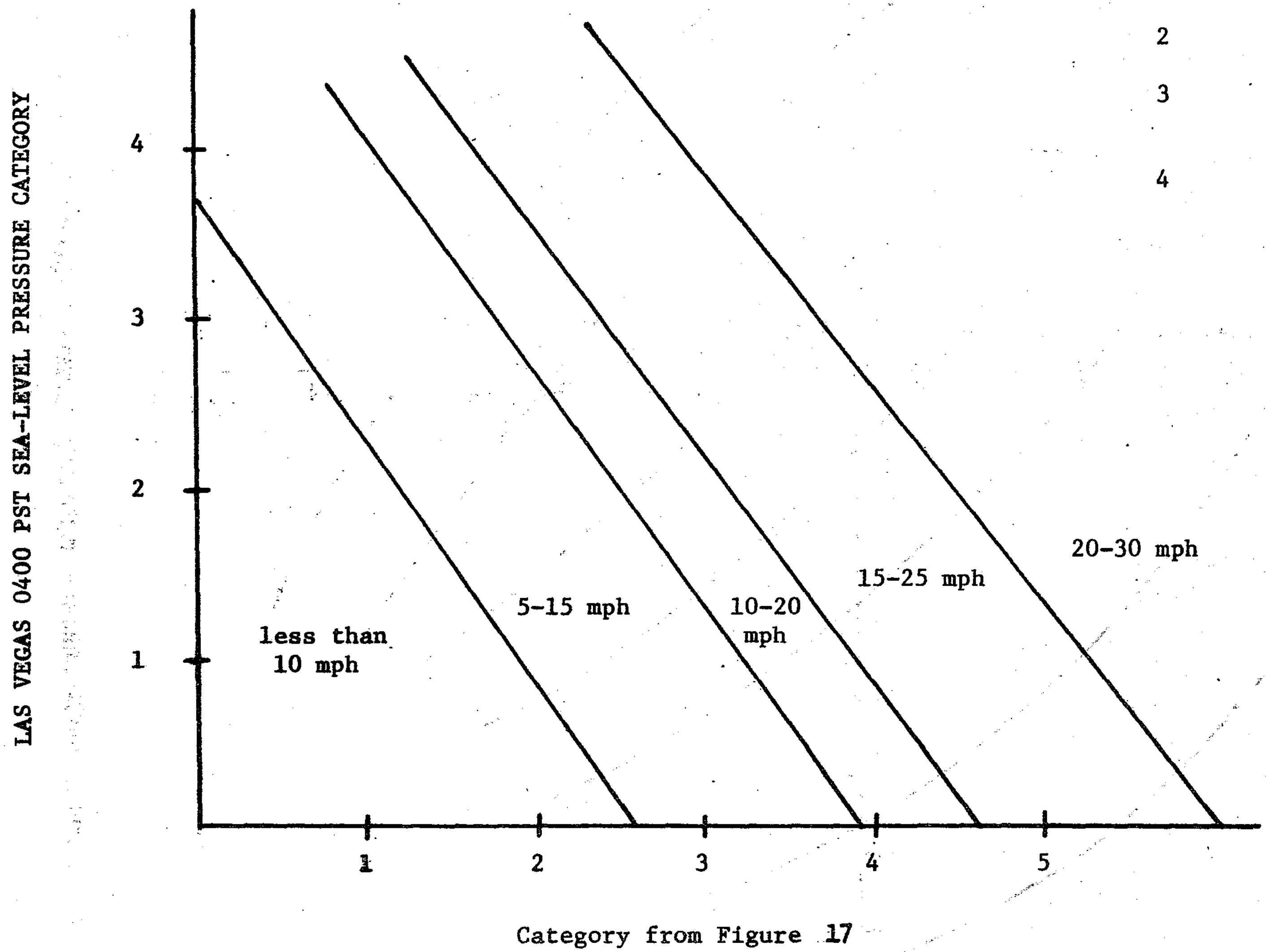


TABLE 1

CATEGORY	LAS VEGAS 0400 PST SLP
1	1006 - 1020 mb
2	1021 - 1025 mb
3	1026 - 1030 mb or less than or equal to 1005 mb
4	greater than or equal to 1031 mb

FIGURE 18

CONTINGENCY TABLE FOR DEVELOPMENTAL DATA

FORECAST

OBSERVED

	<15 MPH	≥15 MPH	TOTAL
<15 MPH	58	15	73
≥15 MPH	15	60	75
	73	75	148

Skill Score* = .59

% Correct = 80%

FIGURE 19

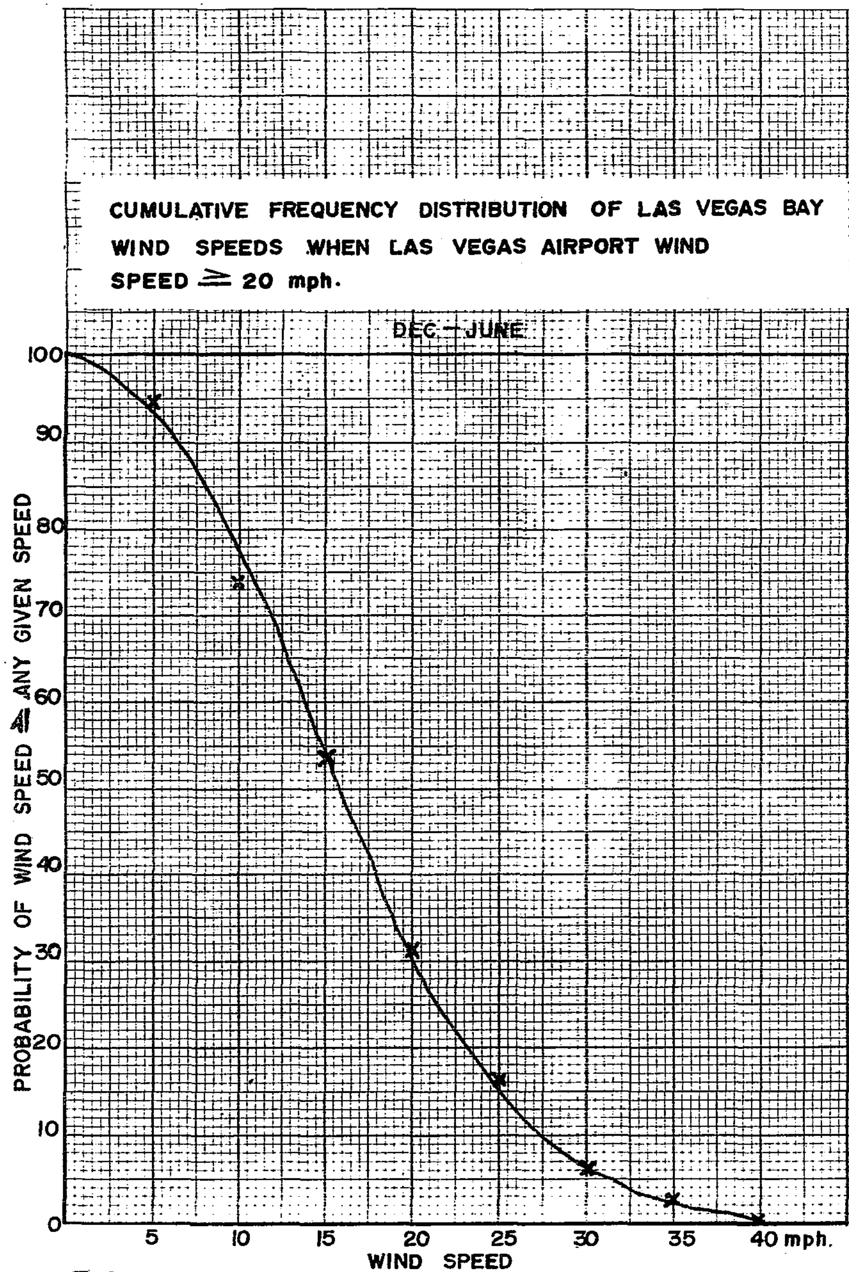

CUMULATIVE FREQUENCY DISTRIBUTION OF LAS VEGAS BAY WIND SPEEDS WHEN LAS VEGAS AIRPORT WIND SPEED ≥ 20 mph.
DEC.-JUNE
PROBABILITY OF WIND SPEED ≥ ANY GIVEN SPEED
100
90
80
70
60
50
40
30
20
10
0
5
10
15
20
25
30
35
40 mph.
WIND SPEED

FIG. 20

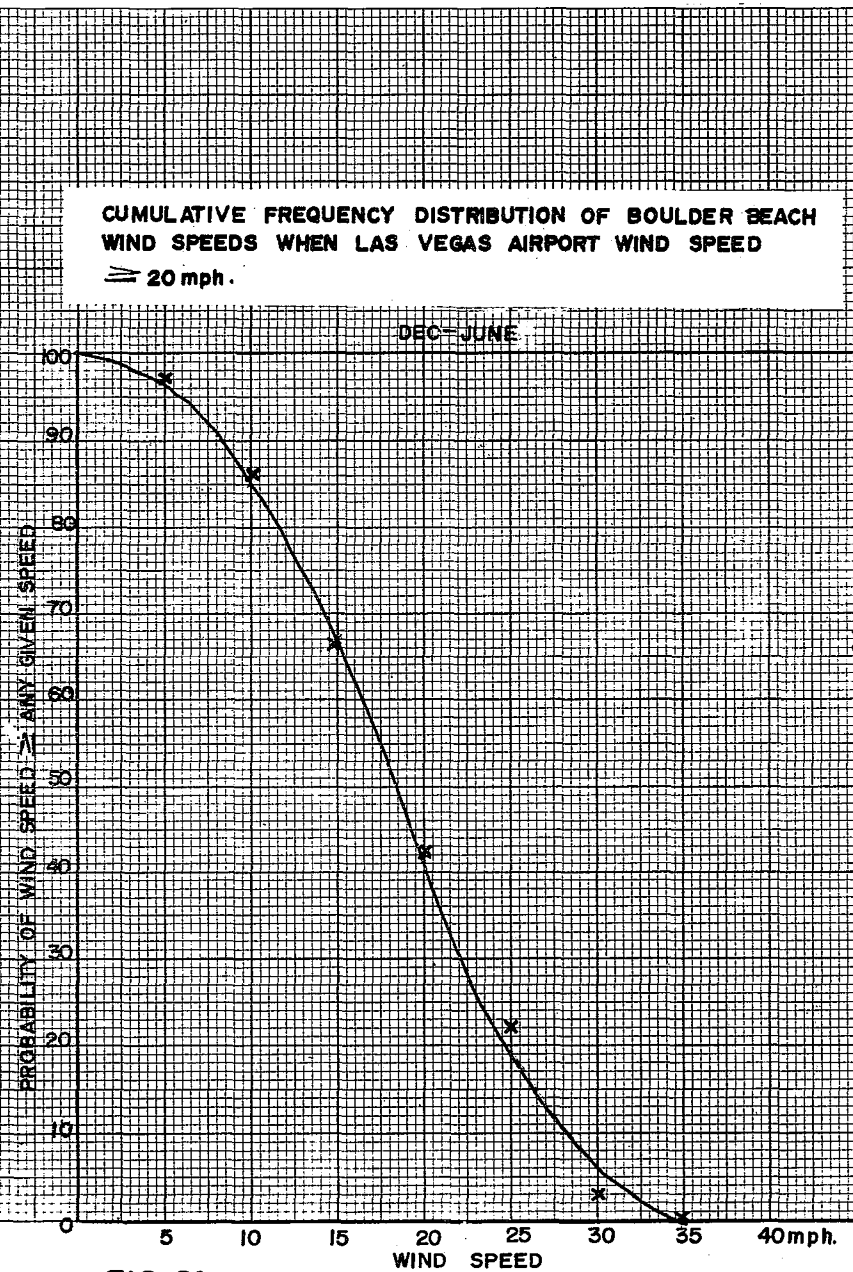

CUMULATIVE FREQUENCY DISTRIBUTION OF BOULDER BEACH WIND SPEEDS WHEN LAS VEGAS AIRPORT WIND SPEED ≥ 20 mph.
DEC-JUNE
PROBABILITY OF WIND SPEED ≥ ANY GIVEN SPEED
100
90
80
70
60
50
40
30
20
10
0
5
10
15
20
25
30
35
40 mph.
WIND SPEED

FIG. 21

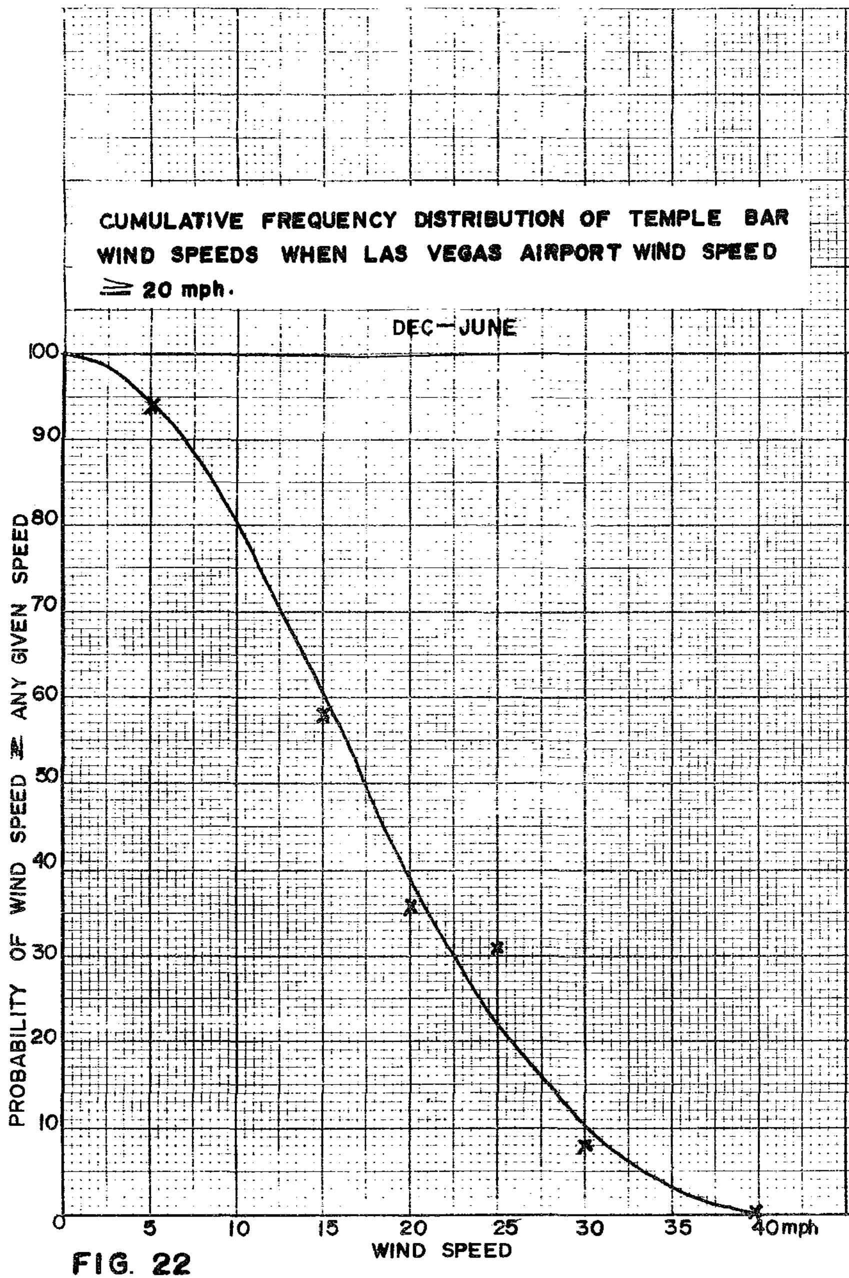

CUMULATIVE FREQUENCY DISTRIBUTION OF TEMPLE BAR WIND SPEEDS WHEN LAS VEGAS AIRPORT WIND SPEED ≧ 20 mph.
DEC—JUNE
PROBABILITY OF WIND SPEED ≧ ANY GIVEN SPEED
WIND SPEED
0
5
10
15
20
25
30
35
40mph
100
90
80
70
60
50
40
30
20
10

FIG. 22

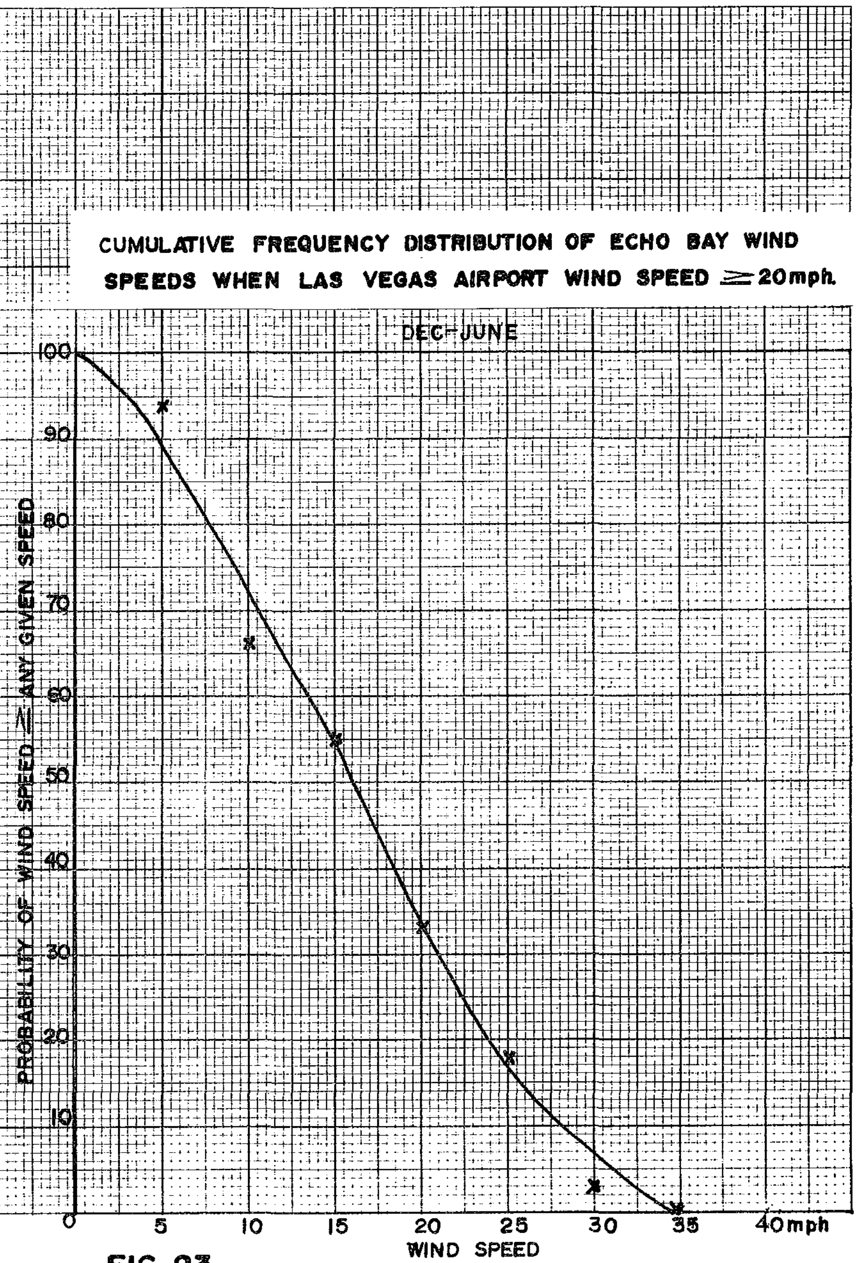

CUMULATIVE FREQUENCY DISTRIBUTION OF ECHO BAY WIND SPEEDS WHEN LAS VEGAS AIRPORT WIND SPEED ≧ 20mph.
DEC-JUNE
PROBABILITY OF WIND SPEED ≧ ANY GIVEN SPEED
WIND SPEED
0
5
10
15
20
25
30
35
40mph
100
90
80
70
60
50
40
30
20
10

FIG. 23

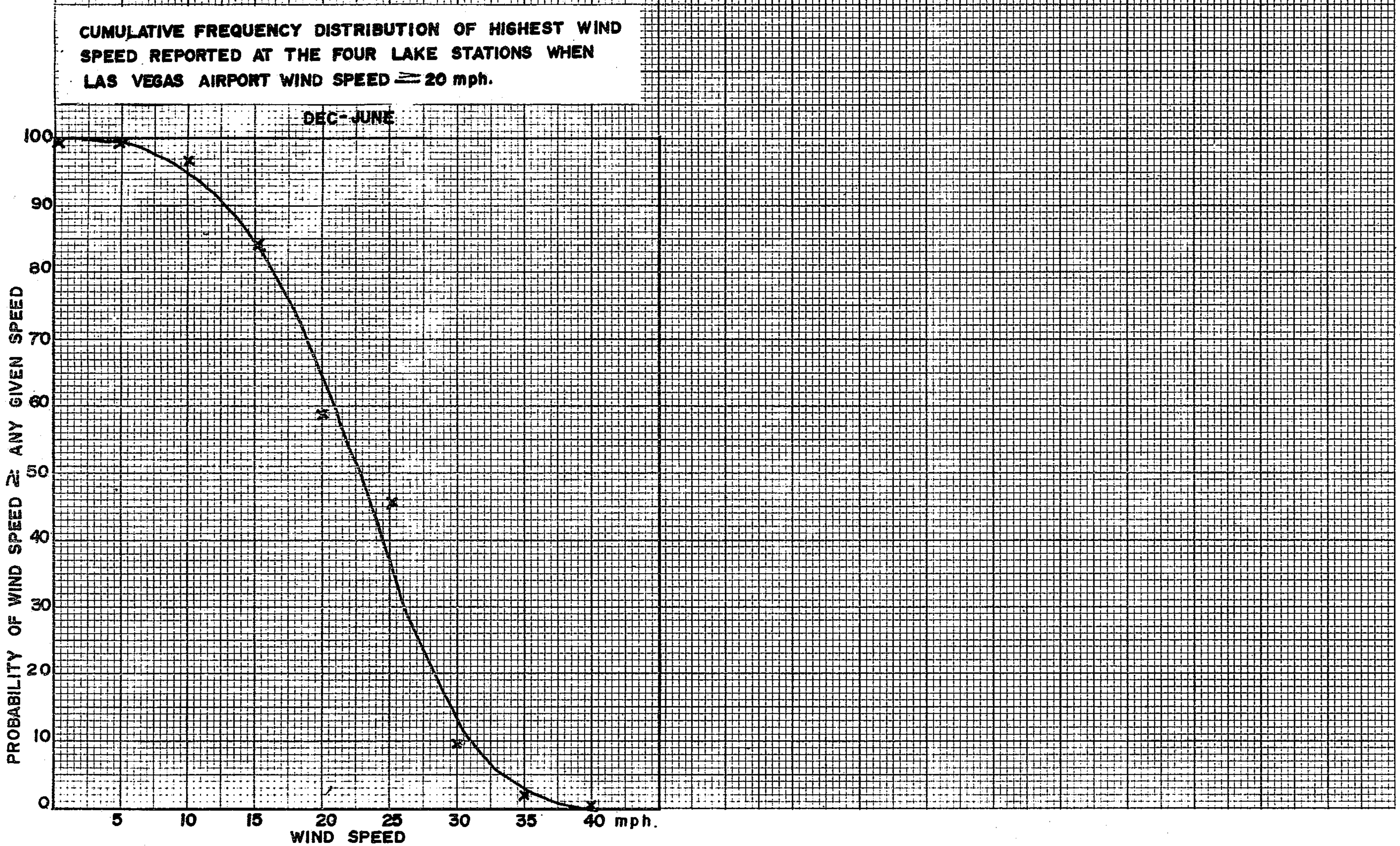

CUMULATIVE FREQUENCY DISTRIBUTION OF HIGHEST WIND SPEED REPORTED AT THE FOUR LAKE STATIONS WHEN LAS VEGAS AIRPORT WIND SPEED ≥ 20 mph.
DEC-JUNE
PROBABILITY OF WIND SPEED ≥ ANY GIVEN SPEED
0
10
20
30
40
50
60
70
80
90
100
5
10
15
20
25
30
35
40 mph.
WIND SPEED

FIG. 24

Western Region Technical Memoranda: (Continued)

No. 24 Historical and Climatological Study of Grinnell Glacier, Montana. Richard A. Dightman. July 1967.

No. 25 Verification of Operational Probability of Precipitation Forecasts, April 1966 - March 1967. W. W. Dickey. October 1967.