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U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

Climatology Of Rainfall Probabilities For Oahu, Hawaii

ARTHUR N. HULL AND JON PITKO

PACIFIC REGION
HONOLULU, HAWAII
April 1972

NOAA TECHNICAL MEMORANDUM

National Weather Service, Pacific Region Subseries

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Arthur N. Hull and Jon Pitko

Pacific Region
Honolulu, Hawaii
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CONTENTS

INTRODUCTION

This study was conducted as the first step necessary in the preparation of probability forecasts of local and island-wide rainfall for Oahu. Previous work in the field of climatological quantitative forecasting of rainfall for Oahu was conducted by Halstead and Leopold (1948)*who prepared median monthly rainfall charts. The present study, rather than being quantitative, is designed to provide the statistical probability of rainfall by months. Also included is the persistence of "wet" or "dry" periods. The combination of climatological probability of rainfall and the persistence of the present weather are essential information for reaching a logical forecast of rain or no rain for any location on the island of Oahu.

Section I of this study contains maps of the statistical probability of daily rainfall for Oahu for each month of the year as well as an annual summary. Also included is a brief description of the various rainfall regimes that are found on the island. The data used in preparing the maps were extracted from the latest 30 years (1941-1970) of rainfall records. For data sparse regions, shorter periods of record were used but in no case were records with less than 15 years entered into the analyses. In all, the data from 68 stations were plotted and analyzed. Since all stations do not report "trace", the percentage daily frequency of rainfall is based on .01" or greater to be termed a rainy day. In the process of map scale reduction, station numbers were reduced to the near illegible point. Figure 1 indicates the location of 25 primary forecast stations and Table 1 identifies these stations. Figures 2 through 14 are the analyses of the monthly and annual maps of the percent of days with greater than or equal to .01 inches of rainfall. Appendix I contains the computed percent of days with $\geq$ .01 inches of rainfall for the 68 stations used in the analyses.

Section II contains the frequency distribution of hourly rainfall statistics gained by compiling hourly data for five stations representing different rainfall regimes on Oahu. Ten years of hourly data were examined for WSFO Honolulu (station 703) and the Federal Building Honolulu (station 704). Only six years of hourly data were available for the remaining stations. A sixth station, Lualualei (station 804) on the Waianae coastal region, was compiled but not included in this report because it was evident that the months of March through October involved too small a sample of hours of rainfall to be significant. Only the monthly data for WSFO and the Federal Building Honolulu are graphically plotted. These data are considered to be from a large enough sample of the population to be significant. The hourly percentage of rainfall occurrance by month for all five stations is included in Appendix II. Although the three stations with the shorter period of record are considered to be from a sample size to be only marginally significant, the daily tendency for certain groups of hours to be "wet" or "dry" is considered valid and may be used to determine which hours are more favorable for rainfall than others. Figures 17-23 show graphically the percentage of rainfall that occurs each hour each month for WSFO and the Federal Building Honolulu and the annual summary for each of the five stations investigated.

*M. H. Halstead and L. B. Leopold, "Monthly Median Rainfall Maps", PRI & HSPA Report No. 2, Jan. 1948.

I. CLIMATOLOGICAL PROBABILITY OF RAINFALL ON OAHU

Figures 2 through 14 graphically portray the percent of rainy days per month for the island of Oahu. This percentage is also the climatological probability of rainfall for any day within the month.

The lowest percentage of rainy days per month (≤ 20) on an annual basis (Fig. 14) occurs within two miles of the shoreline from Waianae southward to Barber's Point then eastward to the entrance to Pearl Harbor. The highest percentage on an annual basis (≥ 80) occurs at the headwaters of the Manoa and Halemano Streams in the Koolau Mountain Range. Near Mt. Kaala on the Waianae Range the annual percentage is greater than 60%.

Various sub-climates are manifest on the island, each showing its own peculiar annual variation depending upon which regime most greatly affects its weather during the year. With northeast trade winds predominant throughout the year, these regimes can be defined by their locations with respect to the two mountain barriers which are nearly perpendicular to the normal low level winds.

With the exception of most of the windward coast, nearly all of the other shorelines on the island are in a sub-climate that could be labelled the Leeward Coast type. Extending anywhere from 1/2 to 2 miles inland this climate is characterized by a summer minumum and a winter maximum in the frequency of rainy days per month. During the summer when the trade winds are strongest and most persistent, the downslope motion and consequent drying effect to the lee of the Koolau and Waianae Ranges is most pronounced, keeping these areas relatively cloud-free at this time of the year. During the winter when the Kona low and cold front associated rains are much more frequent, the cloudiness in these areas is much higher than in the summer. Oddly enough, in July when the trade winds are at their maximum strength and the descending motion to the lee of the Koolaus and the Waianaes should be most pronounced, most of these stations show a significant increase in the percentage of rainy days from the previous month. The stronger low level winds apparently advect falling rain farther from the lee slopes accounting for the apparent increase in the frequency of rain. Although they are not to the lee of any mountain ranges, the Waimanalo and Kualoa Point areas on the windward shore exhibit an annual variation in percentage of rainy days per month similar to that of the stations on the leeward shores of the Koolau and Waianae Ranges.

The upper and lower windward and leeward slopes of the Waianae and Koolau Mountain Ranges show a summer peak in percentage of rainy days/month, at a time when the trades are strongest and the orographic uplift of these winds, when they strike these mountain barriers, produce a great deal of summer cloudiness. With the trades at their peak in June-August, many of the upper mountain slope stations receive measurable precipitation on 60-70 days during this three-month period. The lower slope stations may receive

.01" or more of precipitation on only 50-60 days during June-August. Whether or not precipitation falls at these locations is primarily dependent upon whether the trades are strong enough to cause the precipitation to be advected downwind over the lee slope locations or to allow the orographic cloud to build upwind over the windward slope locations. As the trades decrease in September, these mountain slope stations show a corresponding decrease in the percentage of rainy days per month. With the advent of the Kona low and frontal rains of winter, the frequency of rainy days at these mountain slope stations again increases, but usually remains 5-10% below the July peak, leading to the conclusion that while winter rains may be heavier than summer rains at these locations, measurable rain falls during more summer days than winter ones. Thus, winter rain here is less frequent than in summer but is of an intense, unstable nature, while the summer rains are of a light showery character.

The windward and leeward slope climates show a secondary minimum in the percentage of rainy days per month in January and February. This minimum is associated with the fact that at this time of the year, the surface subtropical ridge is at its furthest point south, often lying directly over Oahu in February. This coincides with the low-level (700 mb) jet theory proposed by Yeh et al (1951) whereby minimum rainfall in the winter season occurs when the 700 mb jet is between 32 degrees and 37 degrees N.

Another major sub-climate on Oahu is near the saddle area. This climate in the Wahiawa area shows a large degree of uniformity throughout the year, ranging from about 50% of days with 0.01" of precipitation in late spring and late summer to about 60% in mid-summer and early winter.

Keeping in mind that the statistic being discussed is the percentage of rainy days per month and not the mean monthly rainfall, several conclusions can be drawn from the results of this work. For the normally "dry" areas of Oahu, summer finds the lowest percentage of rainy days per month and winter the highest percentage. July presents an anomalously high percentage in most of these dry areas. In the normally "wet" areas of Oahu, summer finds the highest percentage of rainy days per month with winter having the lowest percentage.

The most populated areas of the island have monthly percentages of rainy days per month normally in the range of 40-60% each month. From a climatological point of view this means that in the areas where most of the people live on Oahu the probability that $\geq$0.01" precipitation will fall in these areas during any given day of the year is about 50%.

Thus, from a statistical point of view, forecasting rain or no rain for the heavily populated areas will require great skill to improve on a climatological forecast.

STATION IDENTIFIERS

1	WSFO Honolulu	703
2	Moanalua	770
3	Honolulu Substation	704
4	HSPA Experiment Station	707
5	Waialae Kahala	715
6	Makapuu Point	724
7	Palolo Valley	718
8	Waimanalo Experiment Farm	795.1
9	Nuuanu Reservoir	783
10	St. Stephen's Seminary	788
11	Kailua Fire Station	791.3
12	Kaneohe Mauka	781
13	Waiahole	837
14	Kapaka Makai	905.1
15	Church College Laie	903.1
16	Waimea	892
17	Opaeula	870
18	Koolau Dam	833
19	Camp 84	807
20	Wahiawa Dam	863
21	Waialua	847
22	Makaha Kai	796
23	Lualualei	804
24	Ewa Plantation	741
25	Manana	754.2

Table 1

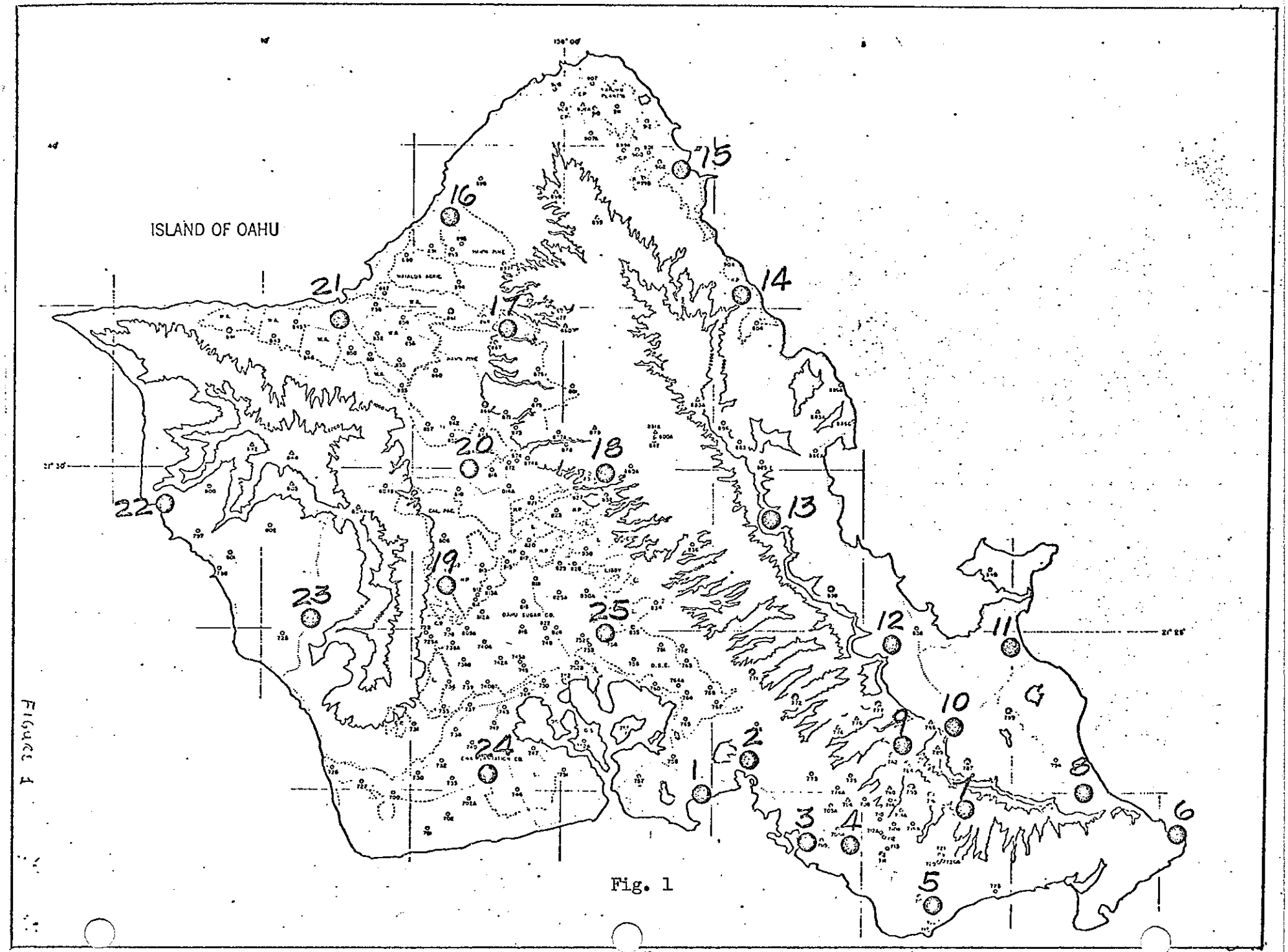
ISLAND OF OAHU
1
2
3
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Fig. 1

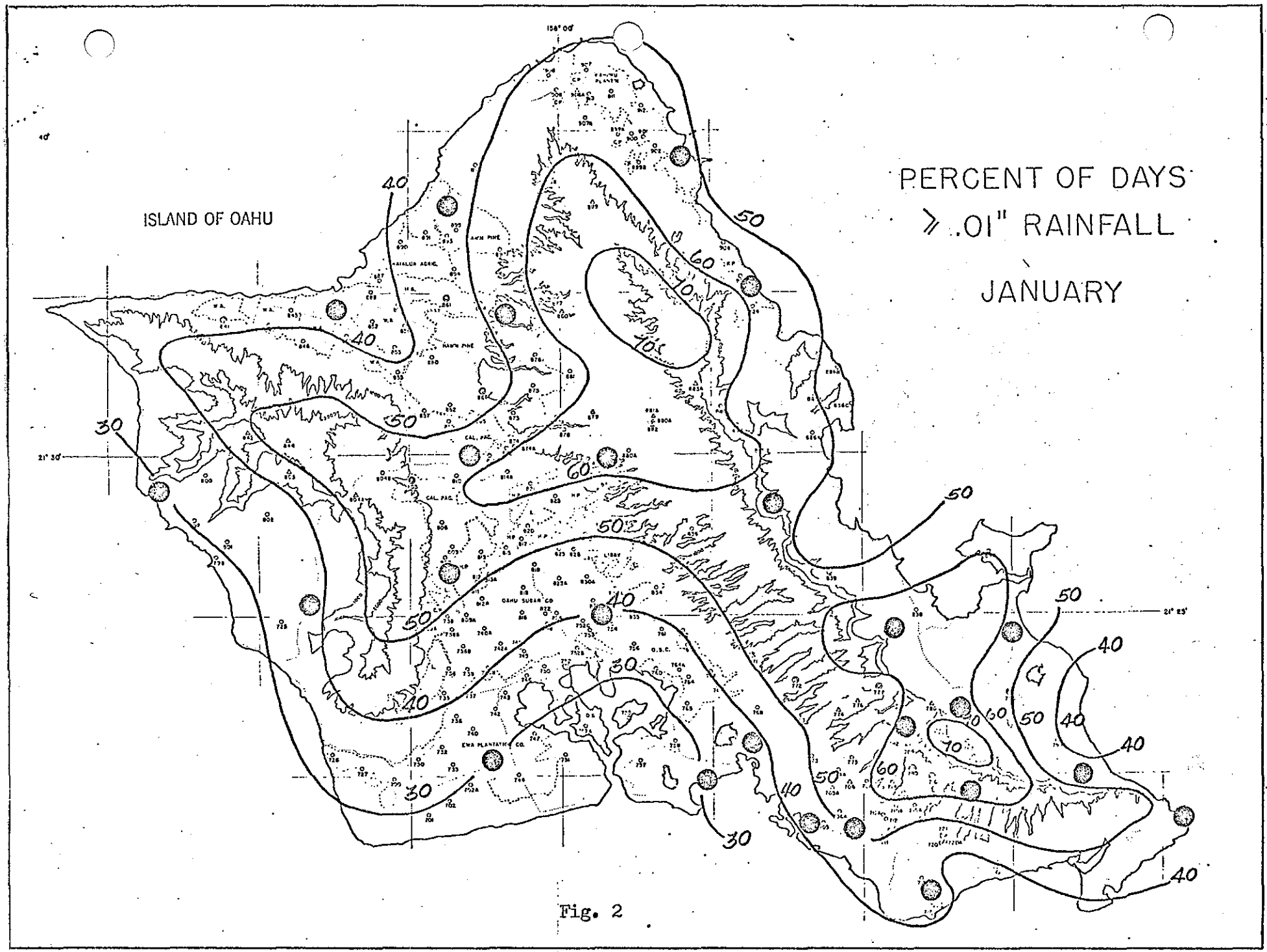

ISLAND OF OAHU
PERCENT OF DAYS
≥ .01" RAINFALL
JANUARY
158° 00'
21° 30'
21° 23'
OAHU SUGAR CO
EWA PLANTATION CO.
CAL. PAC.
O.S.C.
10
30
40
50
60

Fig. 2

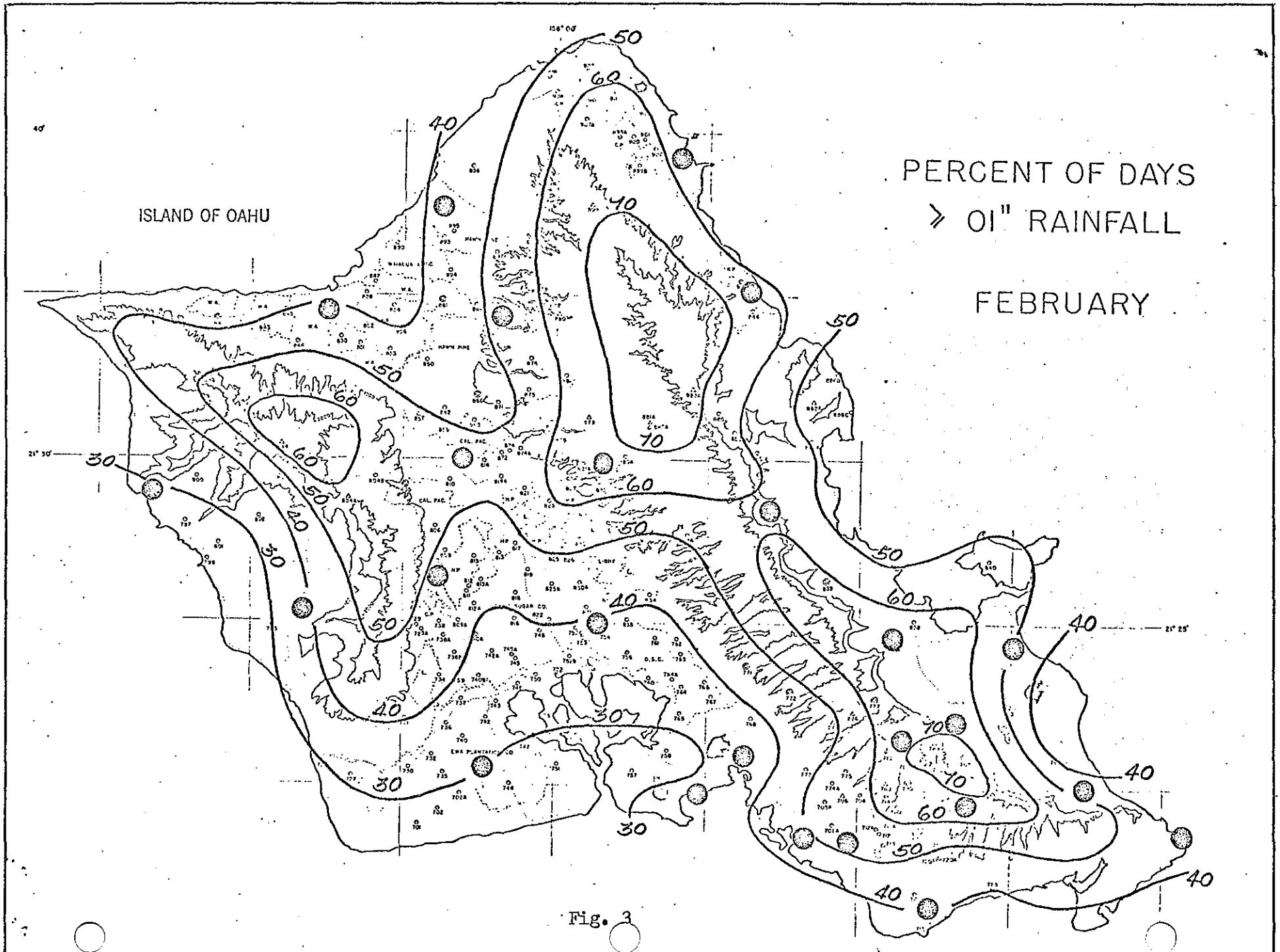


Fig. 3

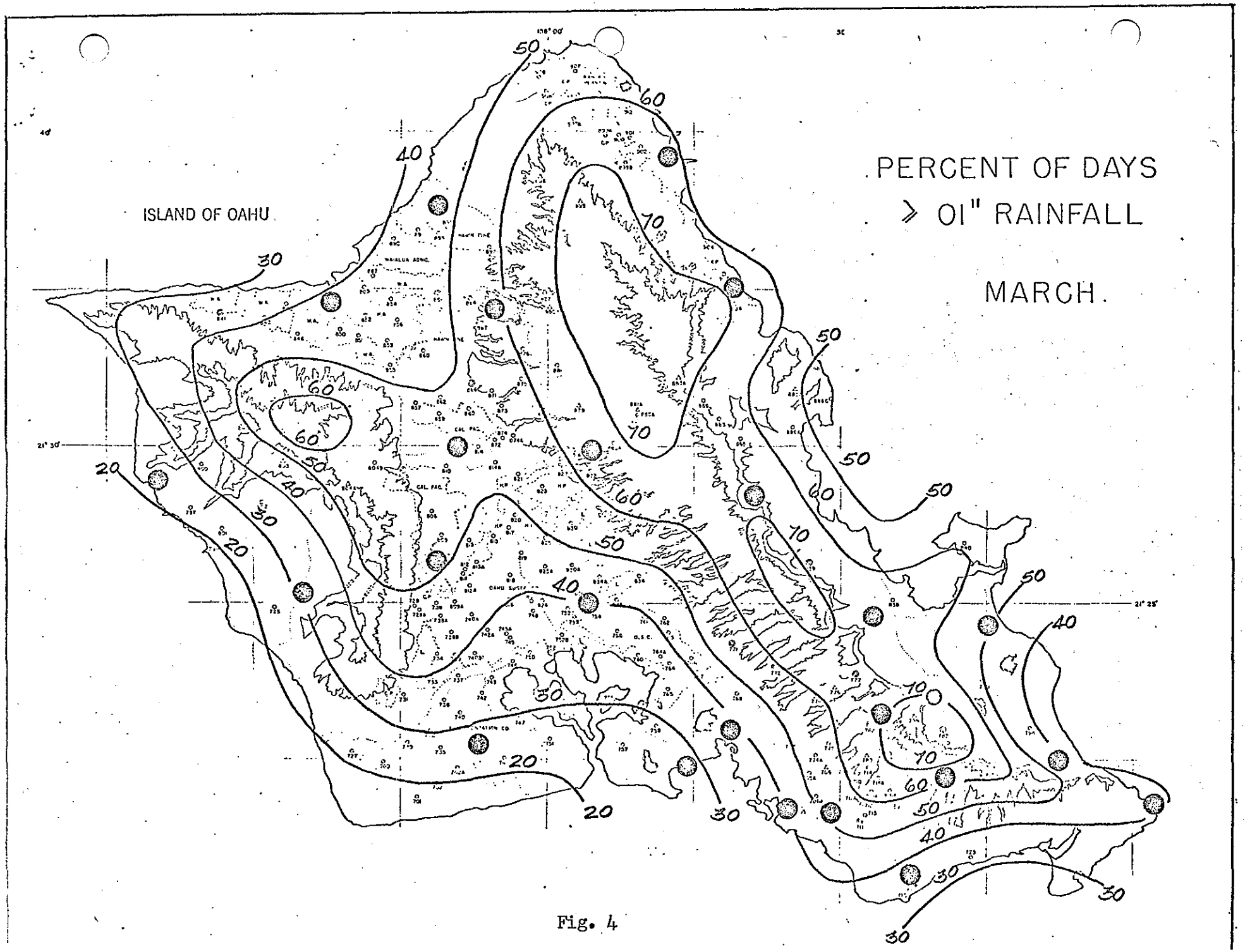


Fig. 4

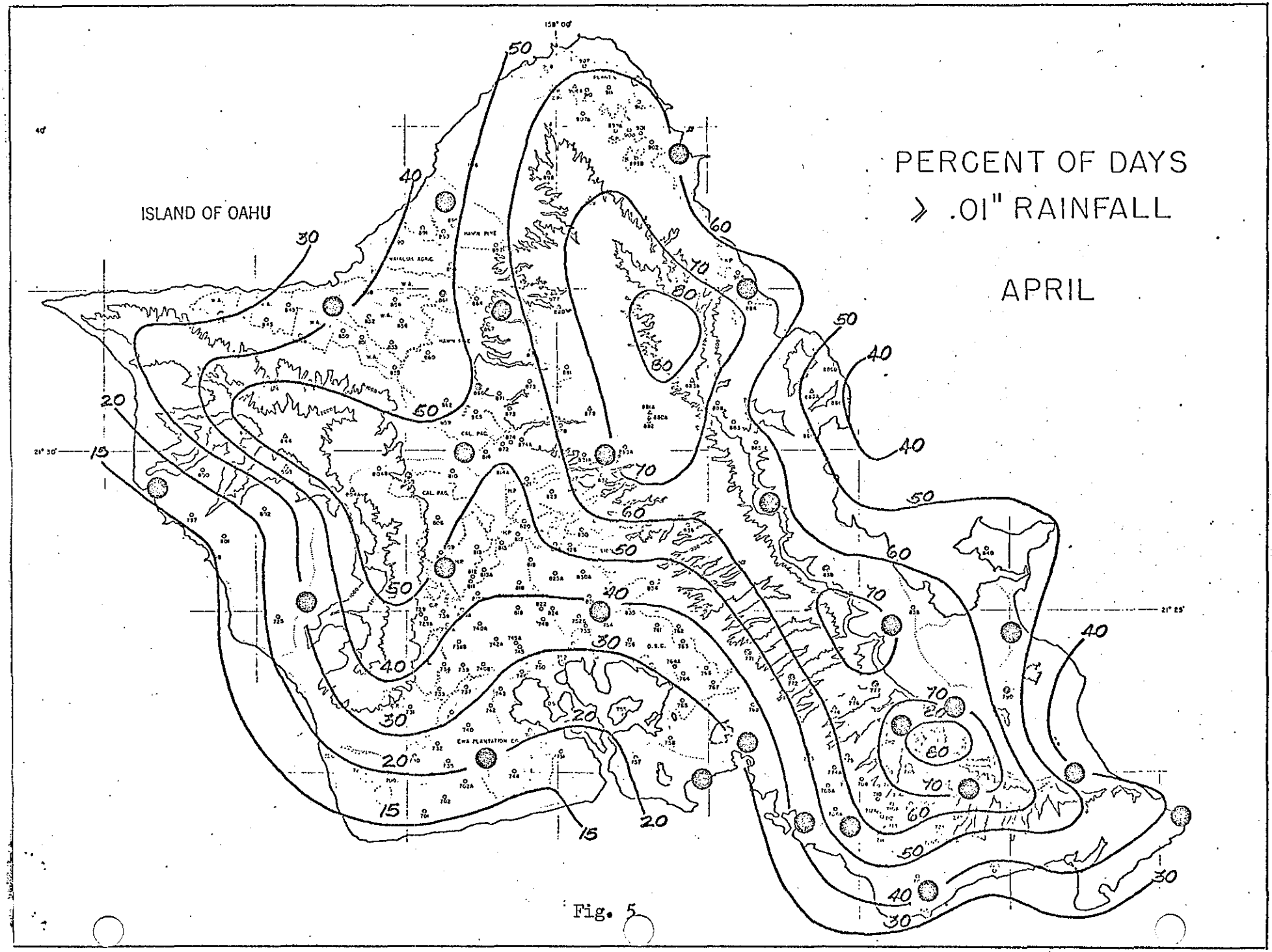
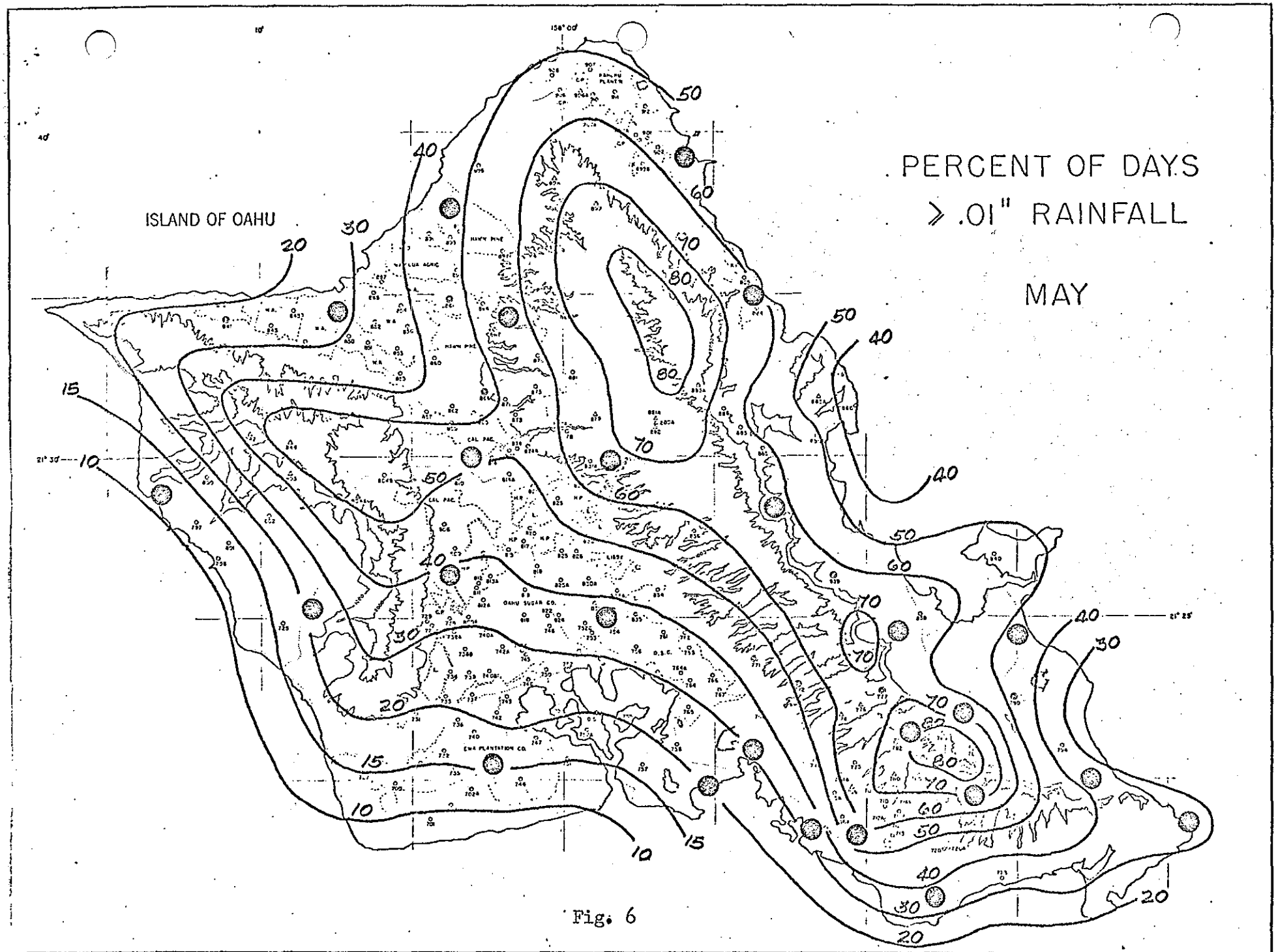


Fig. 5



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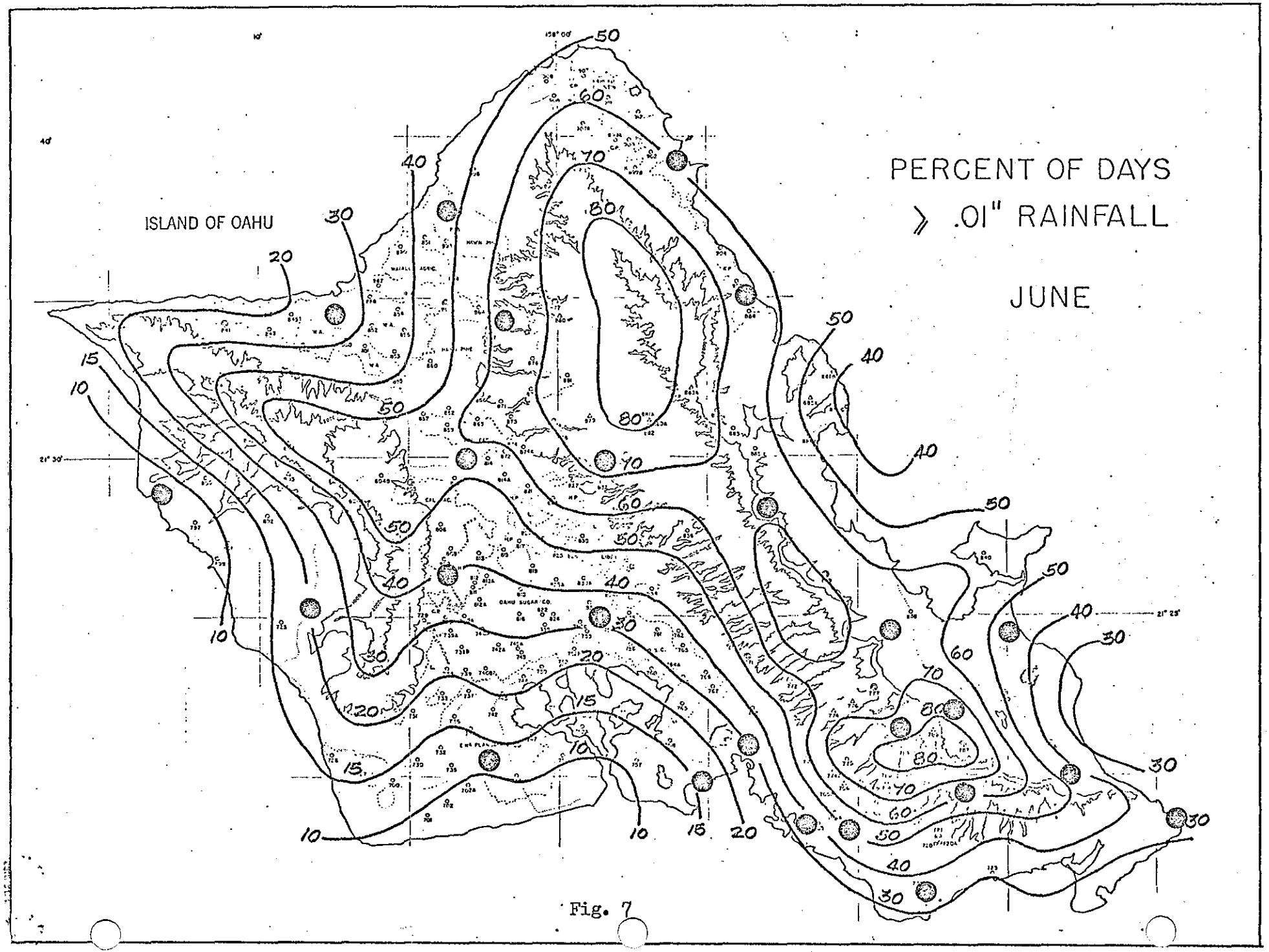

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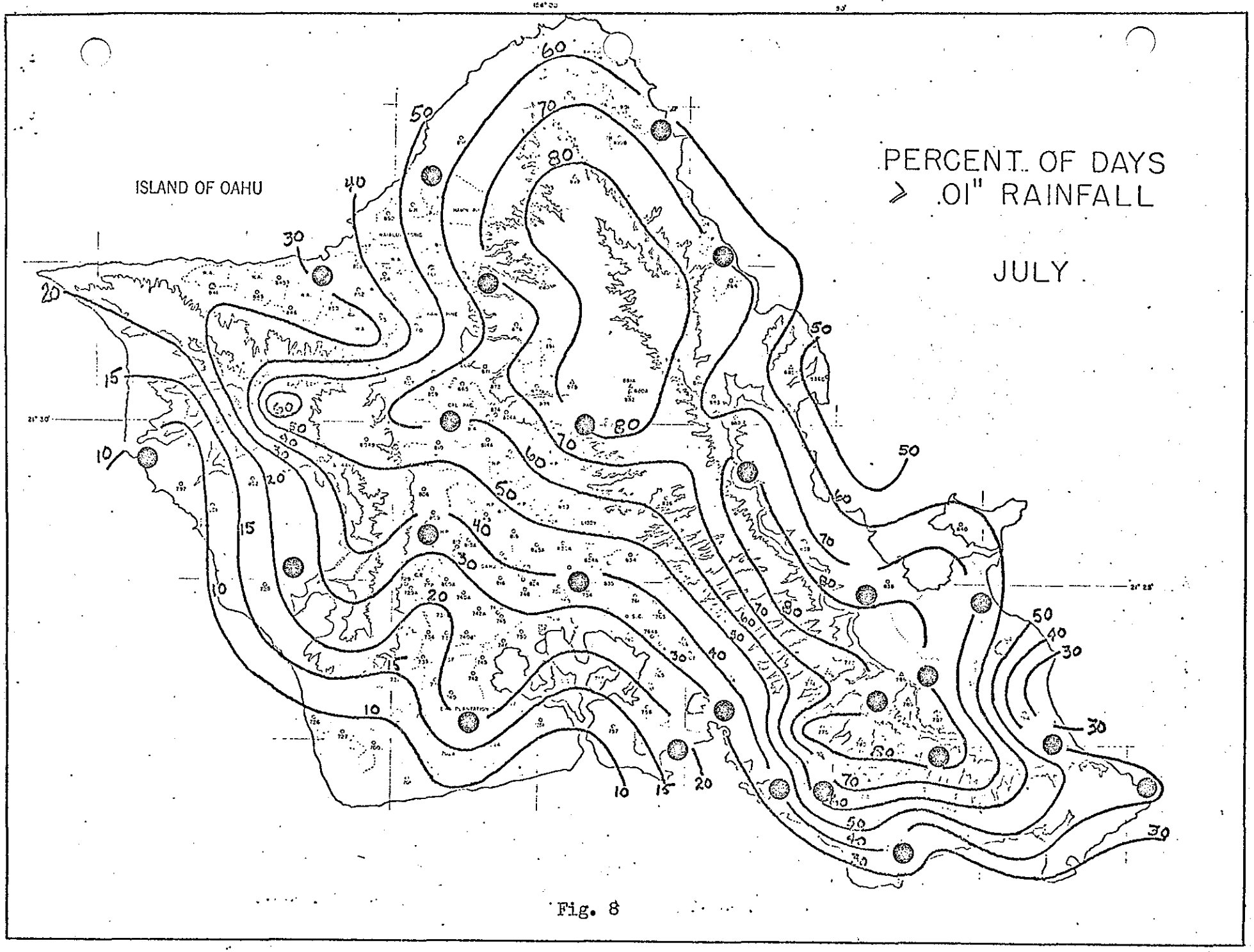


Fig. 8

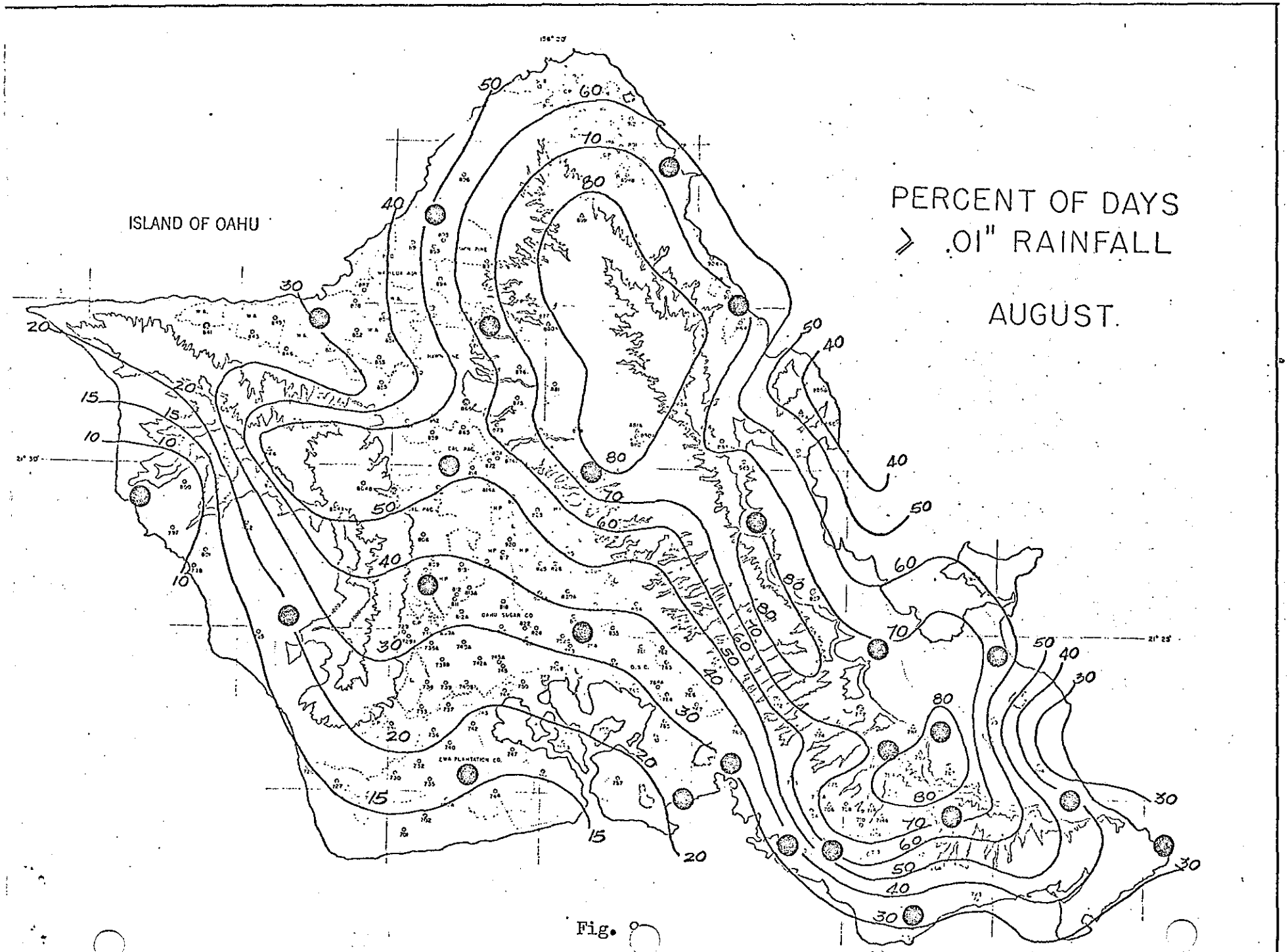


Fig.

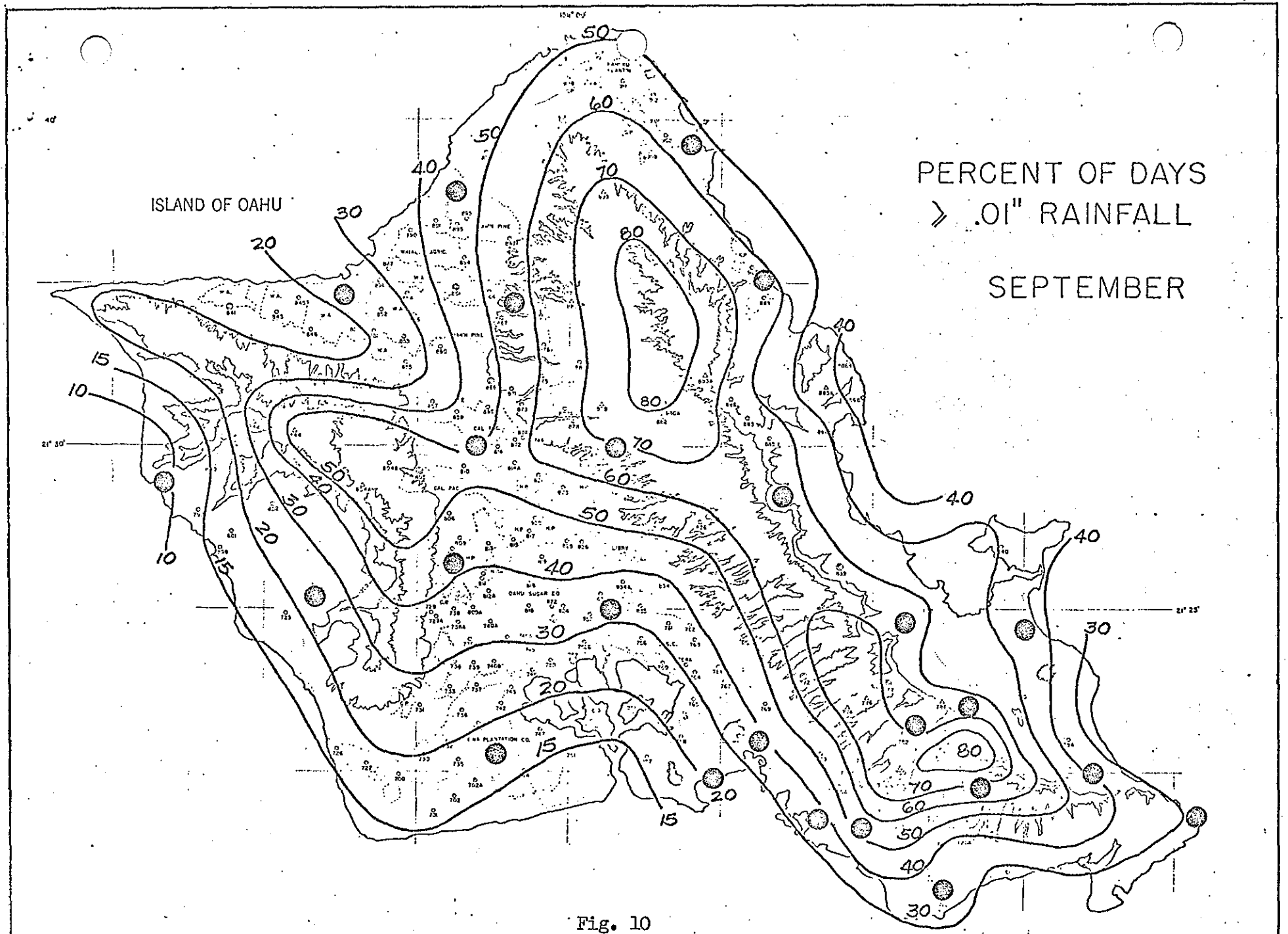


Fig. 10

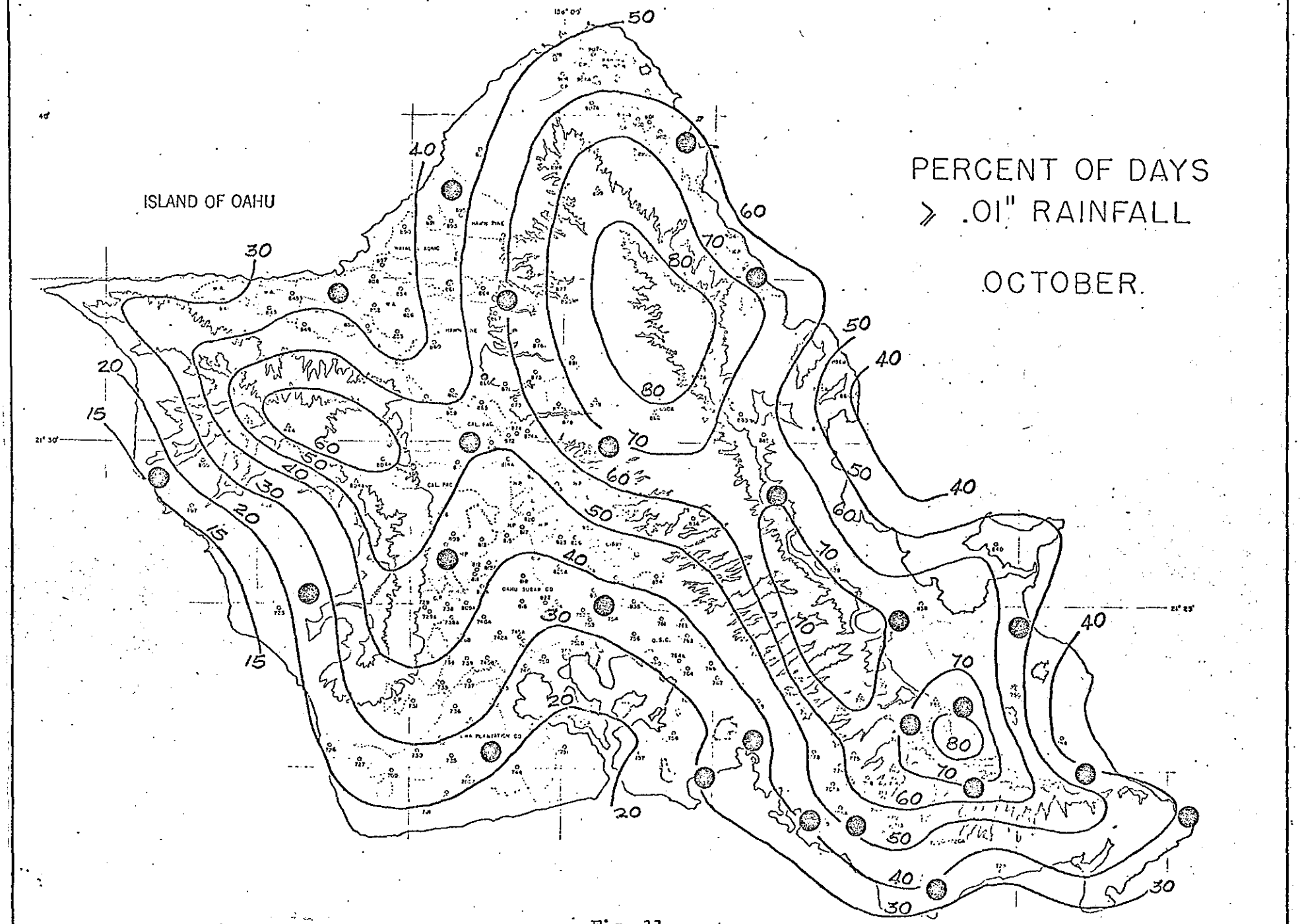


Fig. 11

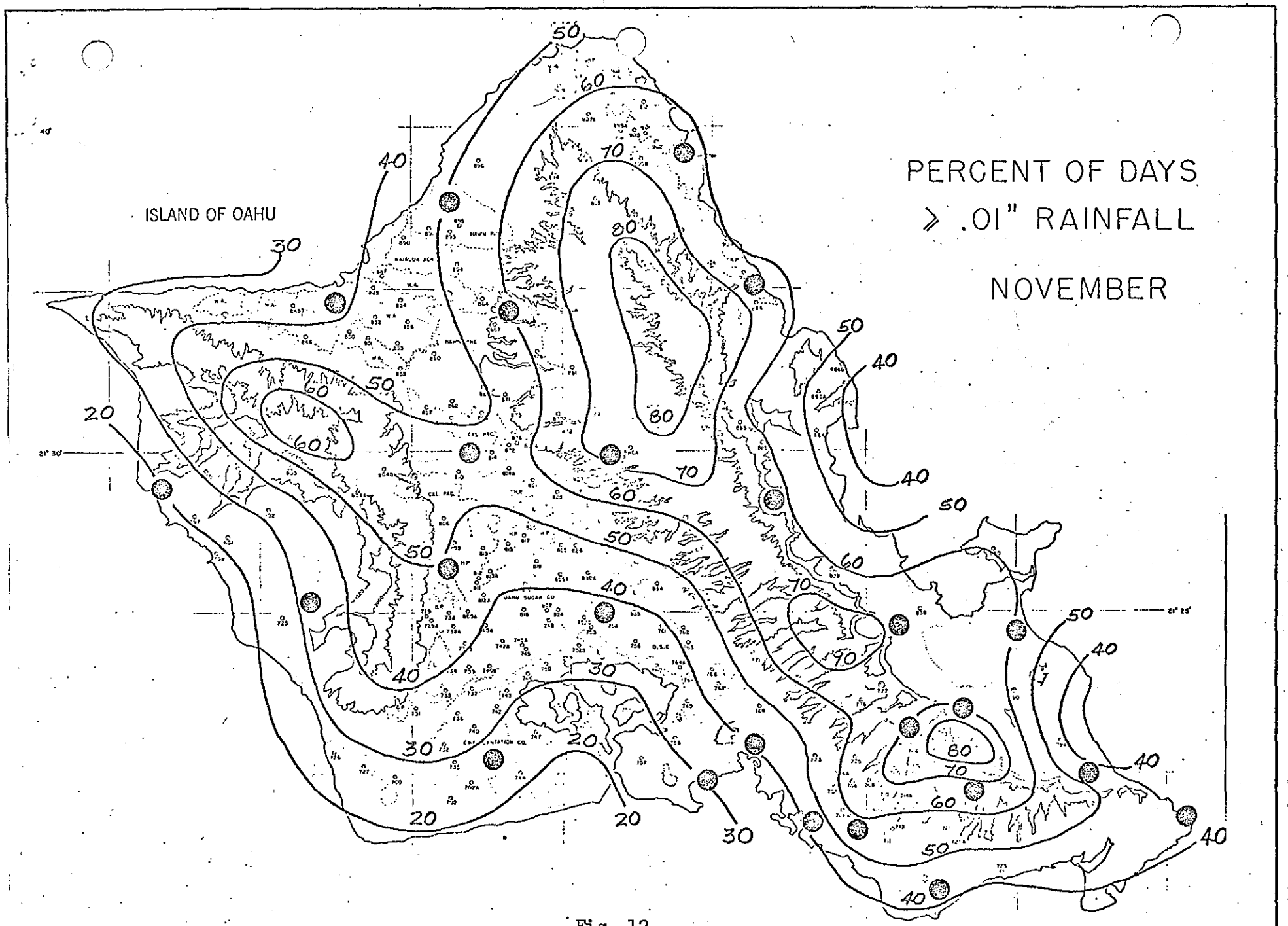


Fig. 12

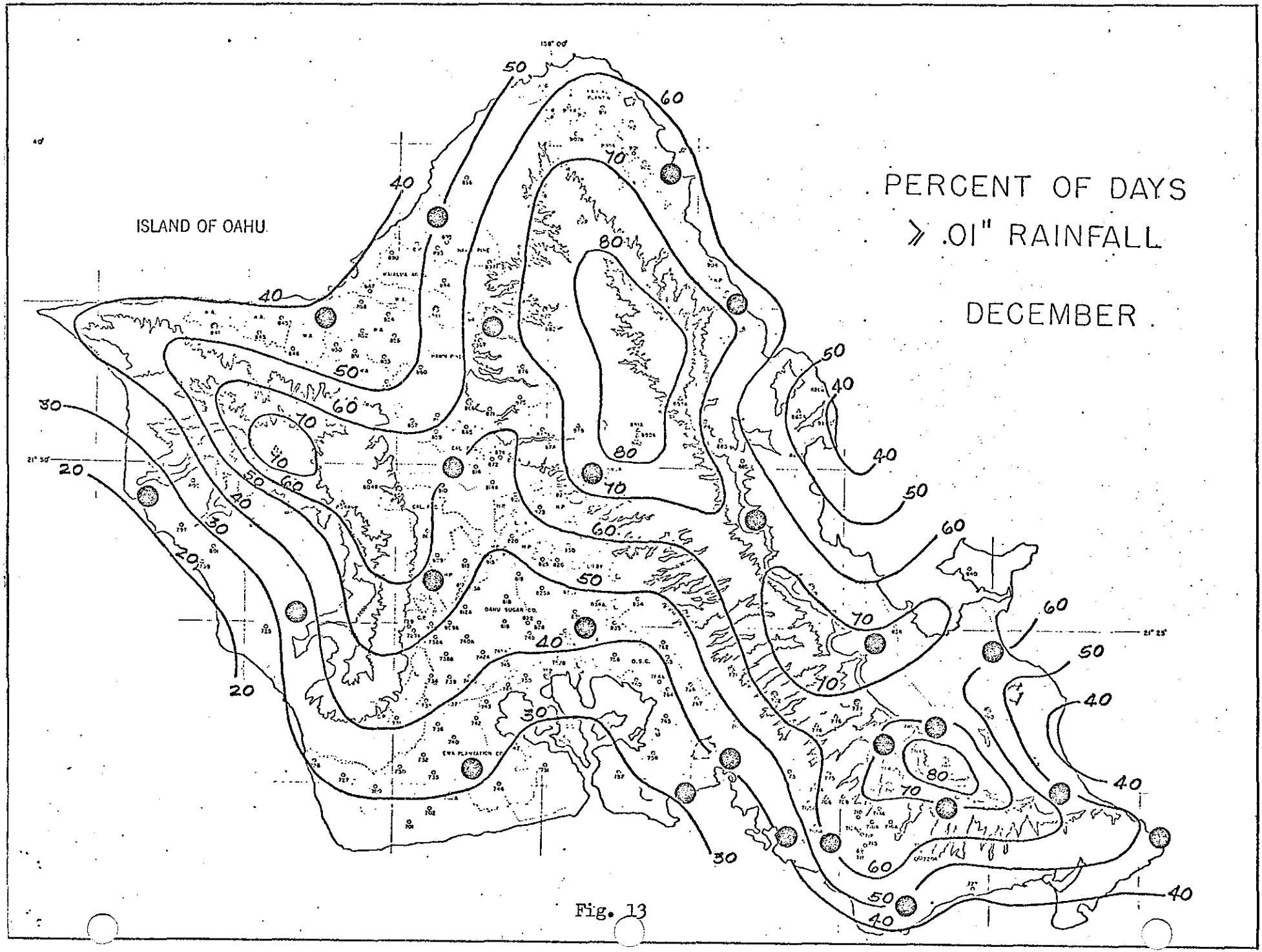


Fig. 13

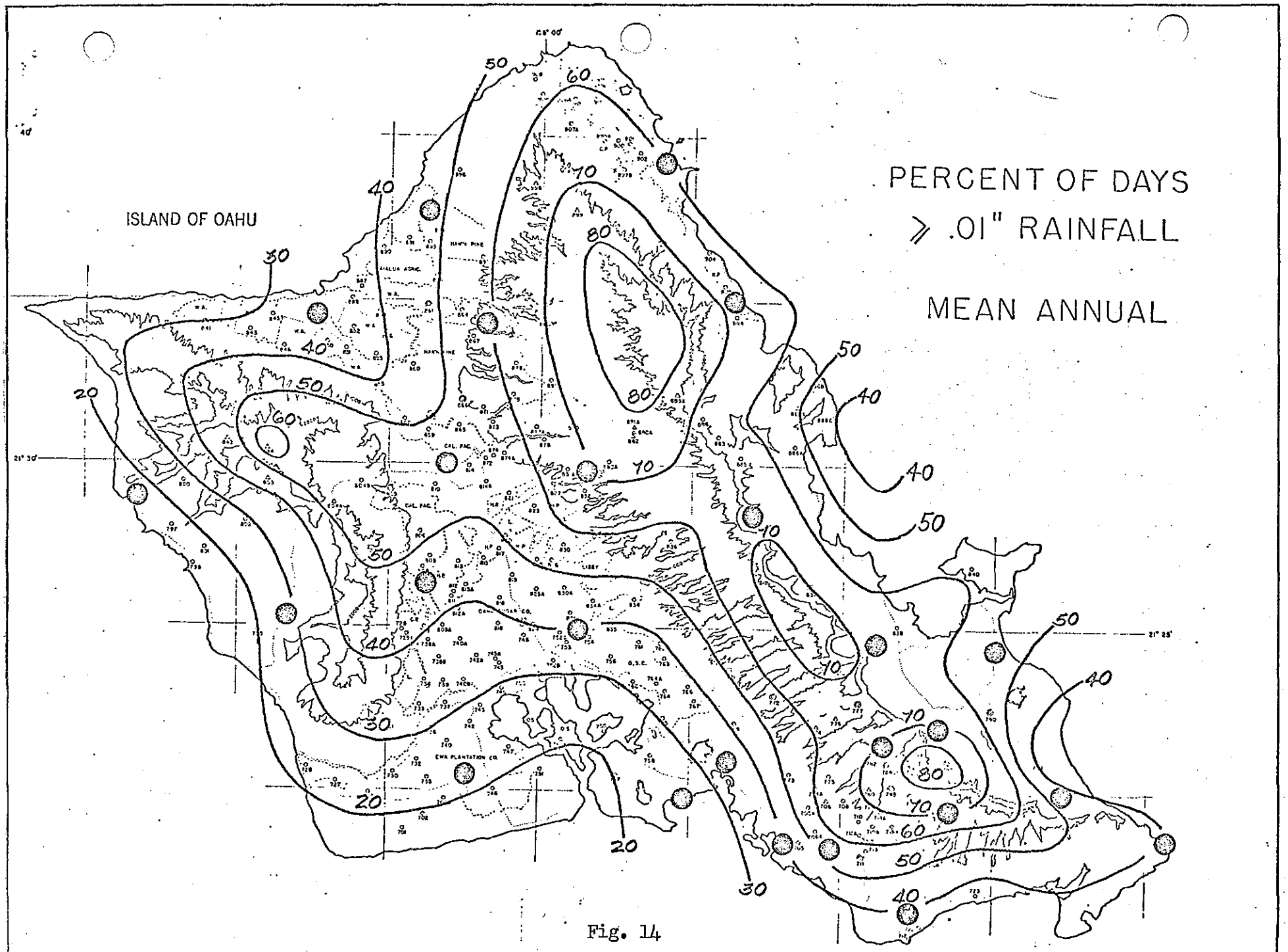


Fig. 14

Table 2 shows the persistence of wet or dry periods for six locations on the Island of Oahu. The figures are to be interpreted as the persistence of the weather for a station either wet or dry. For example, using D for a dry day and W for a wet day, if the following observations were noted, the days indicated 1, 2, 3, and 4 would be termed persistent days.

D	D	W	D	W	W	W	D	D	W	D
	1				2	3		4		

The first dayshas no previous day with which to compare persistence (this was not true, of course, with the actual data). Of the remaining ten days, four were observed to be persistent with the day before. Thus, the persistence of the sample is 40% or .40.

PERSISTENCE (1961-1970)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
WSFO, HON	.66	.67	.74	.66	.72	.71	.69	.69	.66	.60	.73	.67
FED BLDG	.63	.68	.65	.68	.69	.70	.70	.63	.62	.64	.67	.60
MAKAHA KAI	.69	.74	.79	.87	.89	.96	.75	.86	.86	.76	.75	.76
WAIALUA	.56	.60	.65	.66	.67	.73	.65	.71	.66	.69	.68	.62
WAHIAWA DAM	.65	.61	.61	.61	.61	.67	.60	.67	.52	.64	.68	.66
ST. STEPHENS	.64	.60	.62	.61	.65	.73	.69	.67	.62	.63	.64	.63

TABLE 2

We note that the persistence is very high for all stations examined with relatively small changes in going from the summer dry period to the winter wet period except for the Waianae Coast. There, the summertime pattern is rarely wet as evidenced by a 96% persistence in June at Makaha Kai. For the remaining regimes on the Island, the advent of winter rains appears as more persistent rainy days whereas the summer dry period contains more persistent dry days. The transition noted by a minimum value of persistence is only clearly evident at Wahiawa Dam in September. The remaining minimums are usually within 10% of the maximum value of persistence and this is hardly noticeable.

Since the 68 stations used in the analyses of these charts are approximately equally divided between the very frequent and very infrequent categories, a combined average rainfall probability for all 68 stations by month approximates the relative probability of rainfall for the Island as a whole. The average of the data for all 68 stations is shown in Figure 15.

Figure 15 implies that the Island of Oahu experiences two primary rainy

months, July and December, and two primary dry months, May and September, with a secondary rainy month of March and a secondary dry month of February. It must be emphasized at this point that Figure 15 is not quantitative but represents a statistical probability of rainfall. The December maximum does, in fact, represent the wettest month but July produces very little quantity of rainfall. The difference can be explained by Figure 16, the average number of hours of rainfall per month at selected stations. This figure was obtained by counting the number of hours of rainfall for each month for the four stations plotted for the period of record (i.e., ten years for WSFO and the Federal Building, Honolulu and six years for the remaining stations) and obtaining the averages. The net result is that in July, very light rainfall occurs but on a daily basis more frequent than any other month of the year except December.

Probability of Daily Rainfall ≥.01" in Percent

68 Stations Average

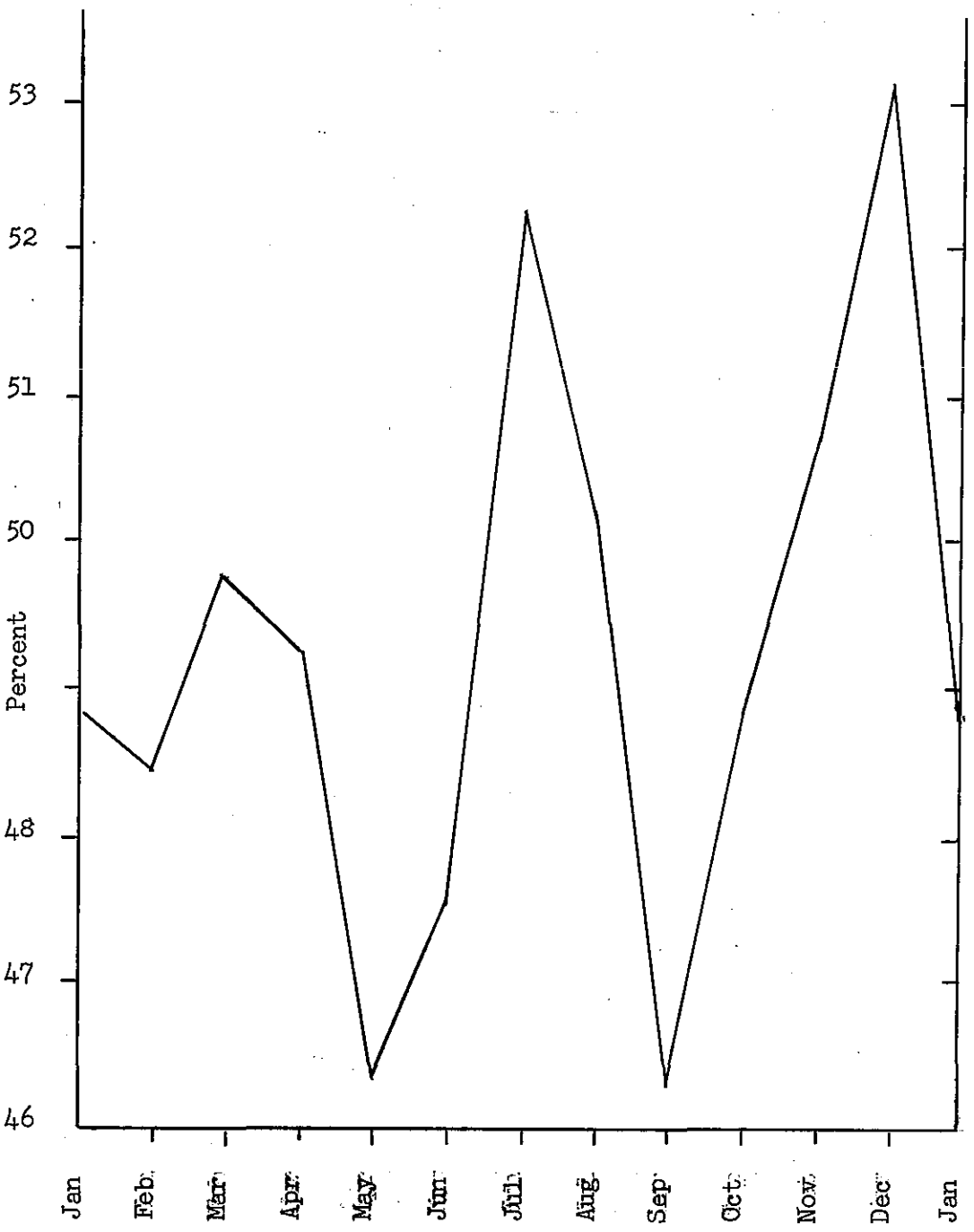


Fig. 15

Average Number of Hours of Rainfall Per Month $\geq$ .01"

Period of Record as Indicated in Table 3a.

a. Maunawili (787.1)
b. Wahiawa Dam (863)
c. Federal Building (704)
d. WSFO Honolulu (703)

Waialua Omitted Because of Clutter

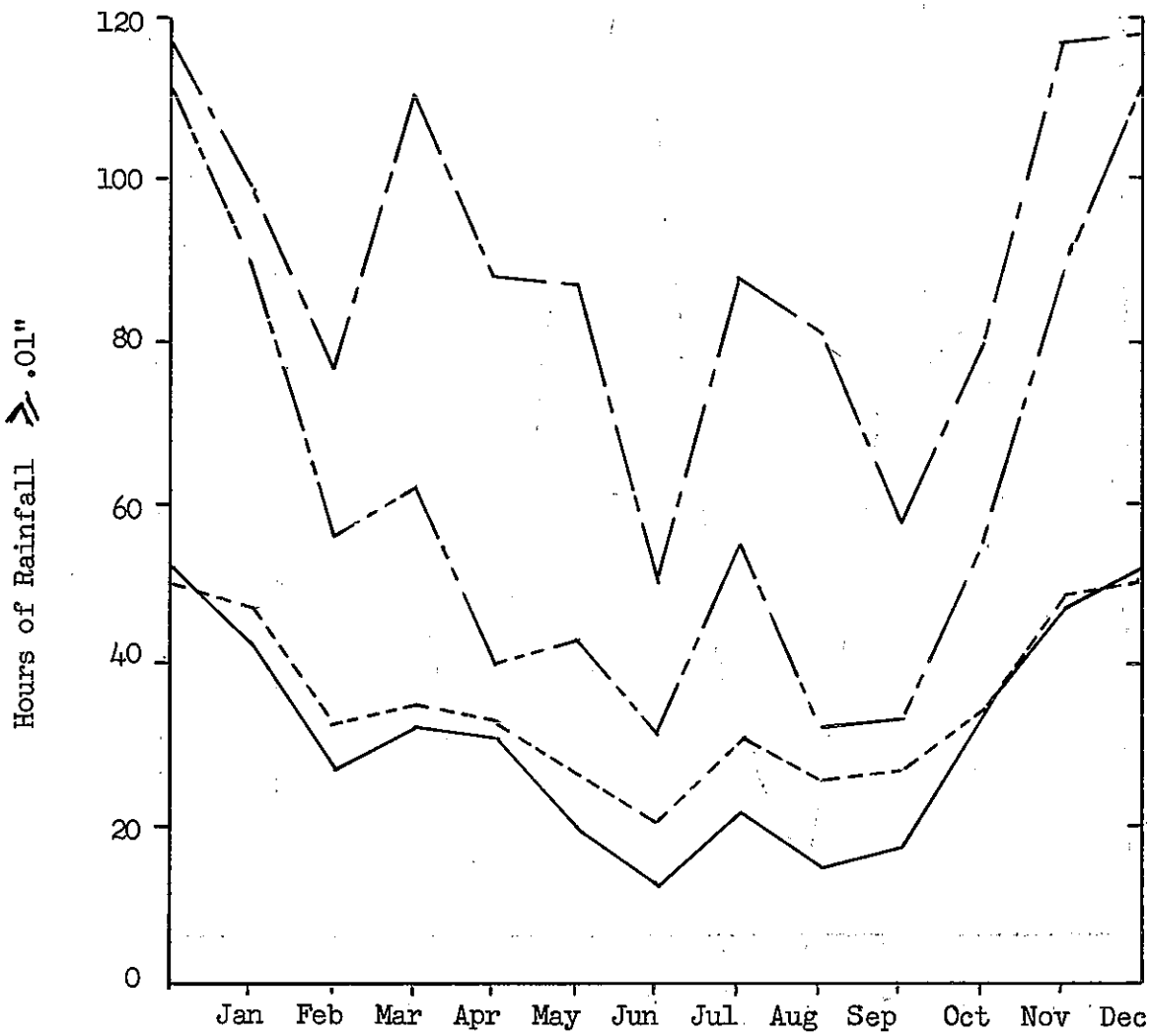


Fig. 16

II. FREQUENCY DISTRIBUTION OF HOURLY RAINFALL

The various island rainfall sub-regimes is more clearly emphasized by the frequency distribution of hourly rainfall by months as well as the annual summary. The annual summary of the frequency of hourly rainfall is shown in Figure 17. The line through all graphs at 4.17% represents the frequency expected if rain falls uniformly every hour of the day.

The Federal Building (station 704) is the best example of the stations studied of preferred nighttime rainfall, the maximum frequency of rainfall is spread rather evenly over the night and early morning hours and the minimum frequency of rainfall is sharply centered at 2 p.m.

Maunawili (station 787.1) is representative of the windward Oahu regimes. A very wet station was selected purposely since the length of hourly rainfall records of all stations, except WSFO Honolulu and the Federal Building, were a maximum of six years. By selecting a very wet station, a more significant number of hours of rainfall for each hour of the day for each month was obtainable.

The frequency of hourly rainfall pattern at Maunawili shows the same general features of maximum and minimum frequency of hourly rainfall as the Federal Building, except the minimum is not nearly as sharply defined and the maximum tends to be more nearly centered in the early morning hours.

WSFO Honolulu exhibits a double maximum near midnight and again in the early morning hours. The fall off in frequency between the maximum and minimum is as dramatic as that observed at the Federal Building. However, the late afternoon period, although below the "average" line, shows a sharp rise after the minimum is reached.

Wahiawa Dam (station 863) and Waialua (station 847) had the least total number of hours of rainfall for the six year period of study, and hence the least significance can be obtained by interpreting the data. Even though the frequency patterns are quite irregular, one can state that on an annual basis the Wahiawa pattern resembles the WSFO pattern with a maximum frequency of rainfall rather evenly spread out over the late evening and early morning hours and a minimum frequency rather evenly spread out over the late morning through late afternoon period.

Waialua appears as the exception to all patterns of hourly rainfall frequency distribution examined. The two maxima, a short period both in the early morning and late afternoon and the minimum in the mid-day are not nearly as pronounced as in the other stations examined. Except for the strong peak at 6 a.m. in Figure 17, all other percentages are within a few tenths of the "average" line. Thus, we may say that the frequency distribution by hour of rainfall in the North Shore area appears to differ from the remainder of the island in that it is more uniformly distributed.

This is perhaps a result of Waialua being located sufficiently westward of the northern Koolau range that it is not in the lee of this mountain range under northeast trades.

Thus, we might say that the North Shore is more representative of a maritime rainfall regime than the remainder of the island of Oahu. This is conjecture, but the idea is further enhanced by noting that the normal annual rainfall for Waialua is very close to that given for the open sea area at the latitude of Oahu, approximately 25-30 inches per year.

The annual frequency of hourly rainfall shows only gross features of the rainfall patterns. Figures 18 through 22 show the monthly frequency distribution of hourly rainfall for WSFO Honolulu and the Federal Building.

January and December show the least amplitude of preferred wet or dry hours. These two months comprise the main part of winter for Oahu. The frequent frontal weather masks any tendency for preferred rainfall hours. As the season progresses into summer the amplitude of wet and dry periods increases and from summer to winter gradually decreases. The Federal Building exhibits a clear minimum in the early afternoon in every month of the year. The month of May at WSFO Honolulu stands out as being an anomalous month when comparing the hourly frequency distribution with all other months. There is no clear cut early morning maximum but there is a definite middle to late afternoon maximum that does not occur in any other month in the year. This feature is also evident at Wahiawa Dam and Waialua in May. This maximum is thought to be caused by a general lack of trade winds in May and considerable solar insolation. These conditions combine to cause buildups over the central portion of Oahu and shower activity in the middle to late afternoon period spreading out as far as WSFO. This is again conjecture, but there appears to be no other plausible explanation since this maximum does not appear at the windward station Maunawili and is not as pronounced at the Federal Building.

Table 3 is a summation from the data used in this portion of the study. It should be noted that the monthly values of rainfall are averages for the period of the hourly rainfall study and not normals. The November data is especially different from the normal because of one year's data - November 1965 in which some stations reported as much as 700% above normal rainfall.

The variability of island rainfall is indicated by the data from Waialua only. Again this data only covers the period used in the investigation.

Lastly, Table 3 lists the average hourly intensity derived by dividing the total rainfall received for the month by the number of hours in which rain fell. The most frequently observed hourly rainfall for WSFO Honolulu and the Federal Building for all months was .01 and .02 inches. Thus, for these stations, high hourly average intensities imply occasional very heavy showers. This is actually true for all stations. Maunawili has the highest average intensity for most months of the year for all the stations examined. This is caused by the location of the station, being on a windward slope where forced convection occurs under trade wind conditions. With the air at upper levels becoming less stable in the winter season, this forced convection leads to considerably stronger shower and thundershower activity.

Appendix II contains the frequency distribution of hourly rainfall in tabular form. An example of how this data may be used follows: Suppose a person is planning an outdoor wedding reception in September in the Pacific Heights area. He wishes to know what four-hour period has the least likelihood of the party being rained out.

From the map of September of percent of rainy days, (Figure 10), interpolating for Pacific Heights, we obtain approximately a 54% chance of rain for each day in September. The hourly data compilation for the Federal Building, the most nearly representative of the area in question, shows for the hours 1 p.m. to 5 p.m. the following (note the hourly percentages are for the hour ending at the time indicated)

2 p.m.	2.7%
3 p.m.	1.7%
4 p.m.	2.0%
5 p.m.	1.7%
Total:	8.1%

The figure 8.1% means that of all hours of rainfall recorded, 8.1% occurred between the hours of 1 p.m. and 5 p.m. Thus, climatologically there is a 54% chance of rain on the day of the reception. If it rains, there is an 8.1% chance the rain will fall between the hours of 1 p.m. and 5 p.m. Thus, climatologically there is a (54) x (.081) = 4.4% chance of rain occurring during the reception, a risk most people would be willing to take.

a. AVERAGE RAINFALL

WSFO AND FED. BLDG. (1961-1970)
REMAINING STATIONS (1965-1970)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
WSFO	4.25	1.64	2.96	1.88	1.61	0.48	0.87	0.59	0.72	1.75	4.89	4.46	26.10
FED BLDG	4.39	2.36	3.30	2.27	1.20	0.63	0.85	0.69	1.03	1.69	4.99	4.51	27.91
WAIALUA	7.27	3.26	3.72	2.34	1.22	0.33	1.54	1.11	0.67	2.53	6.37	4.42	34.78
WAHIAWA DAM	6.55	3.81	3.83	2.52	2.00	1.13	2.45	1.57	1.30	3.71	8.21	7.14	44.22
MAUNAWILI	10.21	7.84	10.70	9.05	7.25	2.61	5.39	4.75	4.52	8.71	13.91	13.07	98.01

b. VARIABILITY OF OBSERVED MONTHLY RAINFALL

WAIALUA ONLY - OTHER STATIONS SIMILAR

HIGH	20.33	6.43	8.01	6.42	3.68	0.92	3.17	2.83	1.56	6.73	13.44	8.05
LOW	0.96	1.45	0.18	0.63	0.26	0.09	0.53	0.19	0.27	0.68	3.12	1.21

c. AVERAGE HOURLY INTENSITY - HUNDREDTHS OF AN INCH PER HOUR

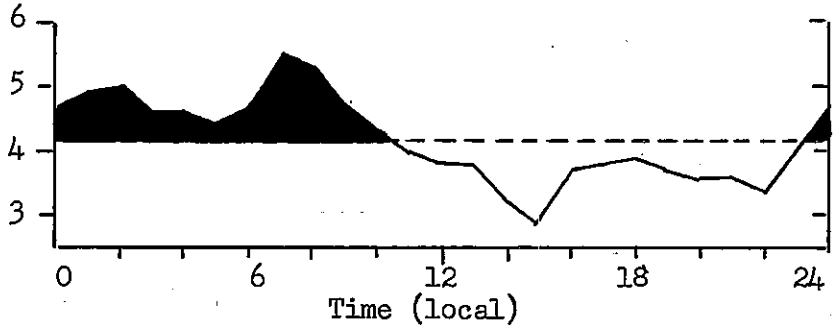
WSFO	10.0	5.8	9.2	6.2	8.2	3.6	4.0	3.8	4.3	5.3	10.4	10.0
FED BLDG	9.0	6.6	8.4	5.7	5.4	2.9	3.0	3.3	4.0	6.0	10.6	8.9
WAIALUA	10.8	8.6	7.4	6.5	4.5	3.4	6.0	7.3	4.5	7.6	10.1	6.2
WAHIAWA DAM	8.5	6.4	6.4	5.7	6.1	3.8	4.5	4.8	3.9	6.6	8.9	6.3
MAUNAWILI	10.3	10.3	9.6	10.3	8.3	5.0	6.1	5.9	7.9	10.9	11.8	11.1

TABLE 3

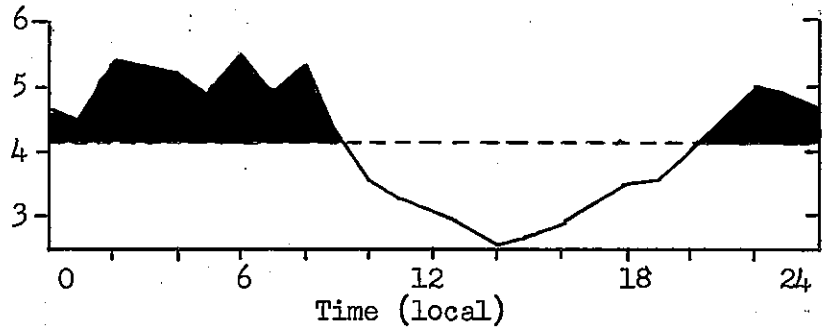
Frequency of Hourly Rainfall

Annual Summaries

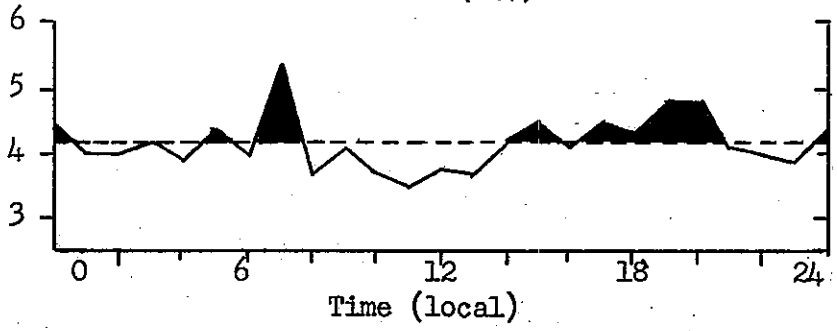
WSFO Honolulu (703)



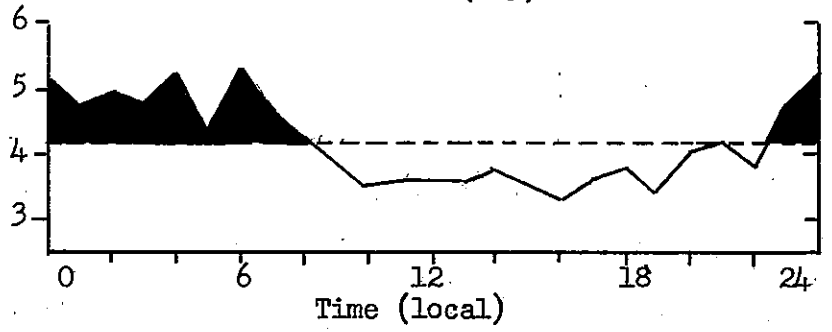
Federal Building (704)



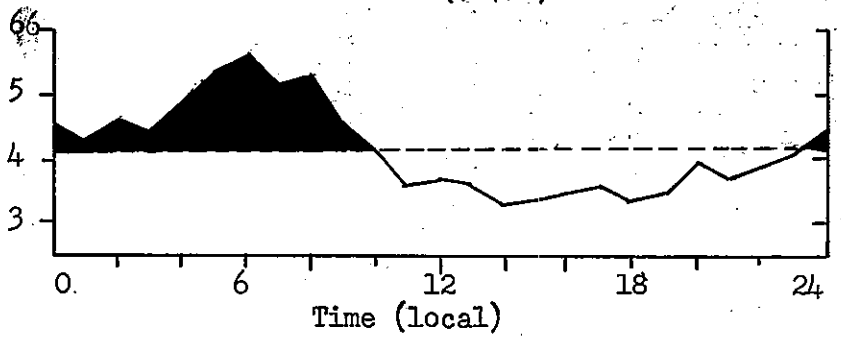
Waialua (847)



Wahiawa Dam (863)



Maunawili (787.1)



Average Hours of Rainfall Per Year

WSFO Honolulu	348
Federal Building	408
Waialua	452
Wahiawa Dam	698
Maunawili	1056

Fig. 17

Frequency of Hourly Rainfall

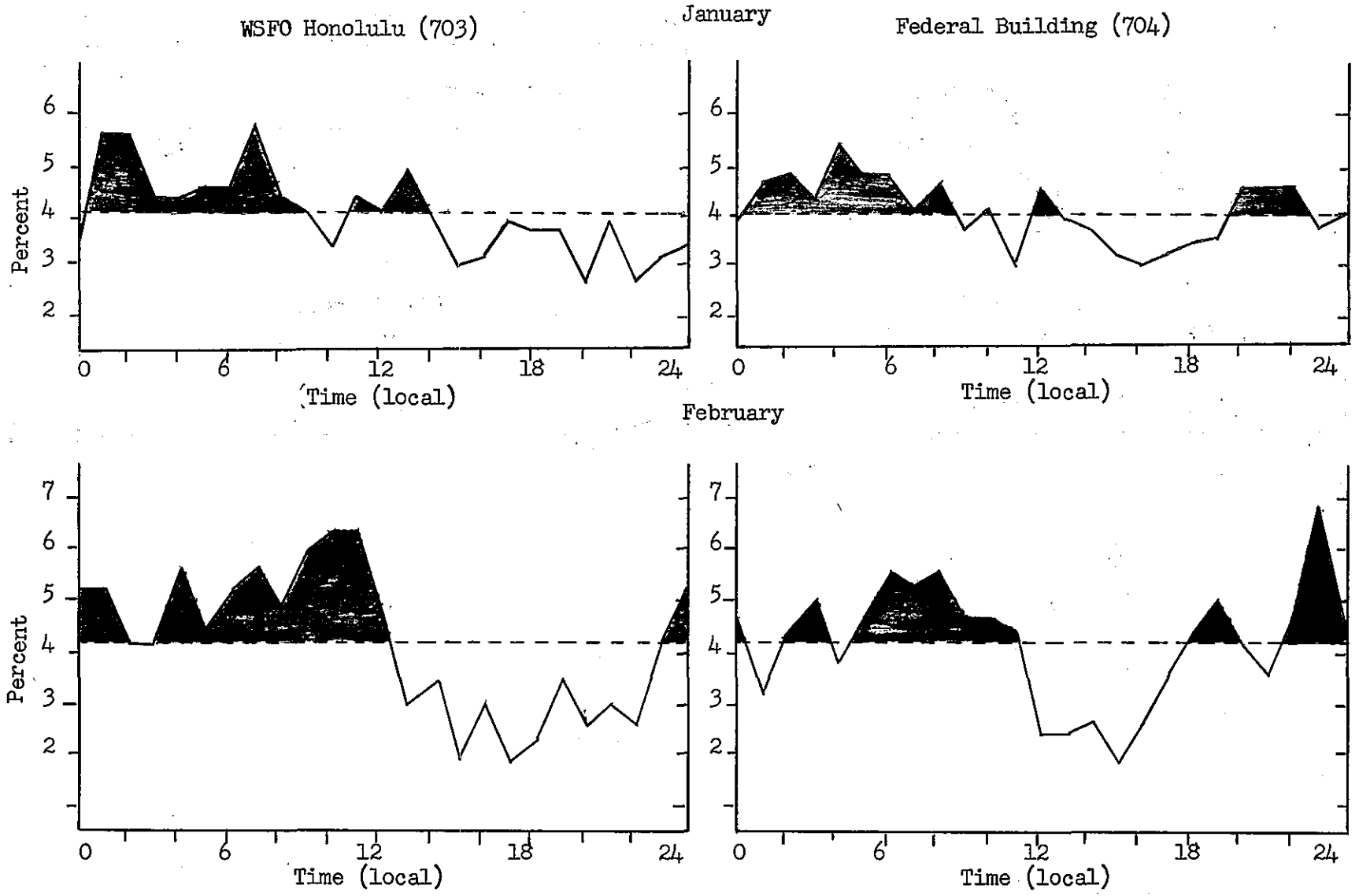


Fig. 18

Frequency of Hourly Rainfall

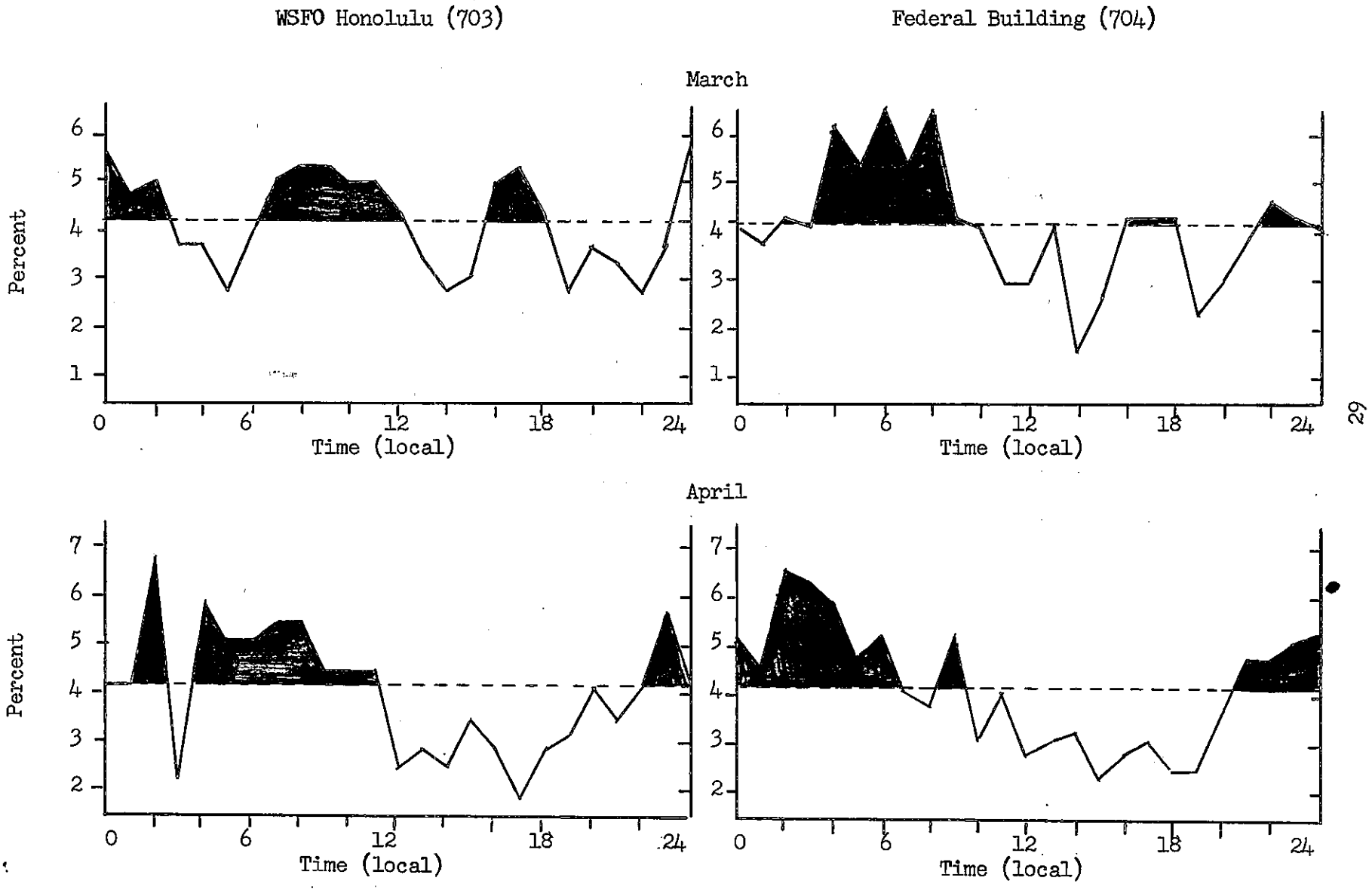


Fig. 19

Frequency of Hourly Rainfall

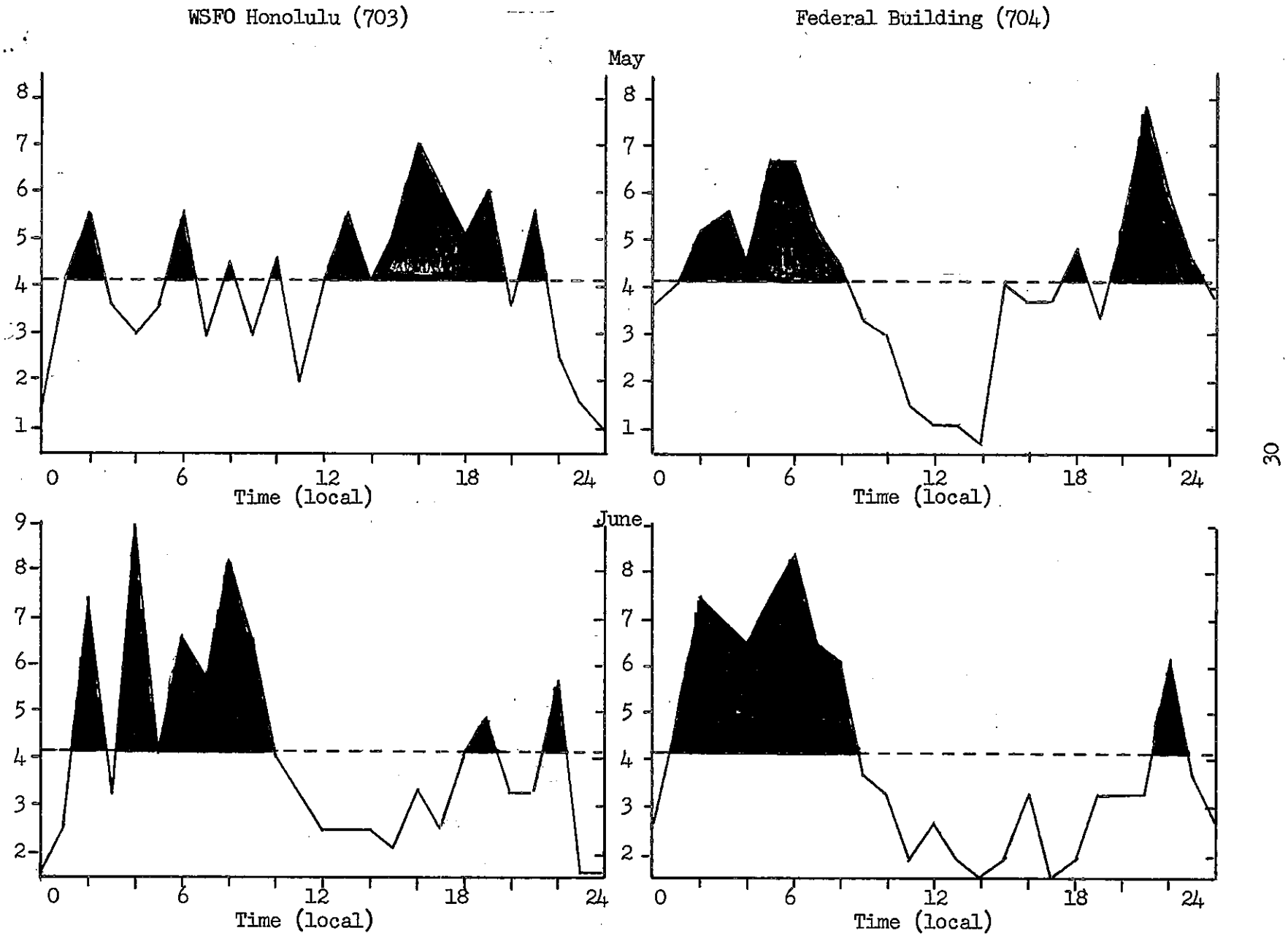


Fig. 20

Frequency of Hourly Rainfall

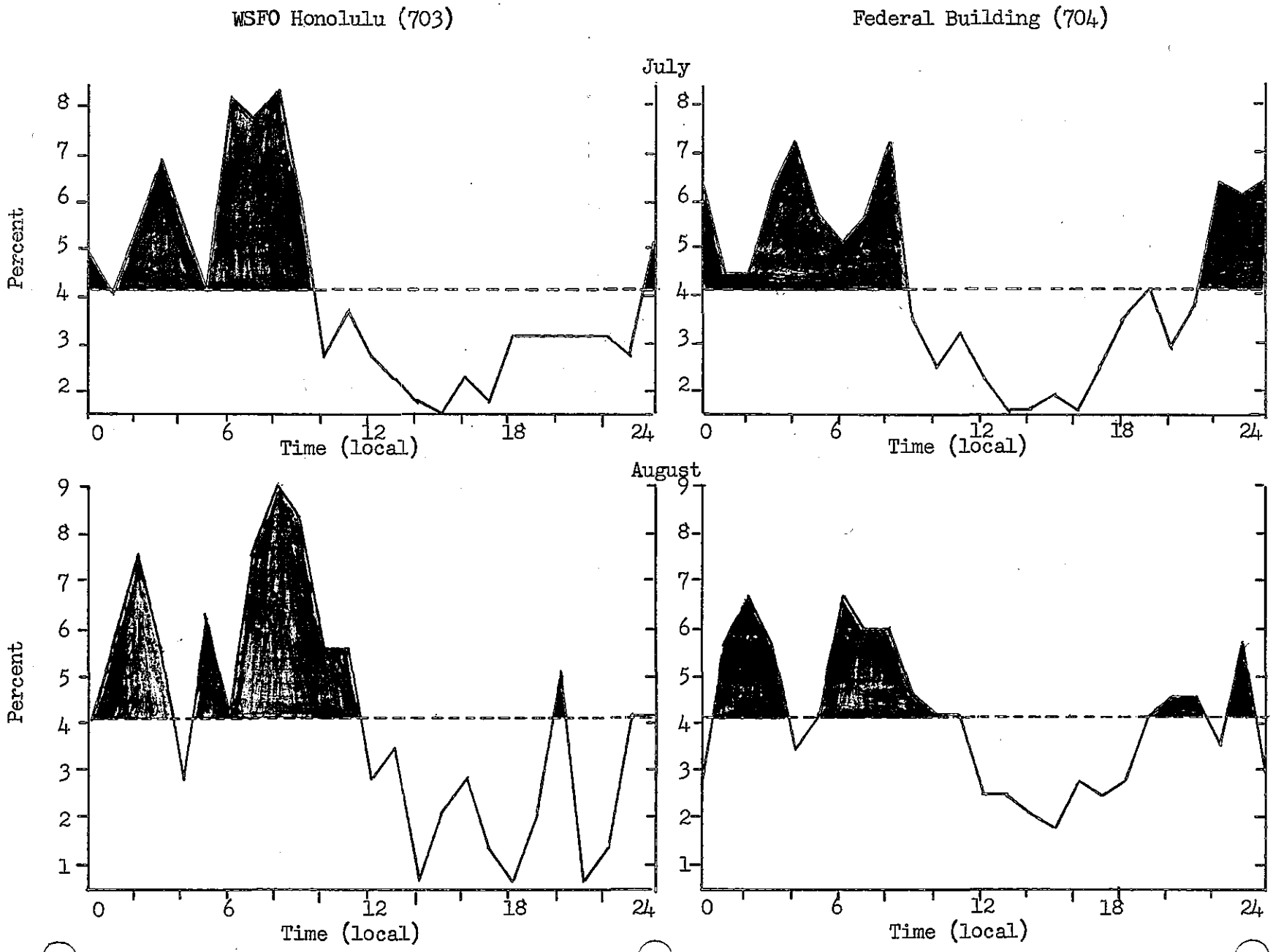


Fig. 21

Frequency of Hourly Rainfall

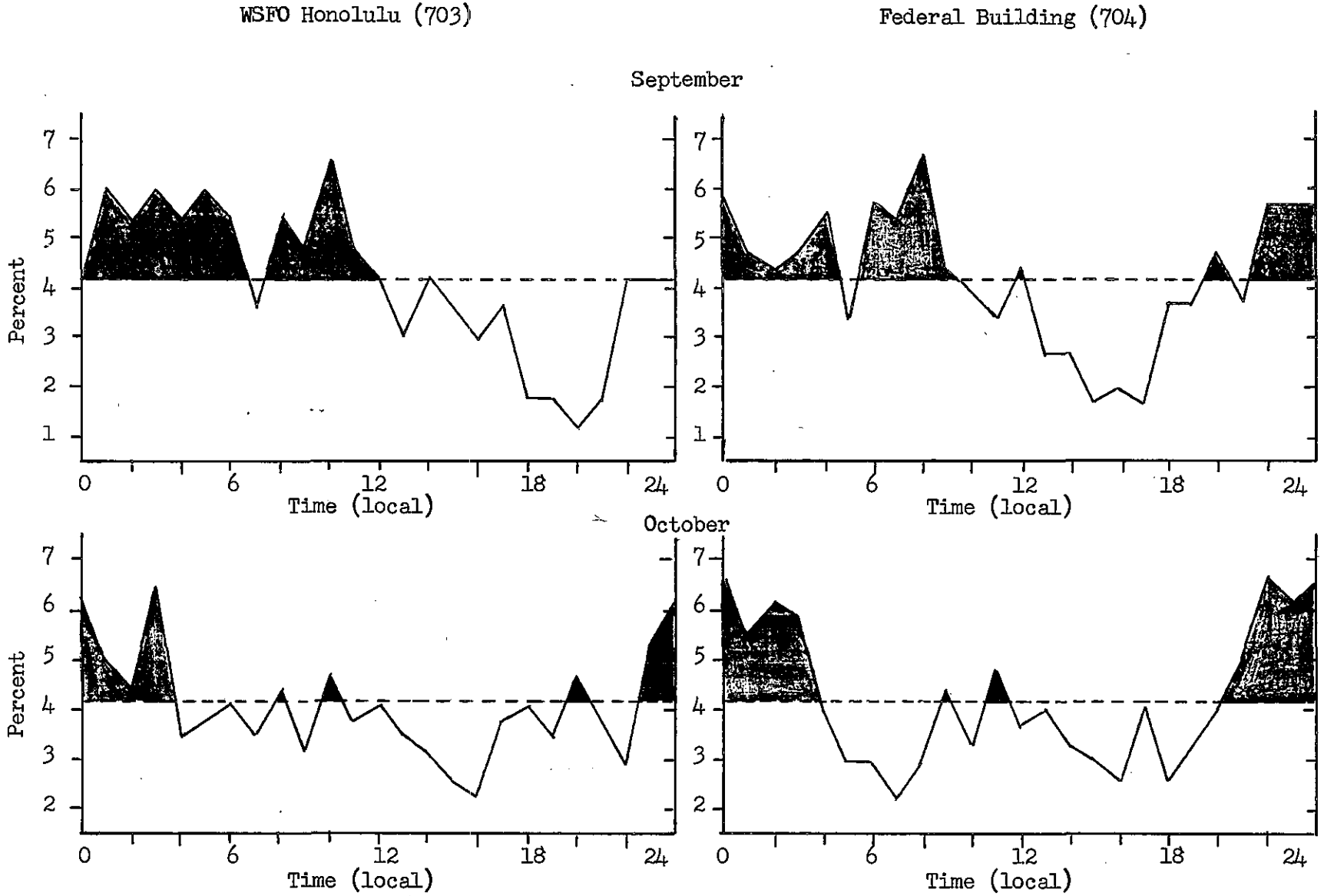


Fig. 22

Frequency of Hourly Rainfall

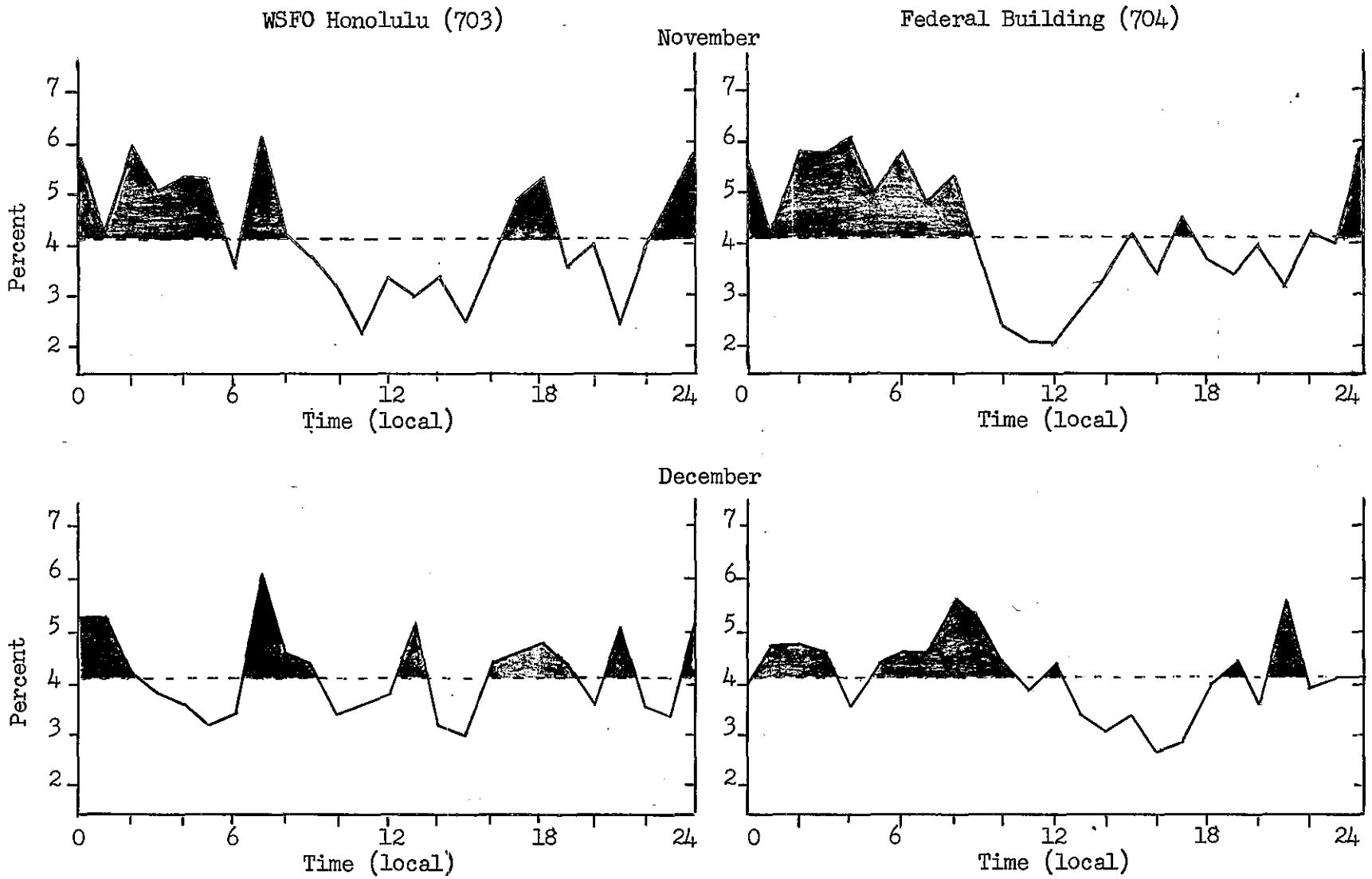


Fig. 23

APPENDIX I

CLIMATOLOGICAL PROBABILITY OF RAINFALL ≥ .01" PER DAY IN PERCENT

OR

PERCENT OF DAYS WITH ≥ .01" OF RAINFALL

STATION NAME	NUMBER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Aiea Field #49	764.1	38	36	38	35	35	32	33	32	31	35	38	39	35
Black Point	717	41	35	36	31	24	30	29	26	32	31	39	40	33
Camp 84 CPC	807	53	48	51	50	48	40	35	36	42	46	48	54	46
Coconut Is.	840.1	62	55	61	58	57	61	70	65	57	61	64	68	62
Ewa Plantation	741	30	30	26	21	17	12	20	18	16	24	27	32	23
Ford Island	755	26	31	31	26	20	17	17	23	18	24	27	31	24
Halemano Int.	881	58	62	65	65	62	74	75	74	77	73	67	70	69
Hauula	904	55	58	59	59	58	65	69	66	60	62	60	59	61
Heeia	839.2	53	52	58	61	57	60	62	62	55	63	62	58	59
Hoaeae	813	53	48	49	45	42	42	41	39	44	45	46	52	46
Honolulu Fed. Bldg.	704	43	44	41	42	34	37	40	39	37	40	43	45	40
Honolulu WSFO	703	31	32	28	26	20	15	26	23	20	31	30	31	26
HSPA Exp. Stn.	707	51	52	54	57	56	53	64	61	54	56	58	60	56
Insane Asylum	774.2	41	41	39	41	30	40	45	42	40	42	44	44	42
Kahana	883	59	61	68	63	61	67	68	66	64	65	62	63	64
Kahuku	912	55	61	61	61	53	57	59	62	53	58	61	63	59
Kailua Fire Stn.	791.3	57	50	52	55	49	48	66	64	47	54	60	62	55
Kalihi Res.	777	58	61	64	67	65	68	79	75	68	69	65	67	67
Kaliula	714.2	64	62	65	73	70	76	81	77	74	68	70	69	71
Kaneohe Mauka	781	66	64	67	70	67	66	78	72	63	69	68	72	69
Kaneohe MCAS	840	59	53	59	55	54	57	64	60	49	55	58	65	57
Kapalama	773	51	49	51	52	50	60	62	60	54	53	52	53	54
Kawaihapai	841	38	36	33	29	24	23	26	24	17	29	36	43	30
Kawai Loa	890	43	39	43	41	40	38	47	40	38	38	43	45	41

STATION NAME	NUMBER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
Kemoo Camp 8	855	42	45	47	42	38	40	32	34	28	38	43	48	40
Koolau Dam	833	62	65	65	68	66	73	80	76	68	68	71	73	70
Kualoa	886.3	46	44	43	39	36	39	45	37	38	39	38	39	40
Laie	903	53	58	64	59	55	60	65	65	55	63	63	62	60
Luakaha Lower	782	61	60	66	71	72	77	78	75	71	68	68	67	70
Lualualei	804	37	38	31	32	21	20	25	20	25	26	33	35	29
Lunalilo Home	724.2	46	43	35	39	29	30	38	37	29	39	43	45	38
Makaha Kai	796	29	29	24	16	12	6	9	7	10	16	19	23	17
Makapuu Point	724	47	45	41	39	33	34	42	35	29	38	44	47	40
Manoa	712	54	56	59	62	61	62	73	70	60	58	60	64	62
Manoa Tunnel #2	716	65	64	72	77	73	76	83	83	76	71	70	72	74
Maunawili Ranch	787	77	72	77	81	82	81	83	87	82	81	83	83	81
Moanalua	770	38	34	37	33	31	30	30	32	37	38	40	42	35
Nuuanu Res. #4	783	62	63	69	72	74	73	79	75	68	71	70	72	71
Nuuanu Res. #5	775	56	55	58	63	67	74	81	72	69	63	64	63	65
Opaeula	870	53	53	57	55	56	62	66	63	56	59	59	63	59
Palolo Valley	718	63	68	65	72	76	67	82	75	66	69	68	70	70
Pauoa Flats	784	63	70	73	81	80	81	84	83	72	74	75	73	76
Pearl Harbor	757.1	24	28	28	22	18	14	14	18	17	19	24	27	21
Puhawai	802.1	41	45	41	34	36	29	27	33	35	37	40	47	37
Punaluu	884	59	66	69	67	62	65	72	72	63	70	68	69	67
Pupukea Farm	896	49	47	49	50	51	50	58	54	49	48	52	52	51
St. Stephens	788	65	66	68	69	65	73	80	81	65	73	68	70	70
Tantulus	780.3	63	62	64	69	71	77	82	77	73	67	68	69	70
Univ. of Hawaii	713	51	52	56	61	56	58	65	63	57	55	56	62	58

STATION NAME	NUMBER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
U. S. Mag. Obs.	702	28	26	20	16	11	10	11	14	17	20	22	27	19
Wahiawa	872	58	54	53	52	51	59	60	52	56	55	55	56	55
Wahiawa Dam	863	55	55	56	55	54	56	61	56	50	57	55	59	56
Waiahole	837	55	57	67	63	61	68	81	79	65	68	63	67	66
Waialae Kahala	715	43	41	37	42	37	37	38	35	34	39	43	47	39
Waialua	847	38	41	42	38	28	27	31	30	25	34	38	43	35
Waianae	798	27	23	19	15	12	10	9	11	17	15	18	24	17
Waiawa	836	55	51	60	58	56	57	64	58	57	57	60	60	58
Waikane	885	61	59	65	67	62	64	71	71	67	64	62	64	65
Wailupe	723	39	40	33	37	33	33	39	35	29	32	41	43	36
Waimalu	756	35	35	36	34	32	30	31	31	29	32	34	37	33
Waimalu 500	761	38	37	39	37	36	32	39	36	34	37	39	40	37
Waimanalo	794	41	40	41	39	34	38	34	34	36	38	42	47	39
Waimea	892	48	43	47	46	47	47	56	52	47	45	50	50	48
Waipahu	750	36	34	34	29	27	23	27	25	27	29	33	37	30
Wheeler Field	810	59	54	56	55	50	51	55	50	50	51	54	58	54
Wilhelmina Rise	721	47	49	51	52	49	48	55	54	42	48	54	58	51
Wylie Street	774.5	57	53	55	59	59	70	75	71	63	60	64	63	62

Percent of stations whose maximum probability occurred during the month.

12.5	4.2	1.2	0.0	0.0	0.0	44.1	5.9	1.5	1.5	0.0	29.2

Percent of stations whose minimum probability occurred during the month.

20.6	20.6	0.8	0.0	10.8	13.7	8.1	4.2	20.8	0.5	0.0	0.0

APPENDIX II

FREQUENCY DISTRIBUTION OF HOURLY RAINFALL .01" IN PERCENT

JANUARY

HOUR ENDING	WSFO HONOLULU (703)	FEDERAL BUILDING (704)	WAIALUA (847)	WAHIAWA DAM (863)	MAUNAWILI (787.1)
AM					
1	5.7	4.7	4.2	4.1	3.4
2	5.7	4.9	4.2	5.1	3.7
3	4.5	4.4	4.7	4.7	4.2
4	4.5	5.5	3.5	5.1	4.4
5	4.7	4.9	4.7	4.7	4.5
6	4.7	4.9	5.2	5.1	5.2
7	5.9	4.2	4.7	5.3	5.9
8	4.5	4.7	3.2	4.1	4.7
9	4.2	3.8	3.5	3.9	4.0
10	3.5	4.2	4.0	4.3	4.0
11	4.5	3.1	3.5	4.7	3.7
12	4.2	4.6	5.2	5.3	3.7
PM					
1	5.0	4.0	3.5	4.9	5.2
2	4.0	3.8	4.4	5.3	3.7
3	3.1	3.3	4.7	5.1	3.9
4	3.3	3.1	4.7	3.8	4.0
5	4.0	3.3	4.4	3.6	3.9
6	3.9	3.5	4.9	3.4	3.4
7	3.8	3.6	4.2	2.3	3.0
8	2.8	4.6	4.2	2.8	5.2
9	4.0	4.6	3.0	2.6	3.0
10	2.8	4.6	4.0	3.0	4.2
11	3.3	3.8	3.5	2.8	4.7
12	3.5	4.0	4.2	4.3	4.7
AVG. HRS. PER MONTH	42.4	46.9	67.5	88.8	99.5

APPENDIX II

FREQUENCY DISTRIBUTION OF HOURLY RAINFALL ≥.01" IN PERCENT

FEBRUARY

HOUR ENDING	WSFO HONOLULU (703)	FEDERAL BUILDING (704)	WAIALUA (847)	WAHIAWA DAM (863)	MAUNAWILI (787.1)
AM					
1	5.3	3.2	3.1	3.8	3.9
2	4.2	4.4	4.4	5.0	3.7
3	4.2	5.0	4.4	4.1	2.4
4	5.7	3.8	4.4	5.3	5.7
5	4.5	4.7	4.4	4.1	4.4
6	5.3	5.6	3.1	5.6	4.4
7	5.7	5.3	7.9	3.8	3.5
8	4.9	5.6	4.8	4.1	5.3
9	6.0	4.7	4.8	4.1	5.3
10	6.4	4.7	4.4	3.6	4.8
11	6.4	4.4	4.4	4.1	5.3
12	4.9	2.4	4.4	5.9	4.6
PM					
1	3.0	2.4	5.3	4.7	4.4
2	3.4	2.6	3.5	3.0	3.5
3	1.9	1.8	3.5	2.7	3.5
4	3.0	2.6	3.1	2.7	3.9
5	1.9	3.5	3.1	3.3	4.4
6	2.3	4.4	4.4	3.3	4.4
7	3.4	5.0	4.4	4.7	4.2
8	2.6	4.1	3.1	4.1	3.9
9	3.0	3.5	4.0	4.1	3.1
10	2.6	4.7	3.1	4.4	3.5
11	4.2	6.8	3.1	5.0	3.7
12	5.3	4.7	4.8	4.1	4.2
AVG. HRS. PER MONTH	26.5	32.5	37.8	56.3	76.0

APPENDIX II

FREQUENCY DISTRIBUTION OF HOURLY RAINFALL ≥.01" IN PERCENT

MARCH

HOUR ENDING	WSFO HONOLULU (703)	FEDERAL BUILDING (704)	WAIALUA (847)	WAHIAWA DAM (863)	MAUNAWILI (787.1)
AM					
1	4.7	3.8	4.3	4.0	3.9
2	5.0	4.3	4.3	4.0	4.1
3	3.7	4.1	3.6	2.7	4.4
4	3.7	6.2	3.3	5.1	4.4
5	2.8	5.4	4.6	4.0	6.0
6	4.0	6.5	4.6	5.9	6.2
7	5.0	5.4	6.3	5.9	5.1
8	5.3	6.5	5.6	4.5	5.4
9	5.3	4.3	5.0	4.0	4.1
10	5.0	4.1	4.0	4.5	4.1
11	5.0	3.0	2.3	4.3	3.3
12	4.4	3.0	3.0	2.9	3.0
PM					
1	3.4	4.1	3.3	4.0	3.2
2	2.8	1.6	3.3	3.7	3.2
3	3.1	2.7	3.0	2.7	2.7
4	5.0	4.3	3.3	3.2	3.5
5	5.3	4.3	3.6	3.2	4.1
6	4.4	4.3	5.3	2.9	4.4
7	2.8	2.4	4.0	3.7	4.5
8	3.7	3.0	5.9	5.6	4.7
9	3.4	3.8	3.6	5.3	4.8
10	2.8	4.6	4.3	4.0	3.3
11	3.7	4.3	5.0	5.1	3.6
12	5.6	4.1	4.6	4.5	4.5
AVG. HRS. PER MONTH	32.1	35.3	50.5	62.3	111.0

APPENDIX II

FREQUENCY DISTRIBUTION OF HOURLY RAINFALL ≥ .01" IN PERCENT

APRIL

HOUR ENDING	WSFO HONOLULU (703)	FEDERAL BUILDING (704)	WAIALUA (847)	WAHIAWA DAM (863)	MAUNAWILI (787.1)
AM					
1	4.3	4.6	4.6	5.8	5.7
2	6.9	6.6	3.7	6.3	5.3
3	2.3	6.4	4.2	7.1	4.7
4	5.9	5.9	4.2	6.3	6.6
5	5.2	4.8	4.6	3.8	6.1
6	5.2	5.3	3.7	5.4	5.3
7	5.6	4.1	4.6	5.0	5.3
8	5.6	3.8	2.3	3.3	6.3
9	4.6	5.3	5.1	2.9	4.5
10	4.6	3.1	3.7	2.1	2.7
11	4.6	4.1	4.2	2.9	3.0
12	2.6	2.8	3.2	2.9	4.5
PM					
1	3.0	3.1	4.2	3.8	3.2
2	2.6	3.3	4.6	5.0	2.8
3	3.6	2.3	5.6	3.8	2.7
4	3.0	2.8	4.6	4.6	3.6
5	2.0	3.1	5.1	2.5	3.2
6	3.0	2.5	3.7	4.2	2.7
7	3.3	2.5	3.2	3.8	3.0
8	4.3	3.6	4.2	2.9	2.8
9	3.6	4.8	3.7	3.8	3.2
10	4.3	4.8	4.2	4.6	3.4
11	5.9	5.1	4.2	3.8	4.9
12	4.3	5.3	4.6	3.8	4.4
AVG. HRS. PER MONTH	30.5	33.3	36.0	40.0	88.0

APPENDIX II

FREQUENCY DISTRIBUTION OF HOURLY RAINFALL $\geq$ .01" IN PERCENT

MAY

HOUR ENDING	WSFO HONOLULU (703)	FEDERAL BUILDING (704)	WAIALUA (847)	WAHIAWA DAM (863)	MAUNAWILI (787.1)
AM					
1	4.1	4.1	1.2	5.1	4.0
2	5.6	5.2	2.4	4.3	4.8
3	3.6	5.6	4.9	4.3	4.8
4	3.0	4.5	3.0	3.5	3.8
5	3.6	6.7	4.3	3.5	4.4
6	5.6	6.7	6.1	3.1	6.5
7	3.0	5.2	4.9	2.3	5.5
8	4.6	4.5	1.8	4.3	5.3
9	3.0	3.3	4.3	3.9	4.2
10	4.6	3.0	4.3	2.7	4.0
11	2.0	1.5	1.8	2.7	4.6
12	4.1	1.1	4.3	4.7	3.6
PM					
1	5.6	1.1	4.3	5.4	3.8
2	4.1	0.7	4.9	5.4	4.0
3	5.1	4.1	7.3	7.8	4.4
4	7.1	3.7	4.9	5.4	3.8
5	6.1	3.7	7.9	5.1	3.2
6	5.1	4.8	3.7	3.9	3.1
7	6.1	3.3	4.9	4.3	3.8
8	3.6	5.2	4.3	5.4	4.4
9	5.6	7.8	5.5	5.1	4.6
10	2.5	5.9	3.0	1.6	4.2
11	1.5	4.5	3.0	2.7	2.5
12	1.0	3.7	3.0	3.5	2.7
AVG. HRS. PER MONTH	19.7	25.9	27.3	42.8	87.3

APPENDIX II

FREQUENCY DISTRIBUTION OF HOURLY RAINFALL ≥ .01" IN PERCENT

JUNE

HOUR ENDING	WSFO HONOLULU (703)	FEDERAL BUILDING (704)	WAIALUA (847)	WAHIAWA DAM (863)	MAUNAWILI (787.1)
AM					
1	2.5	4.7	5.2	7.0	4.1
2	7.4	7.5	5.2	6.5	5.4
3	3.3	7.0	3.4	7.0	5.1
4	9.0	6.5	1.7	5.9	5.4
5	4.1	7.5	3.4	3.8	5.7
6	6.6	8.4	5.2	7.0	7.0
7	5.7	6.5	8.6	5.9	6.4
8	8.2	6.1	8.6	2.7	7.3
9	6.6	3.7	5.2	3.8	4.8
10	4.1	3.3	3.4	2.2	6.1
11	3.3	1.9	5.2	1.1	3.8
12	2.5	2.7	3.4	2.7	2.9
PM					
1	2.5	1.9	1.7	1.1	2.2
2	2.5	1.5	3.4	1.6	2.5
3	1.6	1.9	1.7	1.1	2.9
4	3.3	3.3	1.7	0.5	2.5
5	2.5	1.5	3.4	1.6	2.5
6	4.1	1.9	5.2	4.3	2.2
7	4.9	3.3	5.2	4.9	2.5
8	3.3	3.3	5.2	4.9	3.8
9	3.3	3.3	1.7	5.4	3.8
10	5.7	6.1	1.7	5.4	2.5
11	1.6	3.7	3.4	7.0	2.9
12	1.6	2.7	6.9	6.5	5.4
AVG. HRS. PER MONTH	12.2	20.4	9.7	30.8	52.3

APPENDIX II

FREQUENCY DISTRIBUTION OF HOURLY RAINFALL ≥ .01" IN PERCENT

JULY

HOUR ENDING	WSFO HONOLULU (703)	FEDERAL BUILDING (704)	WAIALUA (847)	WAHIAWA DAM (863)	MAUNAWILI (787.1)
AM					
1	4.1	4.5	5.2	5.5	4.0
2	5.5	4.5	3.3	4.5	5.5
3	6.9	6.1	3.9	6.7	6.8
4	5.5	7.3	5.9	7.9	6.6
5	4.1	5.7	4.6	5.5	6.2
6	8.3	5.1	2.0	4.5	7.0
7	7.8	5.7	5.2	6.1	5.5
8	8.3	7.3	5.2	5.8	5.7
9	6.0	3.5	5.2	3.9	4.7
10	2.8	2.5	3.3	3.3	4.2
11	3.7	3.2	2.0	2.7	3.2
12	2.8	2.2	3.9	1.8	3.2
PM					
1	2.3	1.6	3.3	2.4	2.5
2	1.8	1.6	5.2	2.4	3.0
3	1.5	1.9	3.3	2.1	2.8
4	2.8	1.6	3.9	1.8	2.8
5	1.8	2.5	3.9	2.1	2.3
6	3.2	3.5	2.0	4.2	2.5
7	3.2	4.1	5.9	2.1	3.4
8	3.2	2.9	3.3	3.3	3.8
9	3.2	3.8	4.6	3.3	3.4
10	3.2	6.4	5.2	5.5	3.6
11	2.8	6.1	5.2	6.7	3.4
12	5.0	6.4	4.6	5.8	4.0
AVG. HRS. PER MONTH	21.7	30.4	25.5	55.0	88.2

APPENDIX II

FREQUENCY DISTRIBUTION OF HOURLY RAINFALL ≥ .01" IN PERCENT

AUGUST

HOUR ENDING	WSFO HONOLULU (703)	FEDERAL BUILDING (704)	WAIALUA (847)	WAHIAWA DAM (863)	MAUNAWILI (787.1)
AM					
1	5.6	5.7	1.1	6.3	4.5
2	7.6	6.7	3.3	8.9	5.8
3	5.6	5.7	4.3	6.3	4.9
4	2.8	3.5	5.4	5.2	5.6
5	6.3	4.2	5.4	5.2	7.0
6	4.2	6.7	4.3	7.3	6.2
7	7.6	6.0	8.7	4.2	5.8
8	9.0	6.0	6.5	5.8	6.0
9	8.3	4.6	4.3	4.7	4.3
10	5.6	4.2	4.3	4.2	3.9
11	5.6	4.2	2.2	3.7	3.7
12	2.8	2.5	3.3	1.6	3.7
PM					
1	3.5	2.5	4.3	1.6	3.5
2	0.7	2.1	5.4	2.1	2.5
3	2.1	1.8	4.3	2.6	3.1
4	2.8	2.8	4.3	0.0	2.5
5	1.4	2.5	4.3	3.1	3.7
6	0.7	2.8	4.3	2.1	3.3
7	2.1	4.2	2.2	0.5	3.1
8	5.6	4.6	5.4	3.1	2.9
9	0.7	4.6	3.3	4.7	3.3
10	1.4	3.5	2.2	3.7	3.9
11	4.2	5.7	3.3	5.2	3.9
12	4.2	2.8	3.3	7.9	3.1
AVG. HRS. PER MONTH	14.4	25.3	15.3	31.8	81.0

APPENDIX II

FREQUENCY DISTRIBUTION OF HOURLY RAINFALL ≥ .01" IN PERCENT

SEPTEMBER

HOUR ENDING	WSFO HONOLULU (703)	FEDERAL BUILDING (704)	WAIALUA (847)	WAHIAWA DAM (863)	MAUNAWILI (787.1)
AM					
1	6.0	4.7	4.4	4.5	4.1
2	5.4	4.4	3.3	3.5	4.9
3	6.0	4.7	6.6	5.5	4.6
4	5.4	5.4	5.5	6.0	4.6
5	6.0	3.4	5.5	4.5	7.8
6	5.4	5.7	3.3	5.0	5.2
7	3.6	5.4	4.4	4.5	5.5
8	5.4	6.7	2.2	4.0	7.5
9	4.8	4.4	4.4	3.5	7.0
10	6.6	4.0	3.3	3.5	4.3
11	4.8	3.4	6.6	6.0	2.3
12	4.2	4.4	5.5	3.0	3.2
PM					
1	3.0	2.7	5.5	3.5	2.3
2	4.2	2.7	4.4	4.5	2.9
3	3.6	1.7	7.7	3.5	2.9
4	3.0	2.0	5.5	5.0	3.2
5	3.6	1.7	3.3	4.5	3.2
6	1.8	3.7	3.3	4.0	3.2
7	1.8	3.7	5.5	2.5	3.2
8	1.2	4.7	3.3	4.5	2.6
9	1.8	3.7	1.1	2.5	2.6
10	4.2	5.7	2.2	2.0	4.1
11	4.2	5.7	1.1	4.0	3.5
12	4.2	5.7	1.1	5.5	5.2
AVG. HRS. PER MONTH	16.7	26.8	15.0	33.2	57.5

APPENDIX II

FREQUENCY DISTRIBUTION OF HOURLY RAINFALL ≥ .01" IN PERCENT

OCTOBER

HOUR ENDING	WSFO HONOLULU (703)	FEDERAL BUILDING (704)	WAIALUA (847)	WAHIAWA DAM (863)	MAUNAWILI (787.1)
AM					
1	5.0	5.5	3.5	4.2	3.8
2	4.4	6.2	3.0	4.8	4.2
3	6.5	5.9	4.0	6.0	4.4
4	3.5	4.0	4.5	6.3	4.2
5	3.8	3.0	3.5	5.7	4.0
6	4.1	3.0	4.0	6.3	4.4
7	3.5	2.2	4.0	5.4	4.4
8	4.4	3.0	4.0	5.1	5.2
9	3.2	4.4	2.5	4.8	4.8
10	4.7	3.3	2.5	3.9	3.6
11	3.8	4.8	3.0	3.0	3.1
12	4.1	3.7	3.5	3.0	3.3
PM					
1	3.5	4.0	3.5	3.0	4.4
2	3.2	3.3	3.0	3.6	2.3
3	2.6	3.0	4.0	3.6	3.6
4	2.3	2.6	3.5	3.6	4.4
5	3.8	4.0	4.5	3.0	3.8
6	4.1	2.6	4.0	1.5	3.3
7	3.5	3.3	5.5	4.2	3.3
8	4.7	4.0	7.0	2.4	4.6
9	3.8	5.1	7.0	3.6	4.4
10	2.9	6.6	5.5	3.3	4.8
11	5.3	6.2	4.0	3.6	5.6
12	6.2	6.6	6.0	5.4	6.1
AVG. HRS. PER MONTH	34.1	34.3	33.2	55.2	79.7

APPENDIX II

FREQUENCY DISTRIBUTION OF HOURLY RAINFALL ≥ .01" IN PERCENT

NOVEMBER

HOUR ENDING	WSFO HONOLULU (703)	FEDERAL BUILDING (704)	WAIALUA (847)	WAHIAWA DAM (863)	MAUNAWILI (787.1)
AM					
1	4.2	4.2	5.0	5.0	5.2
2	5.9	5.8	4.7	5.2	4.7
3	5.1	5.8	3.9	3.4	3.3
4	5.3	6.1	3.9	4.9	4.0
5	5.3	5.0	4.7	3.4	4.1
6	3.6	5.8	3.4	5.4	4.5
7	6.1	4.8	5.0	3.4	4.4
8	4.2	5.3	2.9	3.0	4.2
9	3.8	3.7	3.2	3.2	4.4
10	3.2	2.4	2.4	2.9	4.7
11	2.3	2.1	3.9	3.2	3.0
12	3.4	2.1	3.4	3.9	3.8
PM					
1	3.0	2.7	4.2	3.7	3.8
2	3.4	3.4	5.0	3.7	4.4
3	2.5	4.2	5.0	2.9	3.7
4	3.6	3.4	3.7	3.7	4.4
5	4.9	4.5	3.9	4.1	3.8
6	5.3	3.7	5.0	5.8	3.5
7	3.6	3.4	5.0	4.9	4.0
8	4.0	4.0	5.3	4.1	4.0
9	2.5	3.2	4.2	5.0	4.0
10	4.0	4.2	3.9	3.7	4.0
11	4.9	4.0	3.7	5.4	4.7
12	5.9	5.8	4.5	6.3	5.7
AVG. HRS. PER MONTH	47.3	47.7	63.3	89.3	117.8

APPENDIX II

FREQUENCY DISTRIBUTION OF HOURLY RAINFALL ≥ .01" IN PERCENT

DECEMBER

HOUR ENDING	WSFO HONOLULU (703)	FEDERAL BUILDING (704)	WAIALUA (847)	WAHIAWA DAM (863)	MAUNAWILI (787.1)
AM					
1	5.3	4.8	4.0	4.9	4.4
2	4.2	4.8	4.5	4.6	4.1
3	3.8	4.6	3.5	4.3	4.2
4	3.6	3.6	3.5	3.8	4.7
5	3.2	4.4	3.8	4.7	4.5
6	3.4	4.6	3.5	4.9	5.4
7	6.1	4.6	4.7	4.6	4.9
8	4.6	5.6	2.4	4.9	3.8
9	4.4	5.3	4.0	4.1	3.9
10	3.4	4.4	4.2	3.4	4.1
11	3.6	3.9	4.0	3.4	3.8
12	3.8	4.4	3.3	3.3	4.4
PM					
1	5.1	3.4	2.4	3.0	4.2
2	3.2	3.1	4.0	3.8	3.9
3	3.0	3.4	4.5	3.7	3.9
4	4.4	2.7	4.9	3.4	2.7
5	4.6	2.9	5.2	4.6	3.8
6	4.8	3.9	3.8	4.1	4.2
7	4.4	4.4	6.4	2.8	3.7
8	3.6	3.6	5.4	4.4	3.9
9	5.1	5.6	4.5	4.6	3.9
10	3.6	3.9	4.5	4.4	4.5
11	3.4	4.1	4.9	5.0	4.4
12	5.3	4.1	4.2	5.2	4.5
AVG. HRS. PER MONTH	52.6	50.3	70.8	112.6	118.2