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# PROBABILITIES OF DROUGHT AND RAINY PERIODS FOR SELECTED POINTS IN THE SOUTHWESTERN UNITED STATES

Christine R. Green

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# PROBABILITIES OF DROUGHT AND RAINY PERIODS FOR SELECTED POINTS IN THE SOUTHWESTERN UNITED STATES

## ABSTRACT

This report presents the results of an investigation of rainfall and drought probabilities in the southwestern United States. Daily weather records for ten weather stations were used to compute the empirical probabilities that droughts of 5, 10, 15, 20, or 25 days or rainy periods of 3, 5, 10, or 15 days will start on any day between April 15 and September 15. The results are presented graphically in smoothed form in 24 figures.

## I. INTRODUCTION.

During the past few years the Institute of Atmospheric Physics at The University of Arizona has received several requests from farmers, ranchers and employees of the U. S. Forest Service and the U. S. Soil Conservation Service for information concerning the most probable dates of drought and rainy periods of various lengths in the southwestern United States. Unfortunately, such information was not available, except in a very generalized form. In order to correct this deficiency the Institute has recently carried out a rather intensive investigation of rainfall and drought probabilities during the late spring and summer at eight weather stations in Arizona and two in New Mexico. The results of the study are given in this report.

Use was made of the Institute's daily #1009 punched-card file and the facilities of the Numerical Analysis Laboratory of The University of Arizona to compute the empirical per cent probabilities that any given day between April 15 and September 15 will be the first day of a drought period with a length of 5, 10, 15, 20, or 25 days or the first day of a rainy period with a length of 3, 5, 10, or 15 days. In this study a drought period was considered to be one which was completely dry, while a rainy period was one during which at least a trace of precipitation was recorded on every day.

## II. DETAILS OF ANALYSIS.

The ten weather stations which had the longest precipitation records were selected from the daily #1009 punched-card deck. These included Santa Fe, New Mexico, with 83 years of record; Yuma, Arizona, with 66 years; State University, New Mexico, with 63 years; Bisbee, Arizona, with 63 years; Clifton, Arizona, with 63 years; Natural Bridge, Arizona, with 63 years; Walnut Grove, Arizona, with 62 years; Parker, Arizona, with 60 years; Granite Reef Dam, Arizona, with 59 years; and Holbrook, Arizona, with 58 years.

The IBM #650 data processing machine tested each station's daily precipitation record beginning with April 15 and continuing through to September 15 to determine the per cent probability that any day was the beginning day of a dry or rainy period of a given length.

The results for each period of drought and precipitation were plotted on graphs with the date on the abscissa and the probability of occurrence on the ordinate. However, these curves were too erratic to be read easily. Therefore, assuming that most of the "wiggles" would be eliminated with more data, the curves were smoothed using a smoothing function of the form

$$\bar{x}_0 = 1/9\ [x_{-2} + 2x_{-1} + 3x_0 + 2x_1 + x_2]$$

where $x_{-2}$, $x_{-1}$, $x_1$, and $x_2$ are, respectively, the computed probabilities two days before, one day before, one day after, and two days after the central day on which the probability was $x_0$. See Figures 1-20.

Dry periods are most common in May and June at all stations. Two well-defined peaks of dryness occur during these months on the graphs for State University, Santa Fe, and Bisbee. The remaining seven stations show smaller fluctuations for the same dates. Generally, between the middle and the last of August and continuing into September, drought conditions become more and more common following a midsummer increase in precipitation, associated with a strong flow of moist air from the Gulf of Mexico. See Figures 1-10.

The probability that any day is the beginning of a rainy period can be determined from the graphs for each station displayed in Figures 11-20. At most locations only 3-day rainy periods are common enough to give probabilities greater than 5 or 10 per cent, even during the wettest days. Therefore, curves for rainy periods of 5 days are presented only for Santa Fe, Bisbee, Clifton, Holbrook and Natural Bridge (Figures 12, 13, 14, 15 and 17, respectively) and for 10 days only for Santa Fe (Figure 12).

The increased precipitation of summer is shown on all ten graphs by a rise of rainy period probabilities in July and August. However, the probability that any day during these two months will be the beginning of even a 3-day rainy period is quite small. This suggests that precipitation at any given point rarely falls on more than two successive days during the July and August "rainy season."

Figure 21 shows for each station the time intervals during which the probability of the start of 5, 10, 15, 20 and 25-day droughts exceeds 50 per cent. Figure 22 shows for each station the time intervals during which the probability of the start of a 3-day rainy period is greater than 2-1/2, 5 and 10 per cent. These two figures summarize the information presented in Figures 1-20.

Figure 23 is a map showing the locations of the ten selected stations and the date of the last early summer day on which the probability of the start of a 5-day drought exceeds 50 per cent. The lines on the map show the westward progression of moist air from the Gulf of Mexico during June and July.

Some earlier calculations by William D. Sellers are included in this report as Figure 24, which shows the probability that any one of seven Arizona stations will report rainfall on a particular day in June, July and August. The stations used were Tuba City, Holbrook, Tombstone, Bisbee, Globe, Jerome and Snowflake. The period of record was 1898 through 1957. Besides the rather sharp increase in rainfall probability between the last week in June and the middle of July, it is interesting to note the extreme variability of the probability during the peak of the "rainy season." Using the F test,[1] the variance of the day-to-day changes of probability during the second half of the period is significantly greater, at the one per cent level of significance, than that during the first half of the period.

## III. CONCLUSION.

The daily #1009 punched-card deck contains data for approximately 110 weather stations in Arizona and New Mexico. The ten stations selected for the present study were those with the longest precipitation records. It is hoped that in the near future it will be possible to perform this analysis for the remaining stations. Whether or not this will be done depends partly on the availability of funds and partly on the interest shown in this type of data analysis.


## ACKNOWLEDGMENTS.

The author wishes to acknowledge the assistance given by the Numerical Analysis Laboratory personnel who set up and ran the computer portion of this study. The direction and assistance offered by Dr. William D. Sellers is greatly appreciated. Also, the writer is indebted to the U. S. Weather Bureau for the original collection and distribution of daily precipitation data.


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[1] Paul G. Hoel, 1947: Introduction to Mathematical Statistics. John Wiley & Sons, Inc., New York, p. 152.

Figure 1

Probabilities of Drought Periods of Various Lengths at State University, N. M.

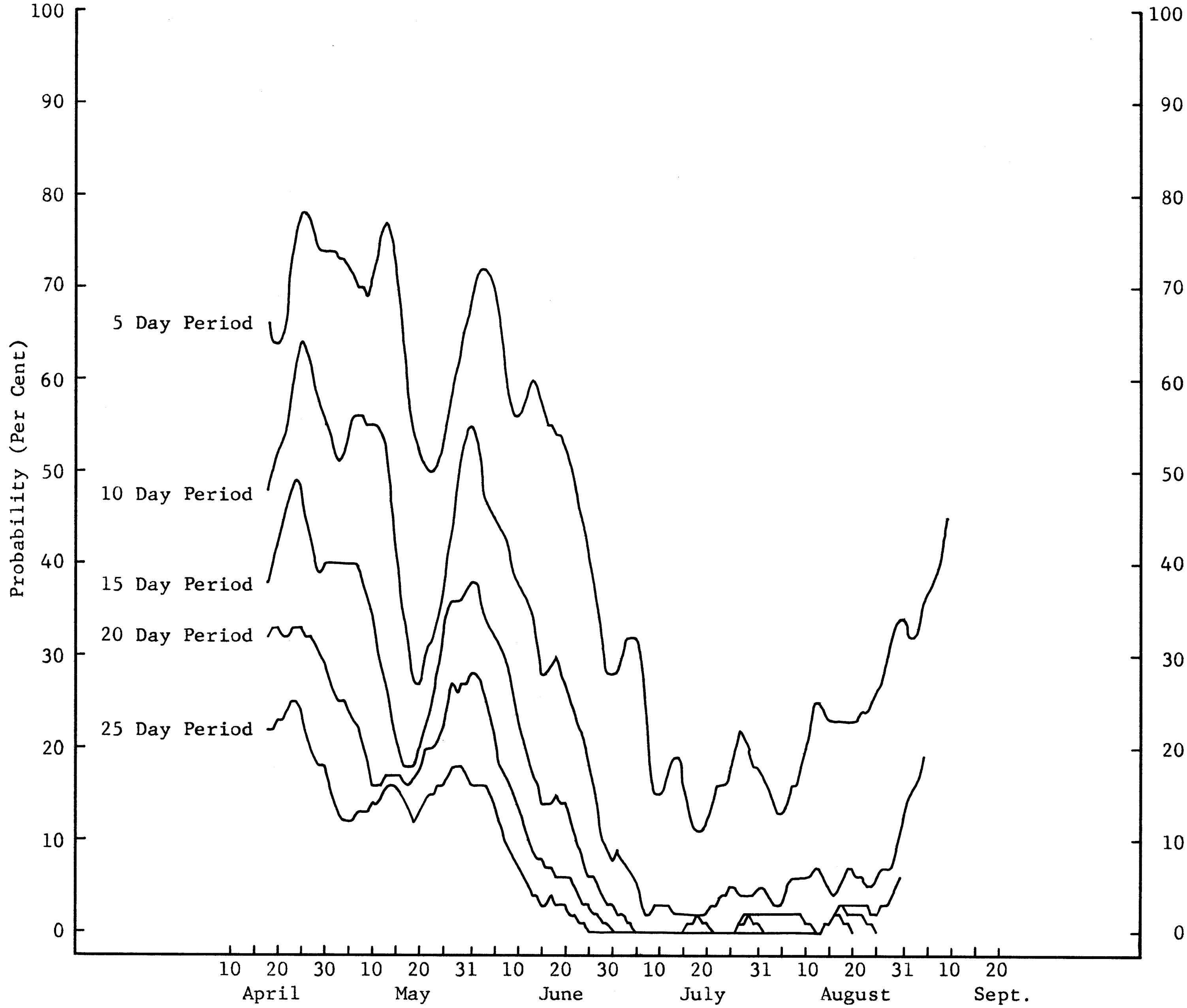

Figure 2

Probabilities of Drought Periods of Various Lengths at Santa Fe, N. M.

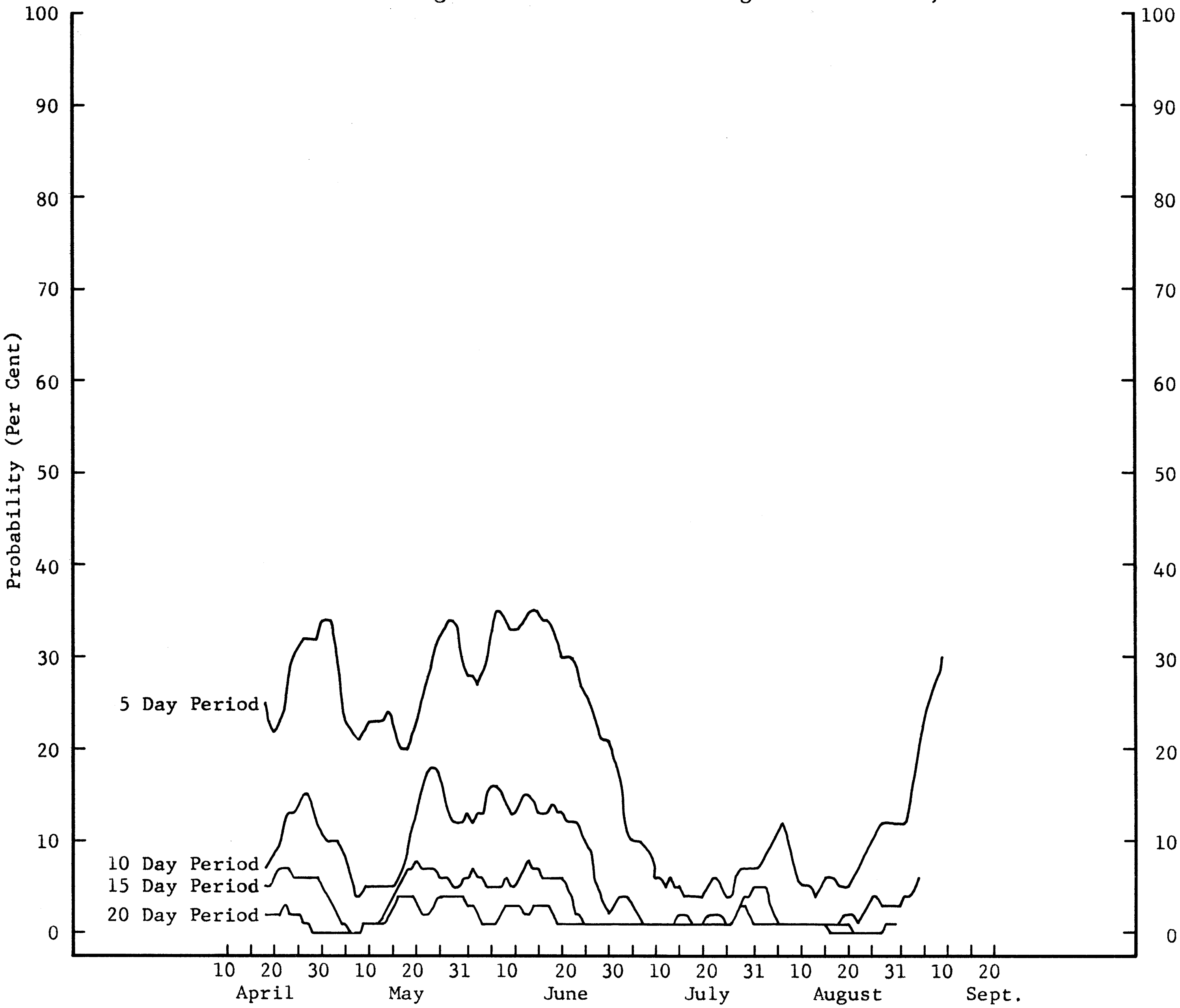

Figure 3

Probabilities of Drought Periods of Various Lengths at Bisbee, Arizona

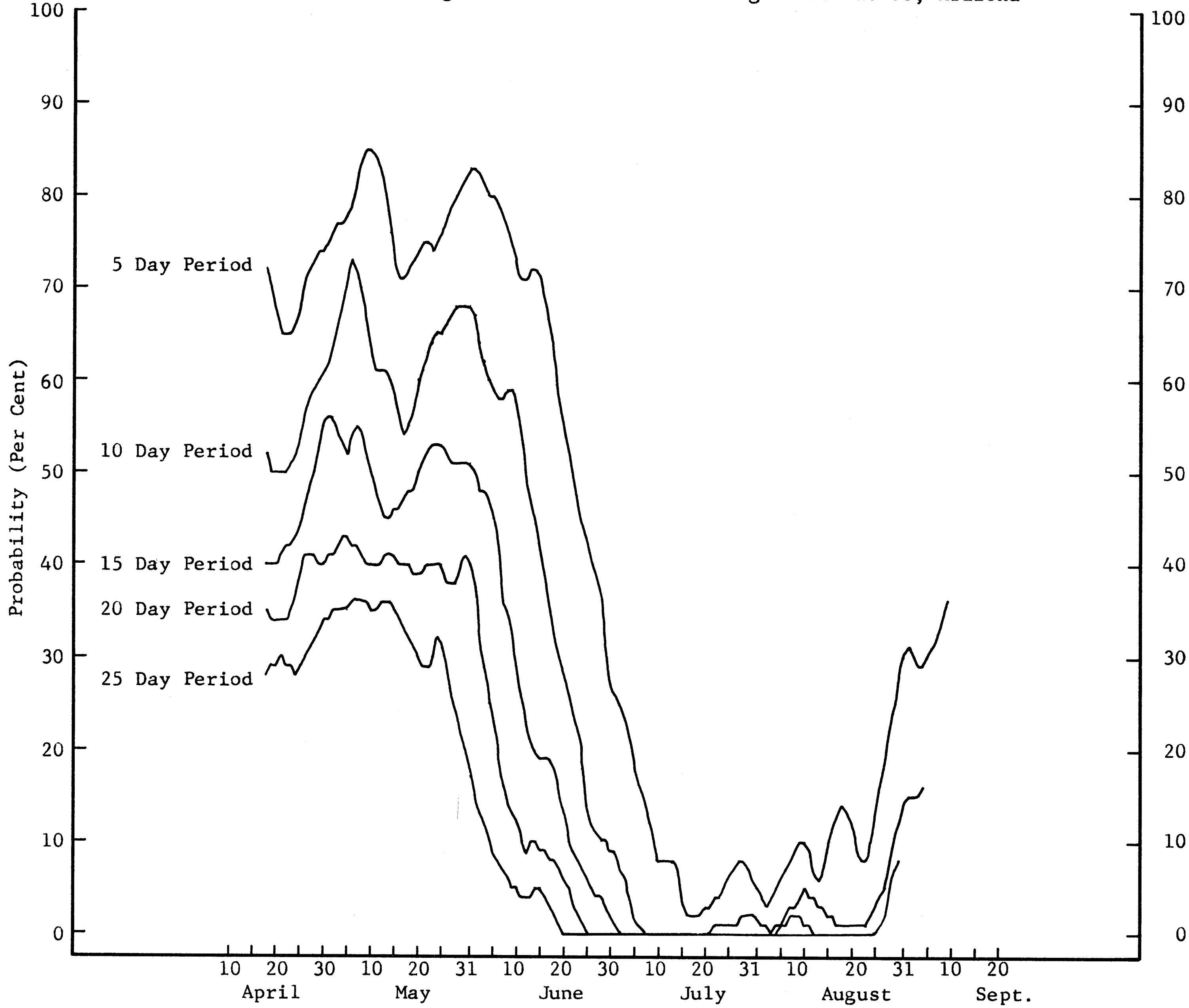

Figure 4

Probabilities of Drought Periods of Various Lengths at Clifton, Arizona

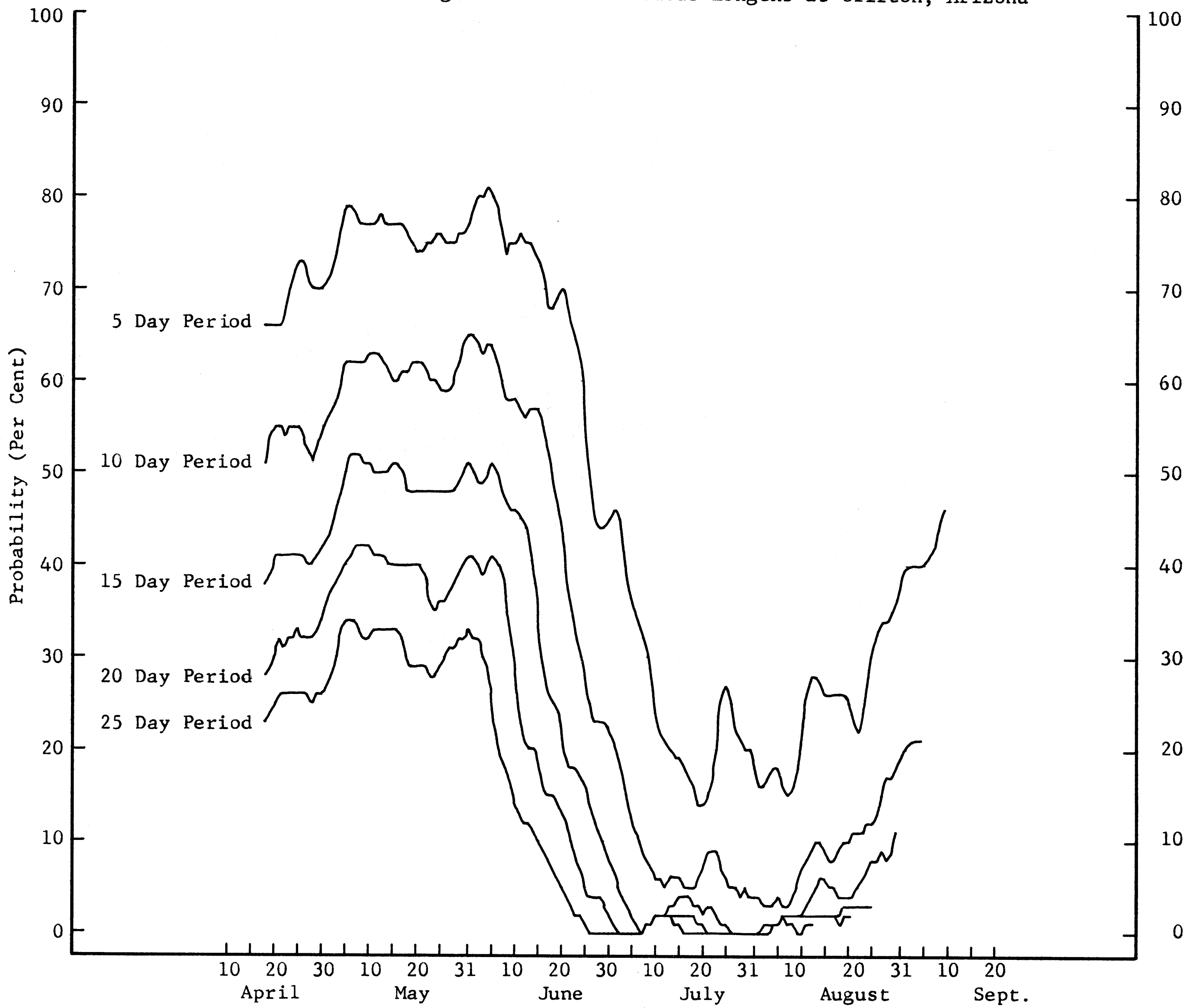

Figure 5

Probabilities of Drought Periods of Various Lengths at Holbrook, Arizona

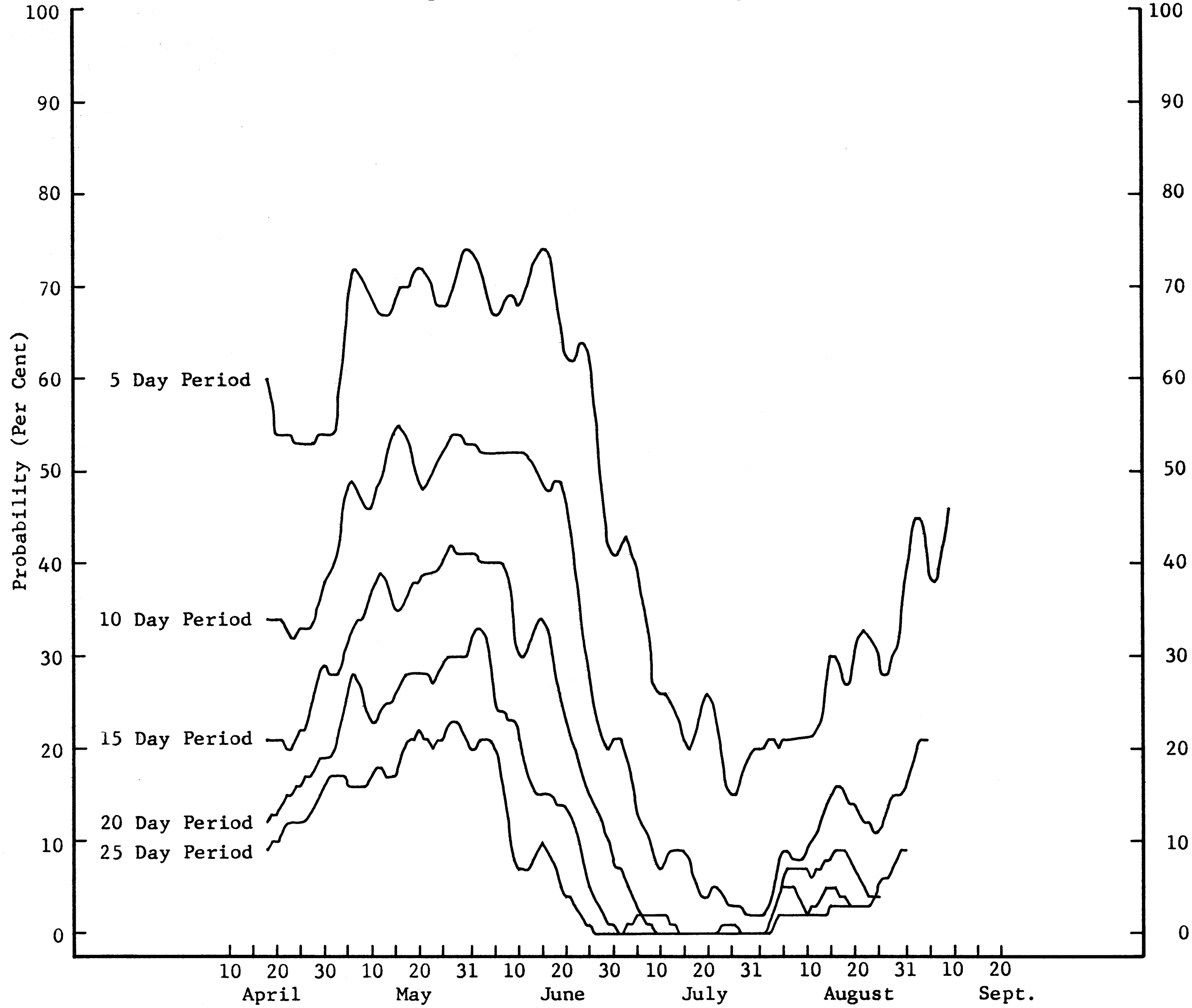

Figure 6

Probabilities of Drought Periods of Various Lengths at Granite Reef Dam, Arizona

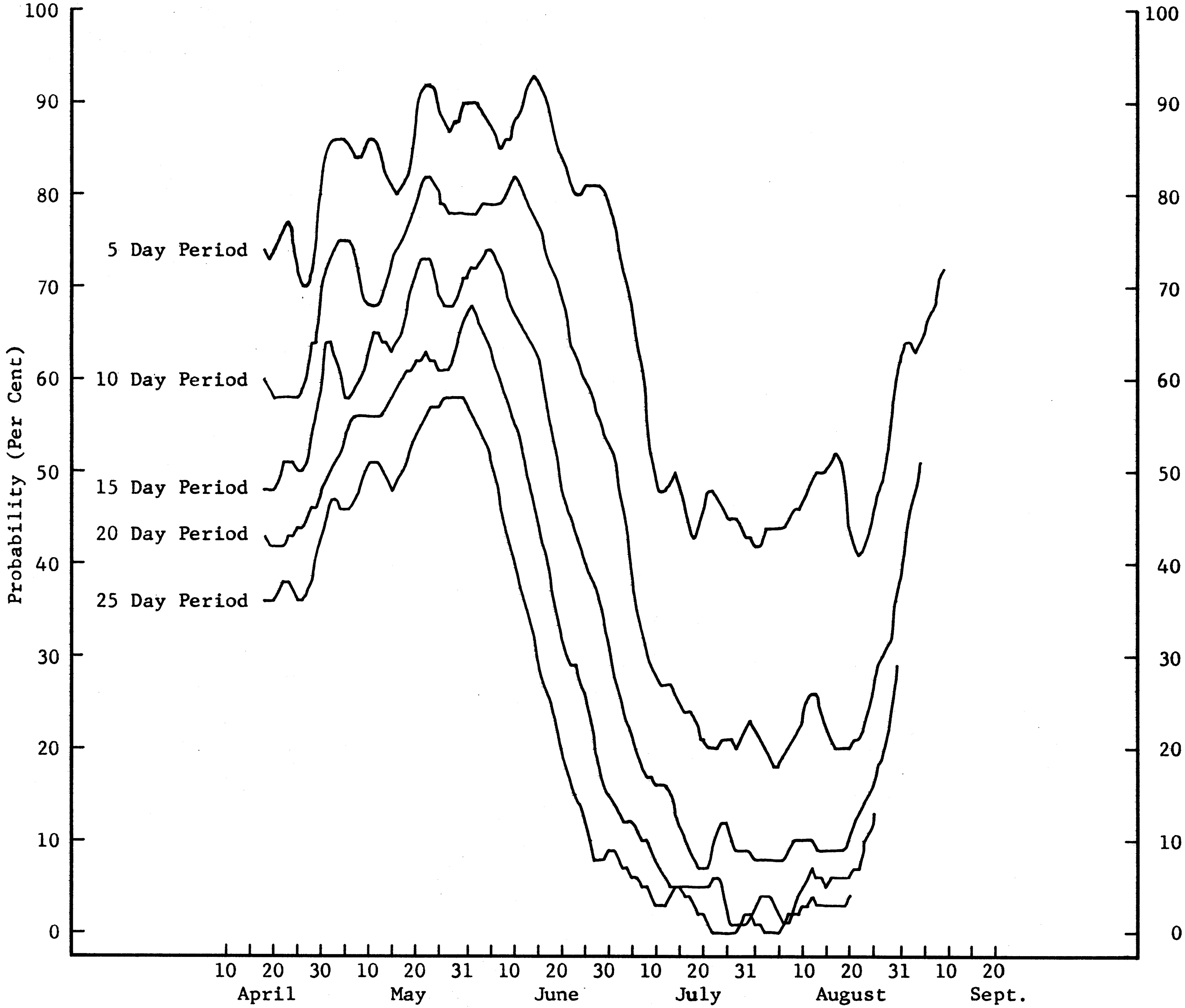

Figure 7

Probabilities of Drought Periods of Various Lengths at Natural Bridge, Arizona

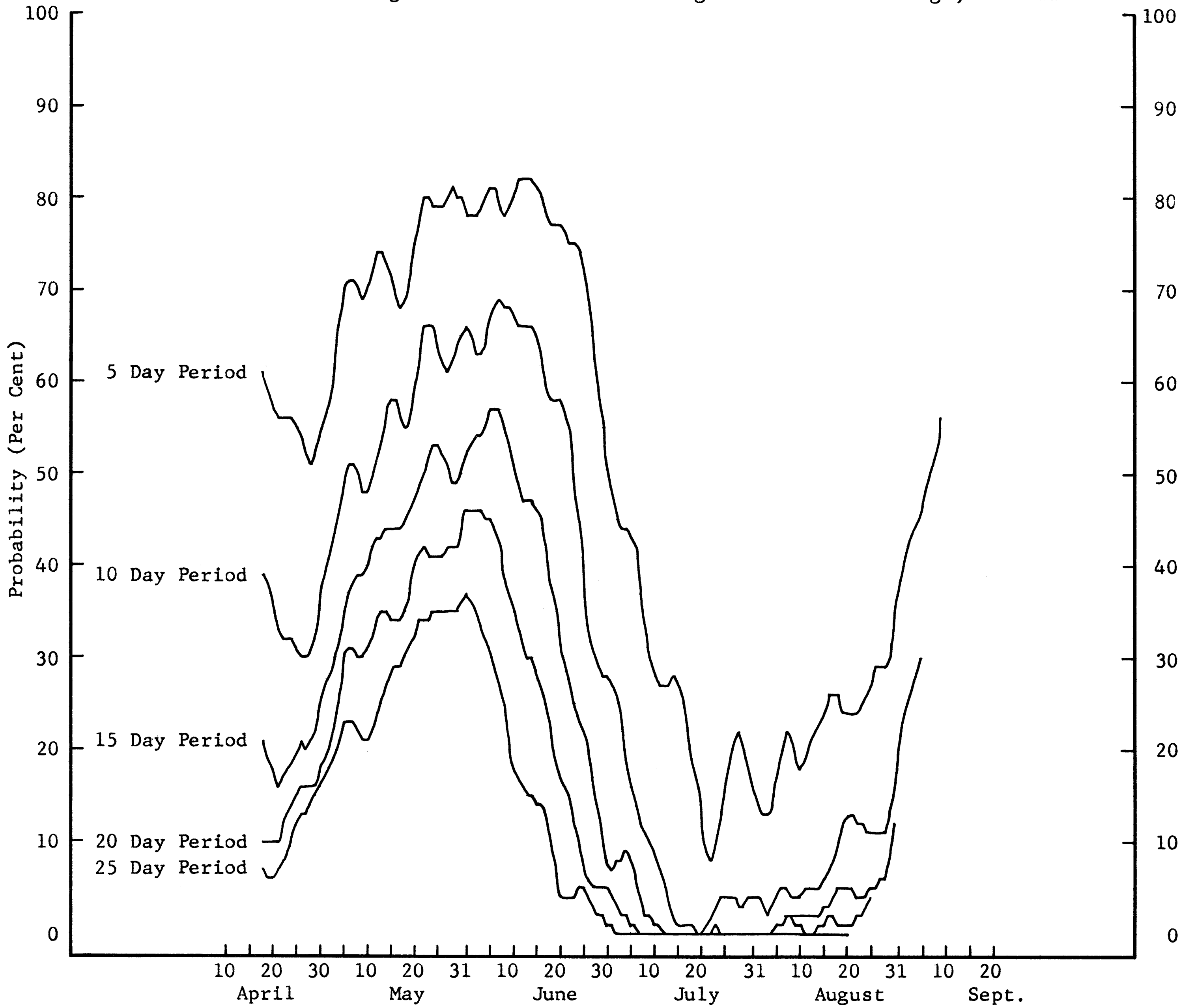

Figure 8

Probabilities of Drought Periods of Various Lengths at Walnut Grove, Arizona

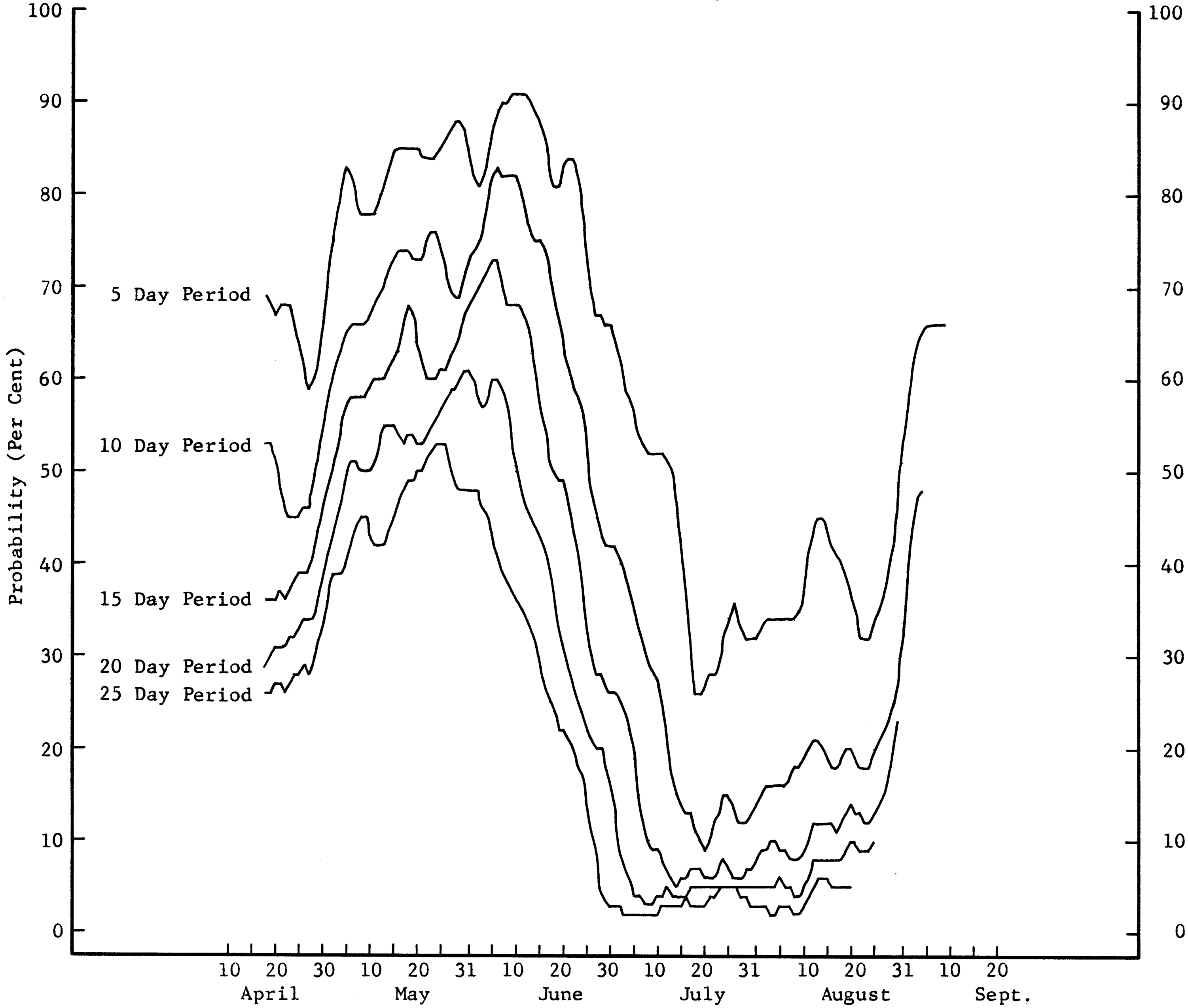

Figure 9

Probabilities of Drought Periods of Various Lengths at Yuma, Arizona

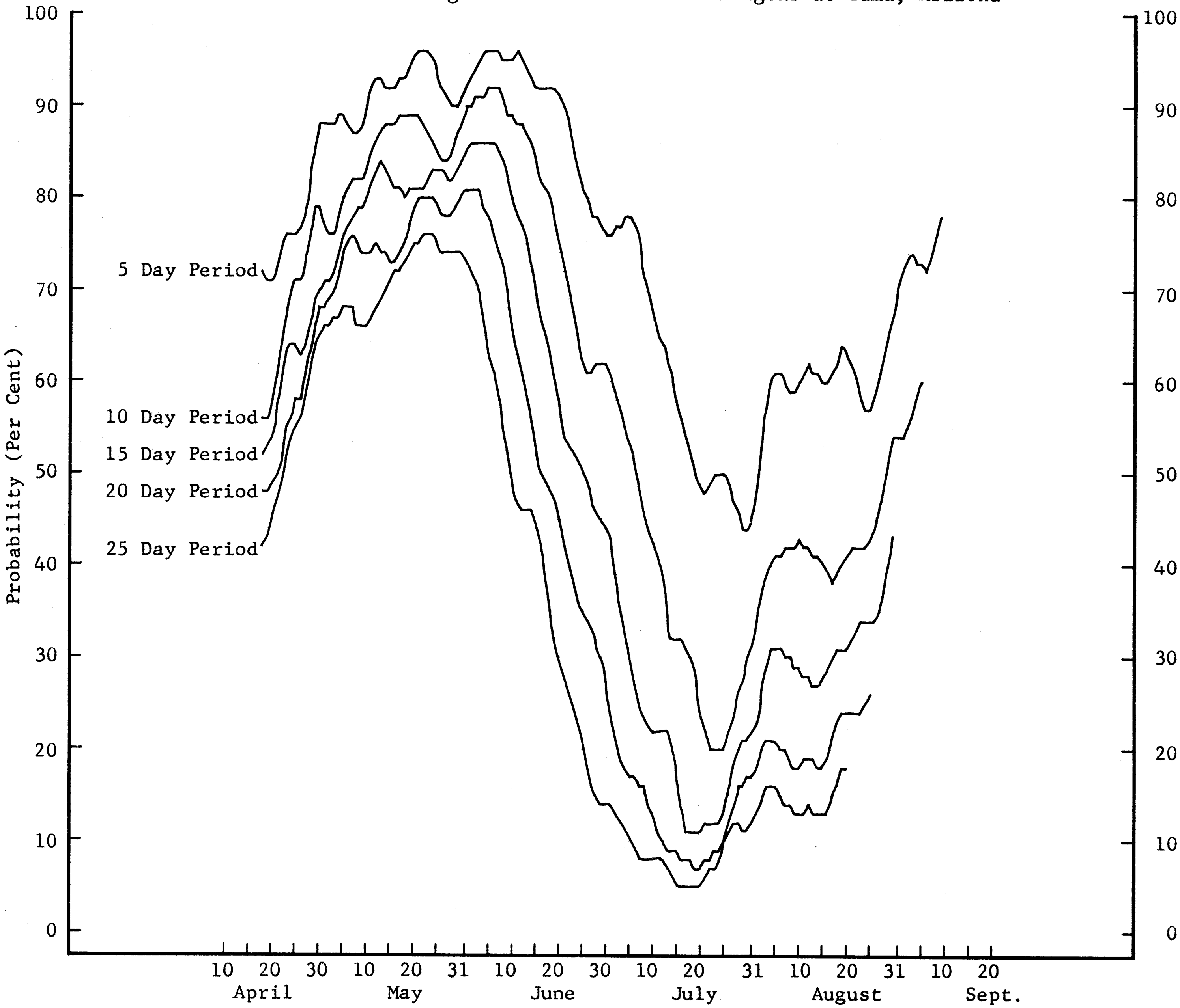

Figure 10

Probabilities of Drought Periods of Various Lengths at Parker, Arizona

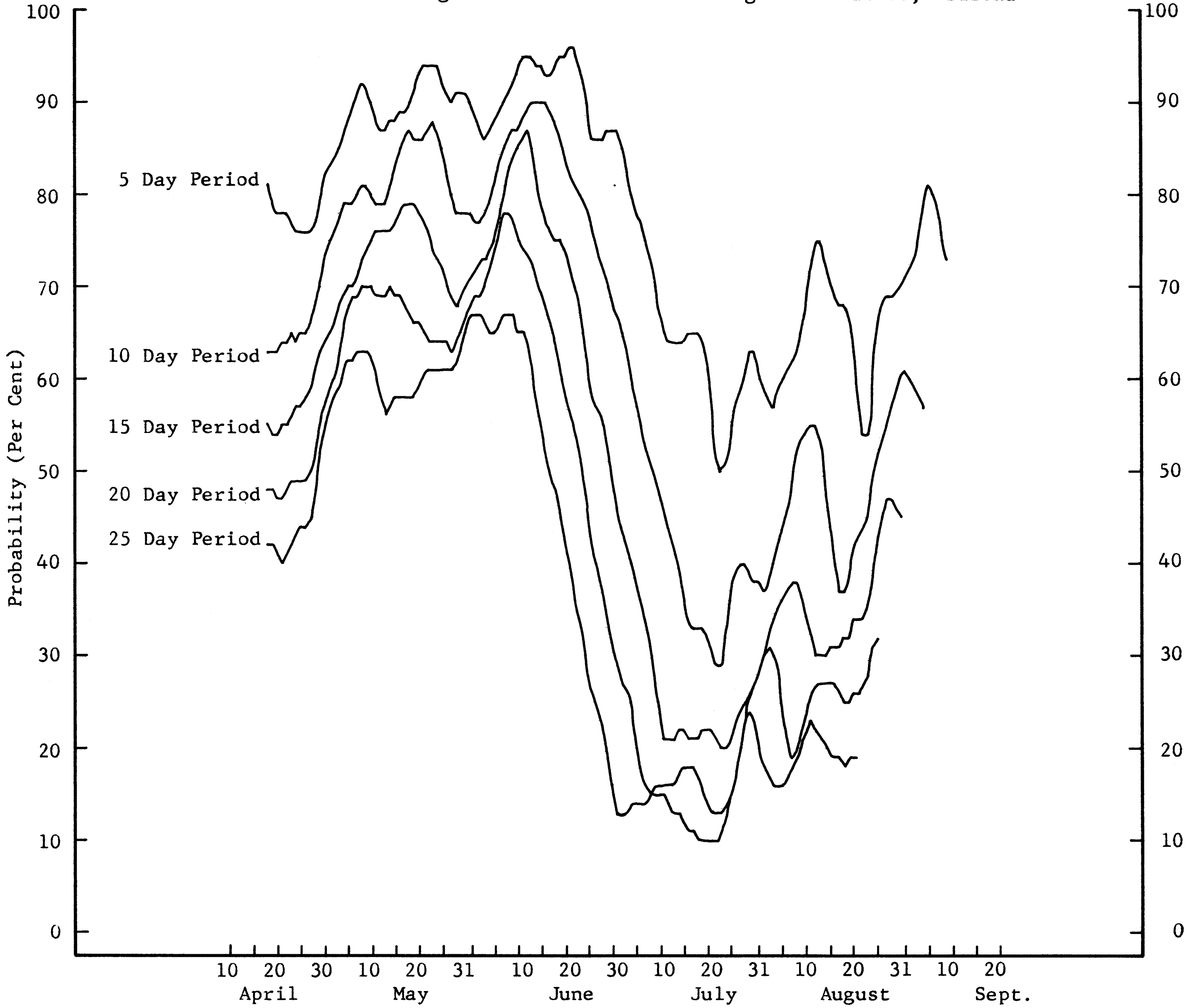

Figure 11

Probabilities of Rainy Periods of 3 Day Lengths at State University, N. M.

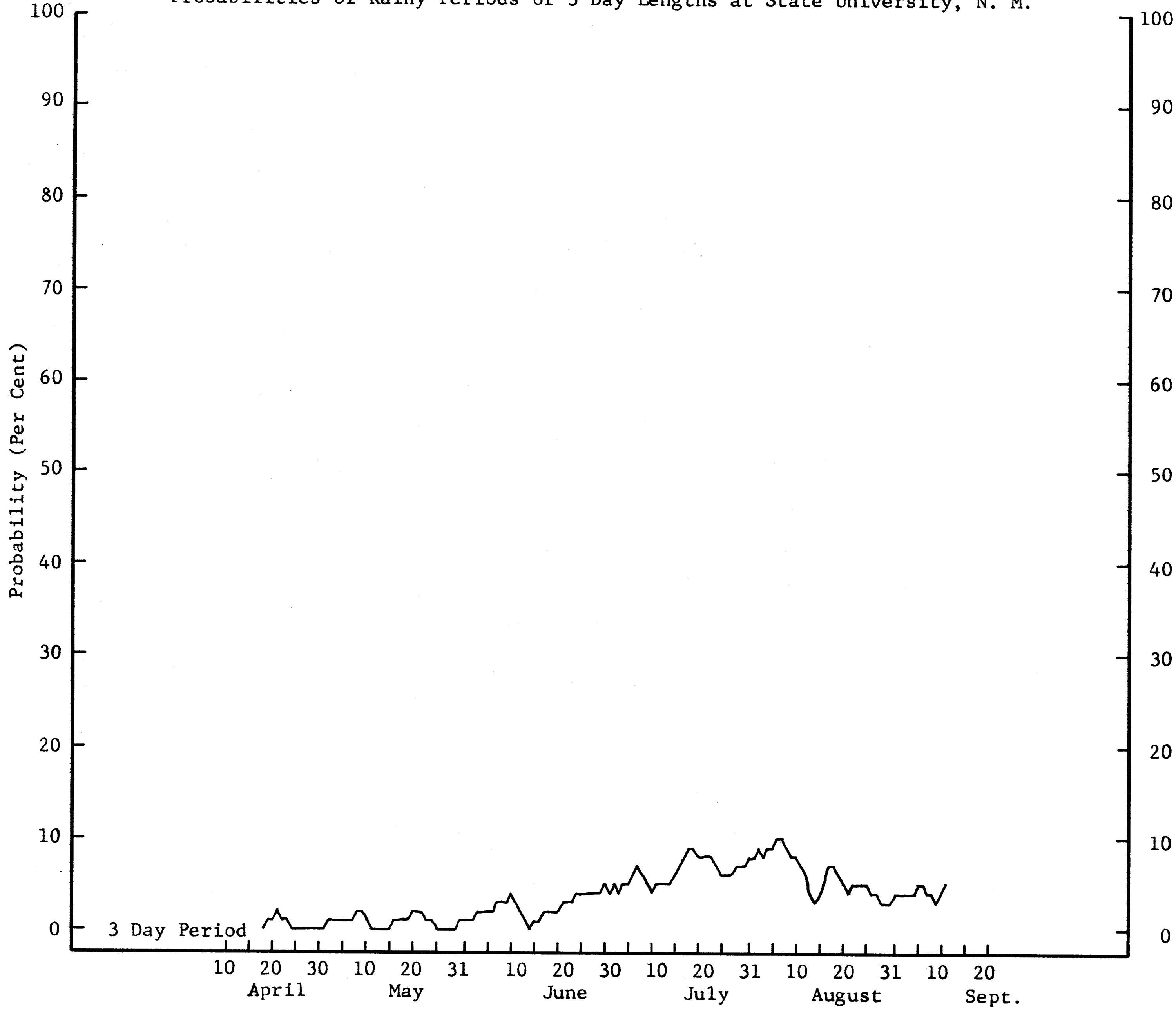

Figure 12

Probabilities of Rainy Periods of Various Lengths at Santa Fe, N. M.

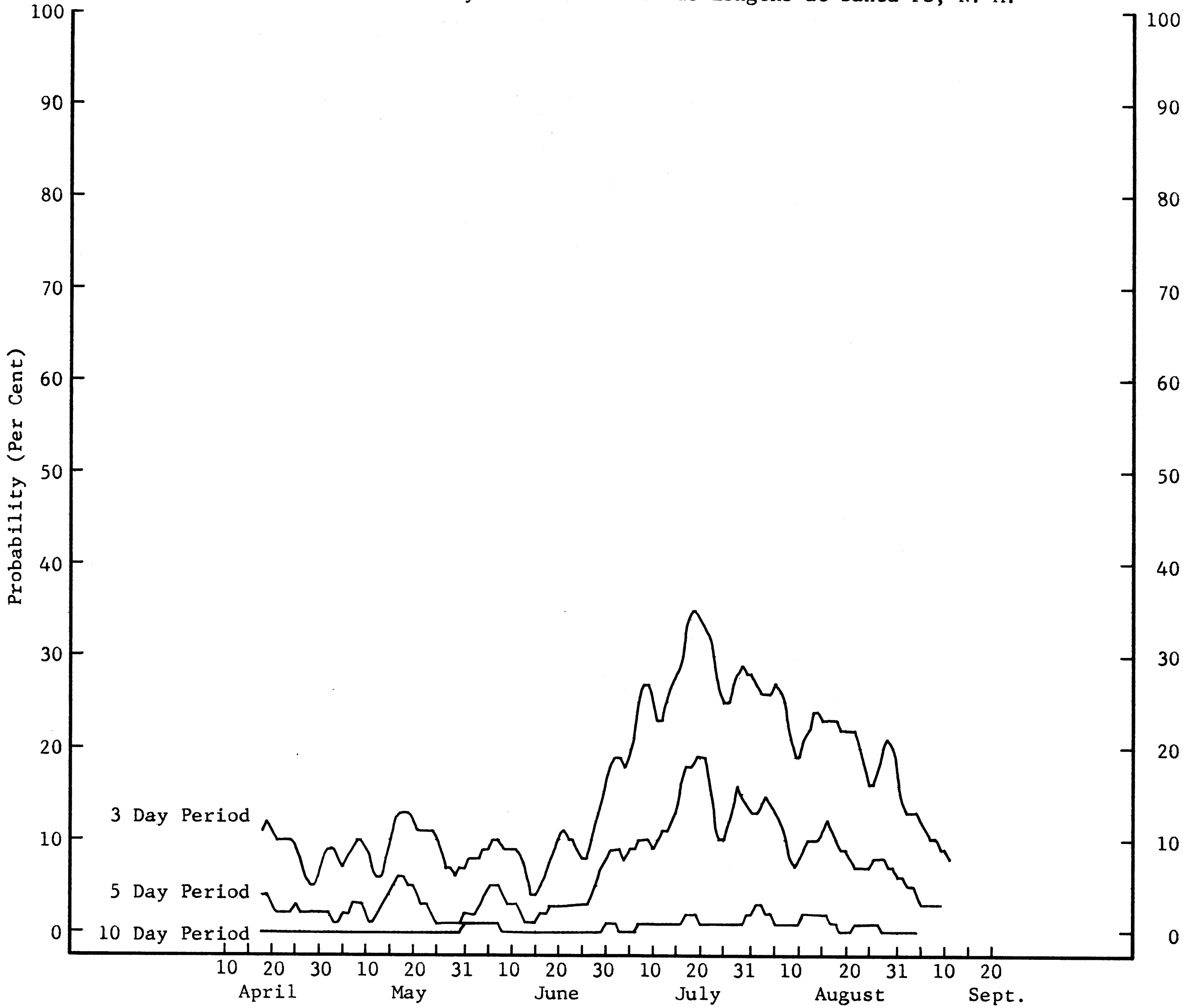

Figure 13

Probabilities of Rainy Periods of Various Lengths at Bisbee, Arizona

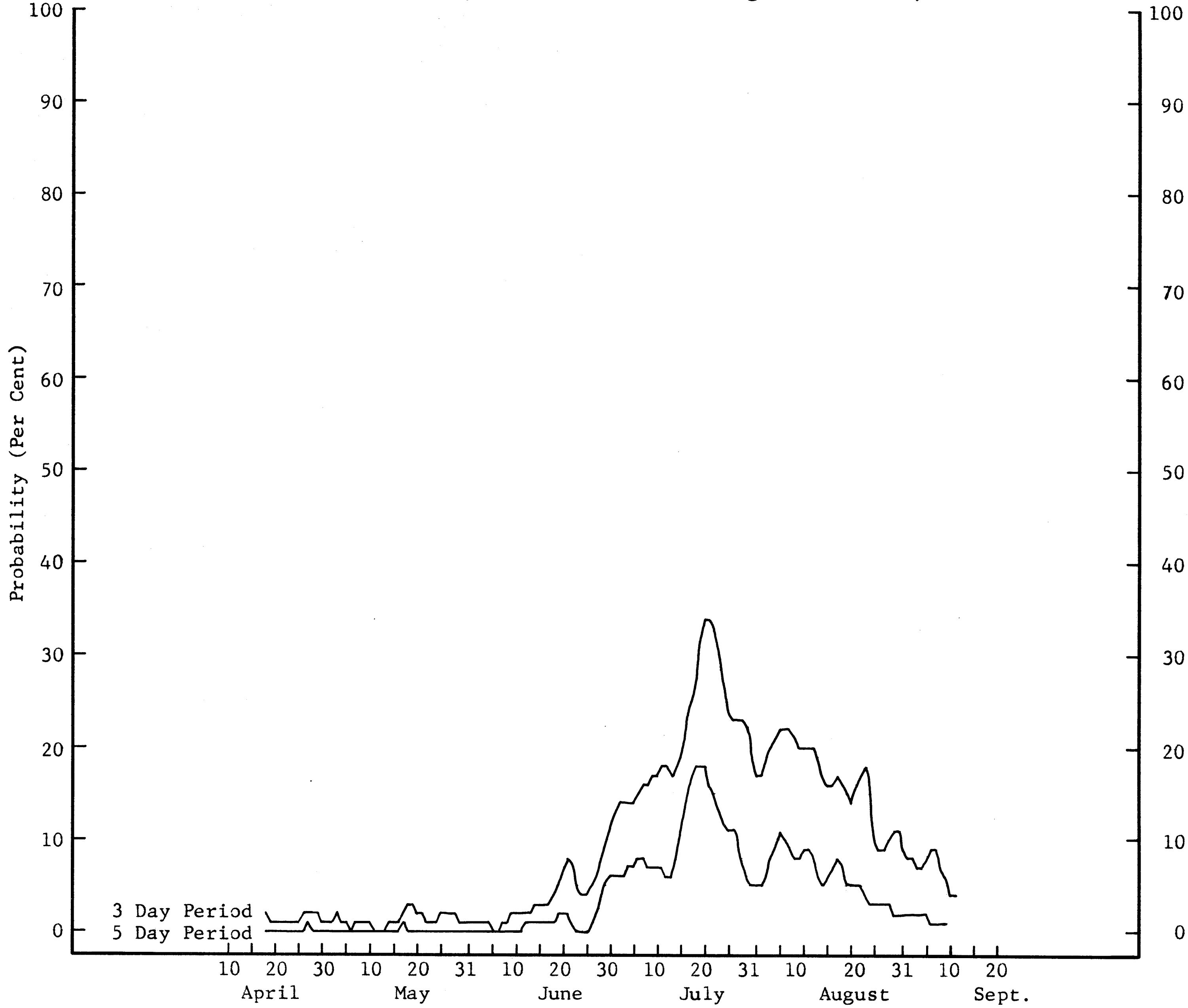

Figure 14

Probabilities of Rainy Periods of Various Lengths at Clifton, Arizona

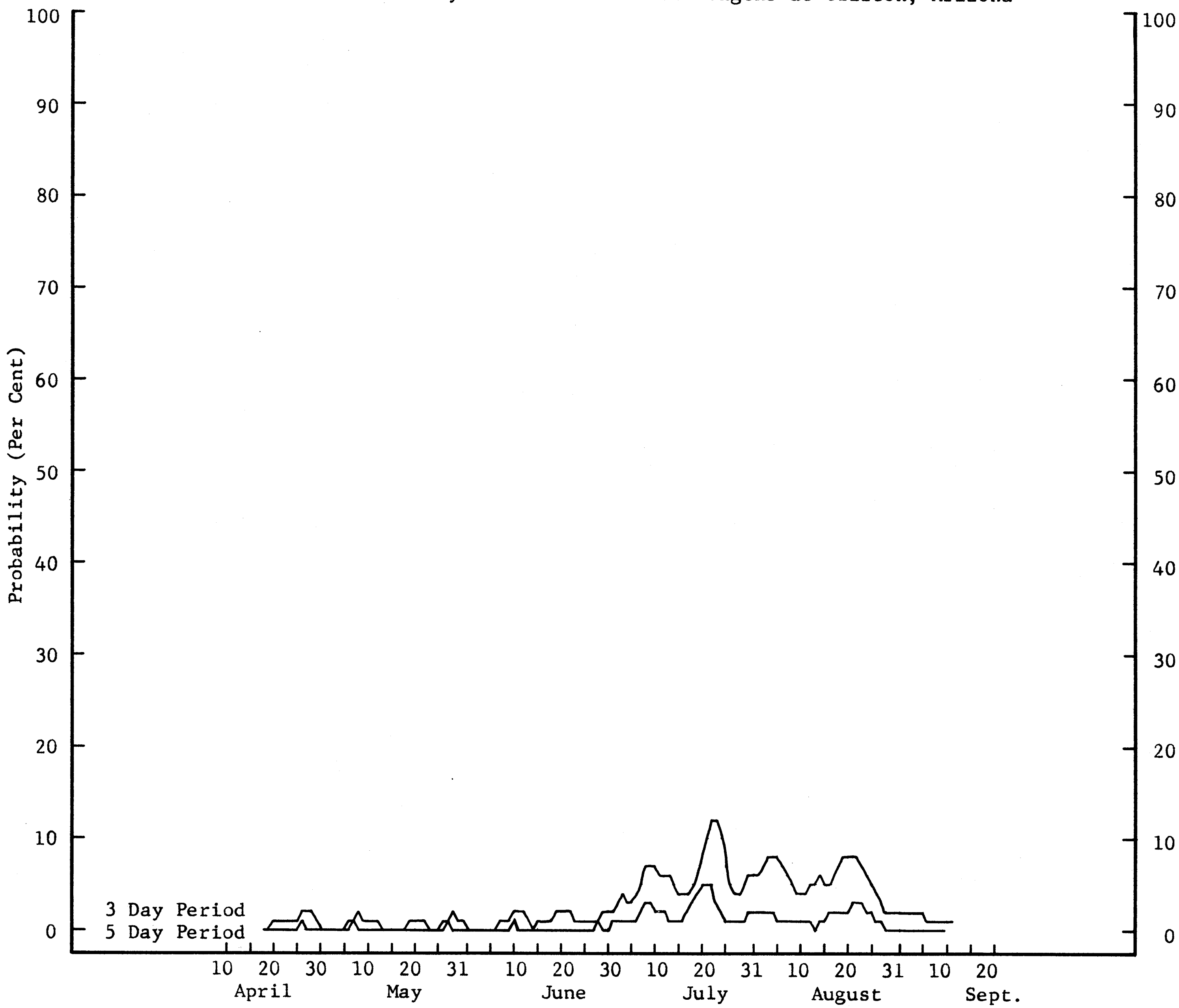

Figure 15

Probabilities of Rainy Periods of Various Lengths at Holbrook, Arizona

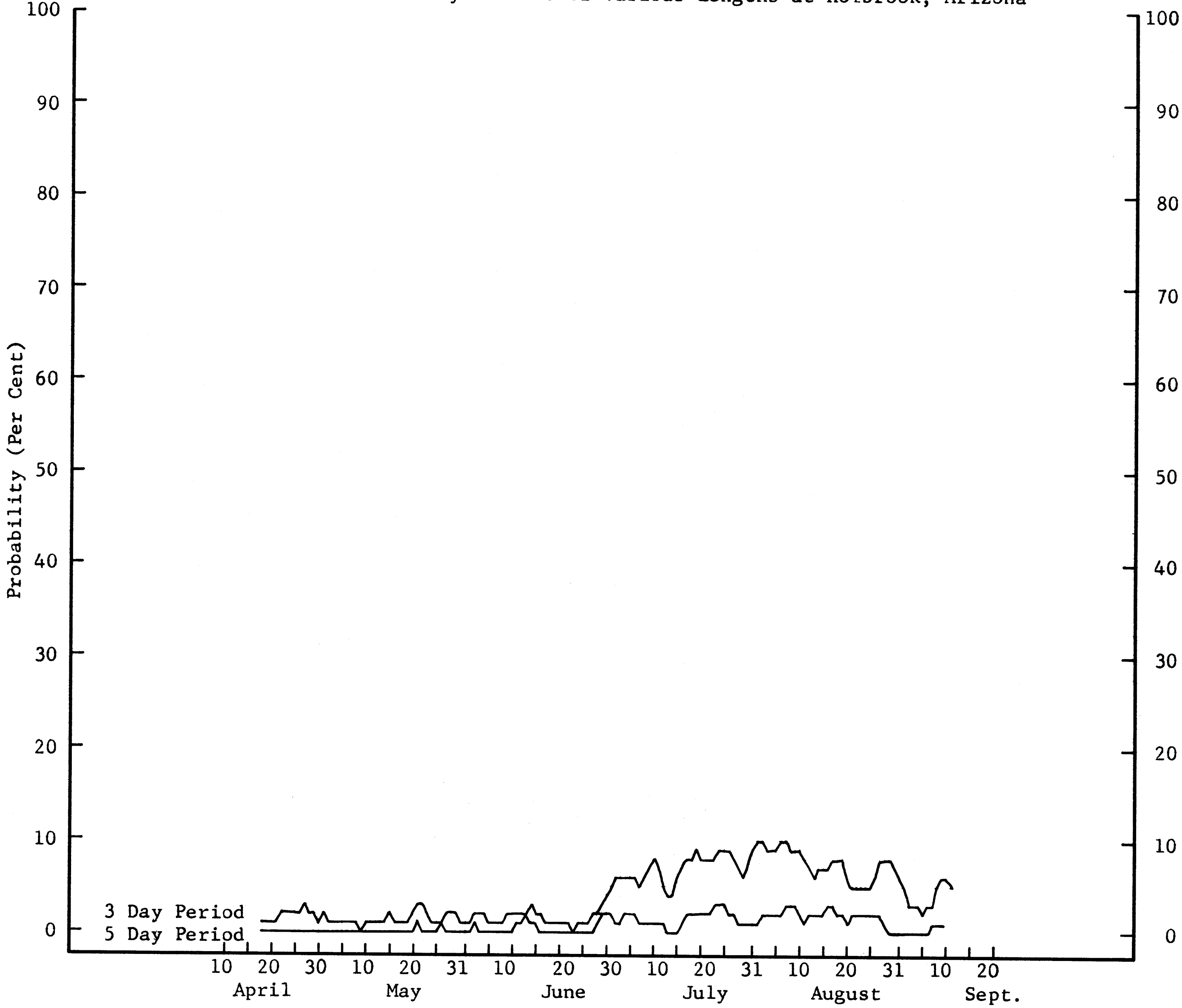

Figure 16

Probabilities of Rainy Periods of 3 Day Lengths at Granite Reef Dam, Arizona

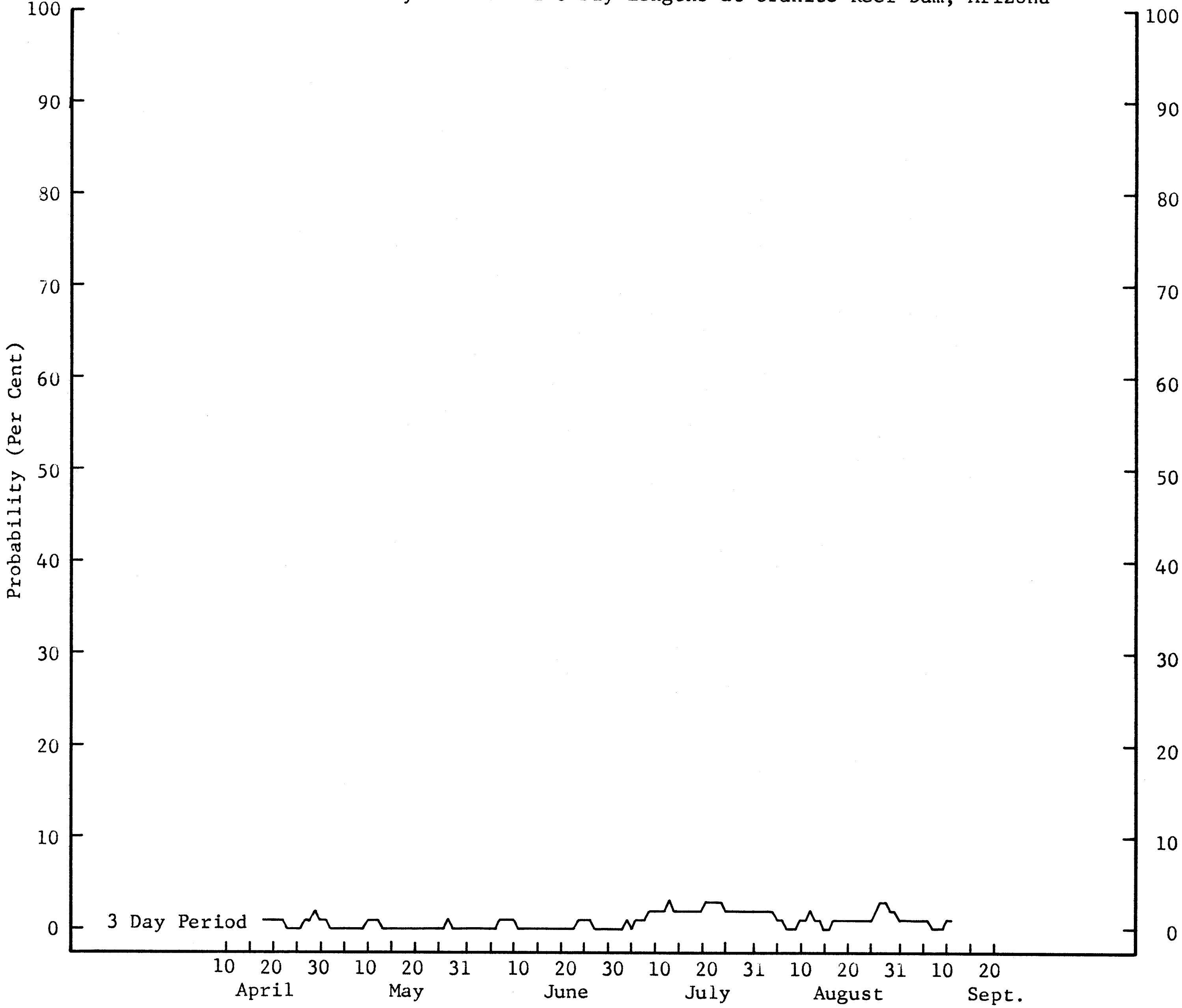

Figure 17

Probabilities of Rainy Periods of Various Lengths at Natural Bridge, Arizona

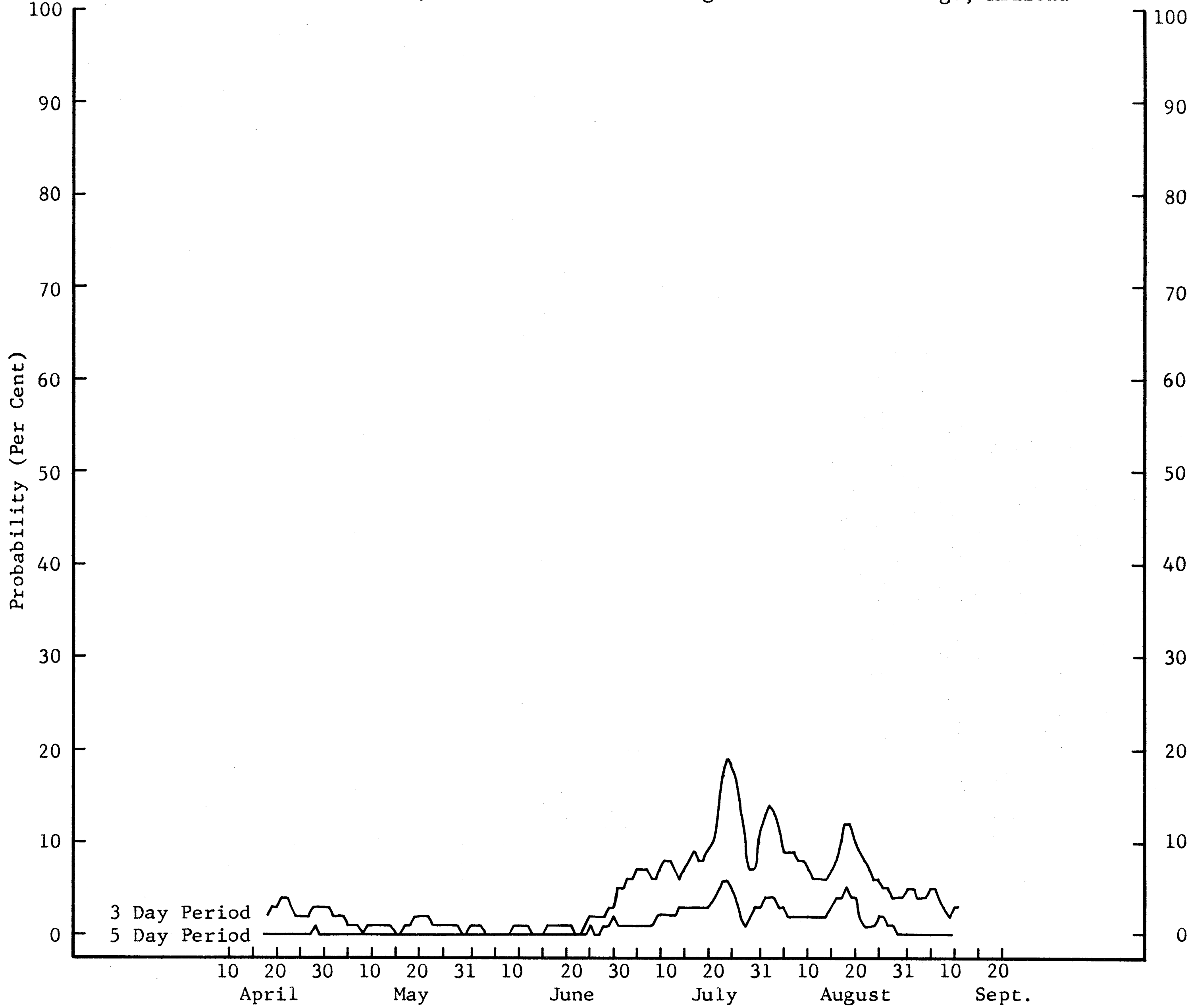

Figure 18

Probabilities of Rainy Periods of 3 Day Lengths at Walnut Grove, Arizona

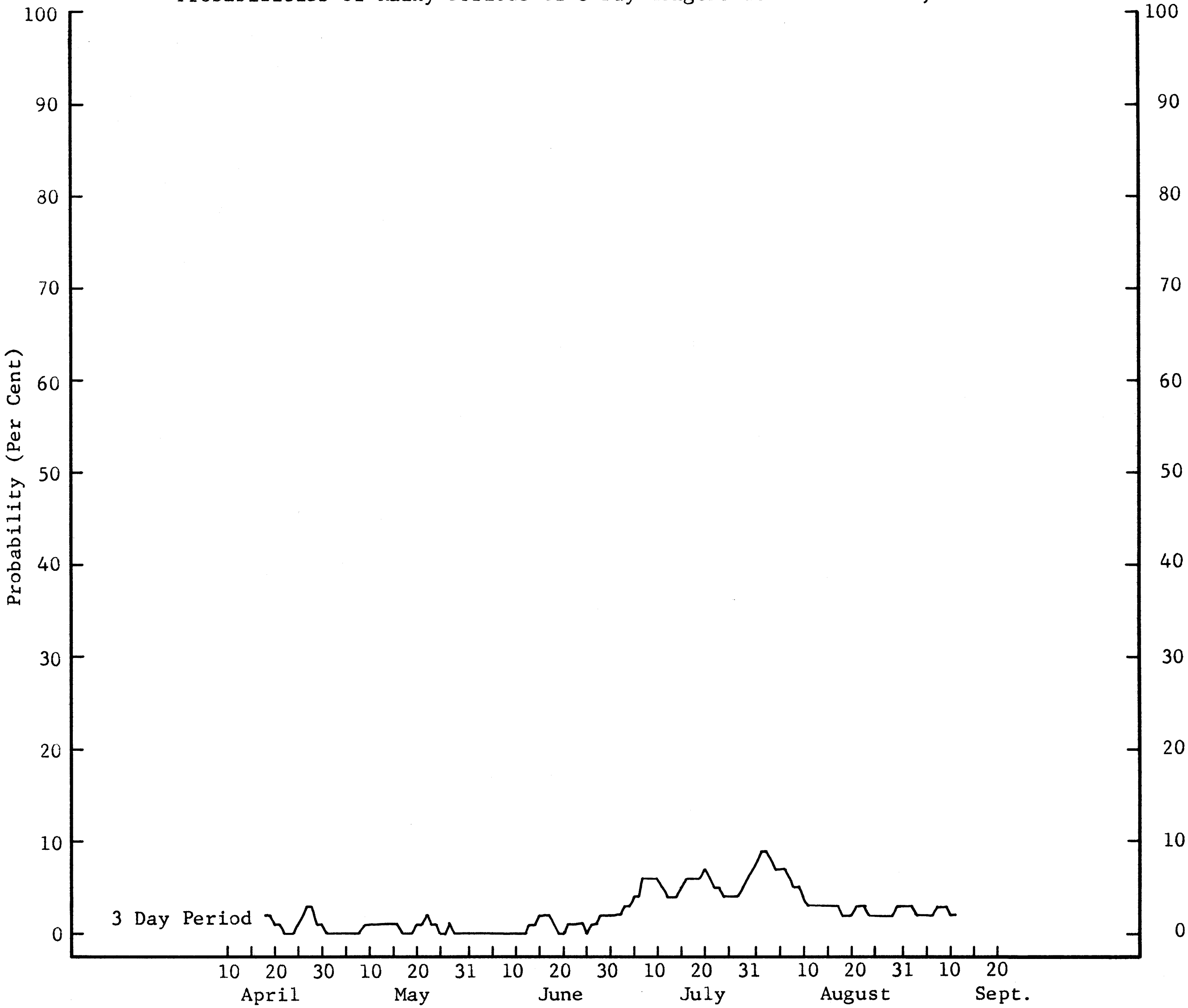

Figure 19

Probabilities of Rainy Periods of 3 Day Lengths at Yuma, Arizona

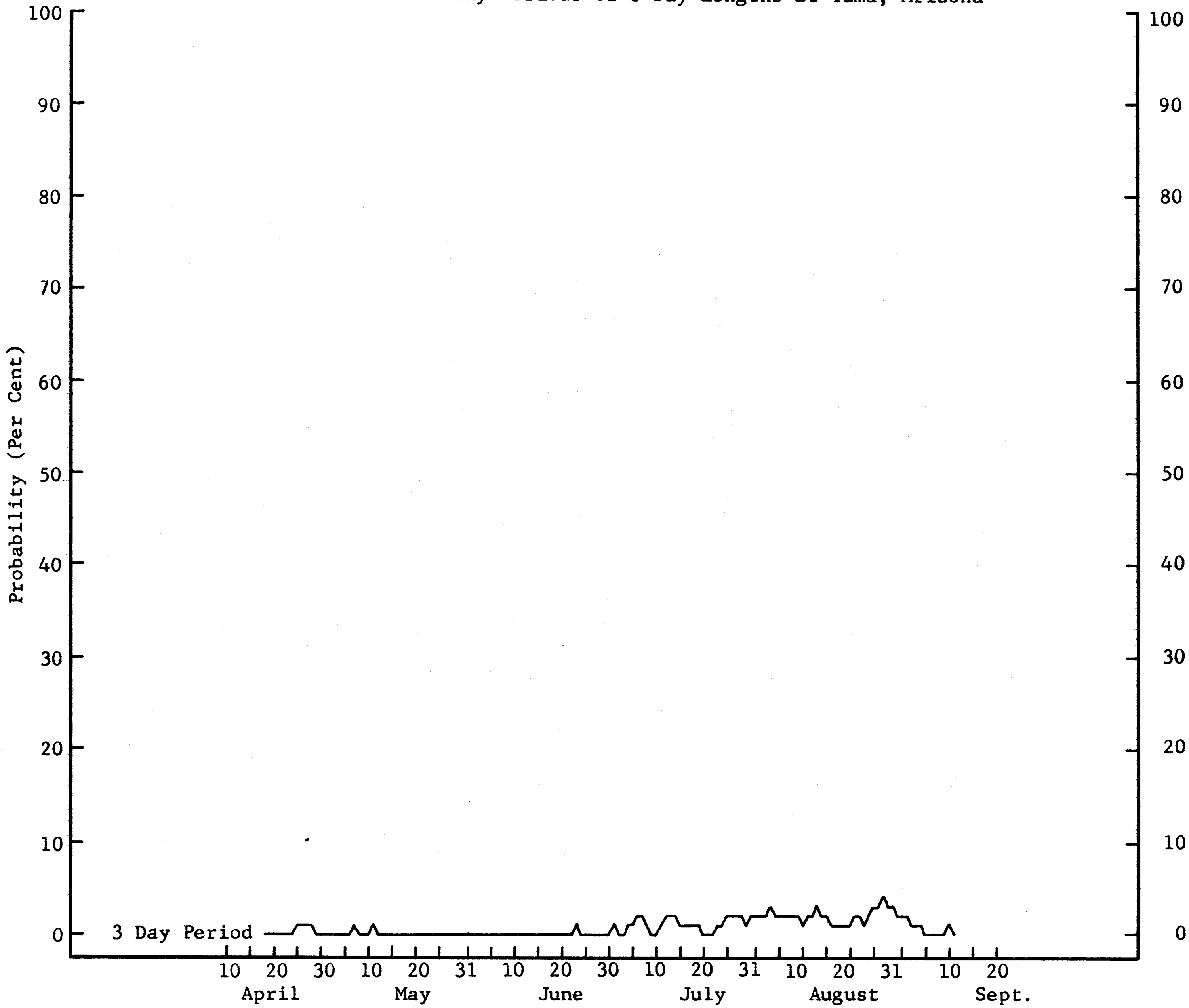

Figure 20

Probabilities of Rainy Periods of 3 Day Lengths at Parker, Arizona

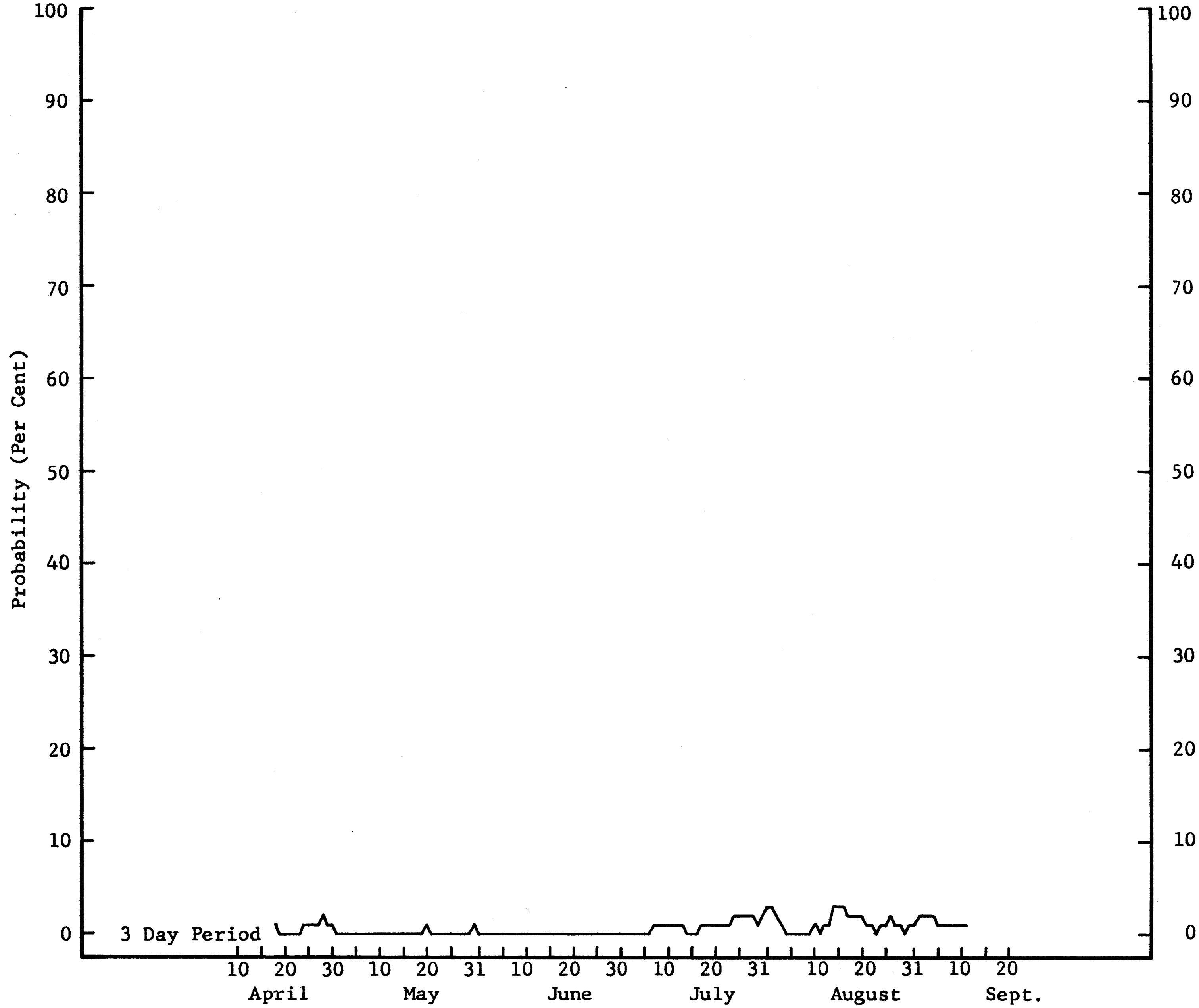

FIGURE 21

TIME INTERVALS DURING WHICH THE PROBABILITIES OF 5,10,15,20, AND 25 DAY DROUGHTS EXCEED 50 PER CENT

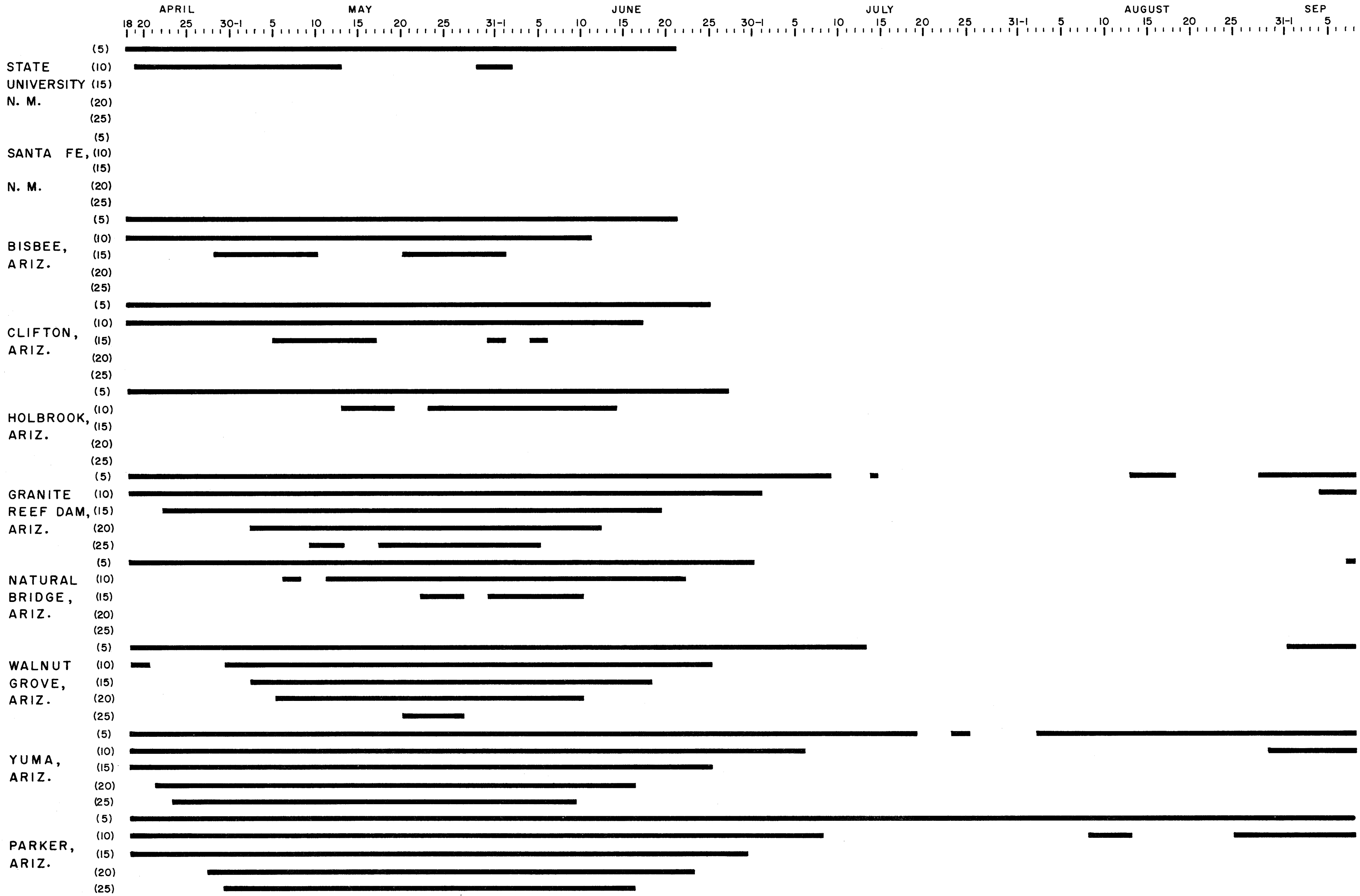

FIGURE 22

TIME INTERVALS DURING WHICH THE PROBABILITY OF THE START OF A 3 DAY RAINY PERIOD EXCEEDS 2 1/2, 5, AND 10 PER CENT

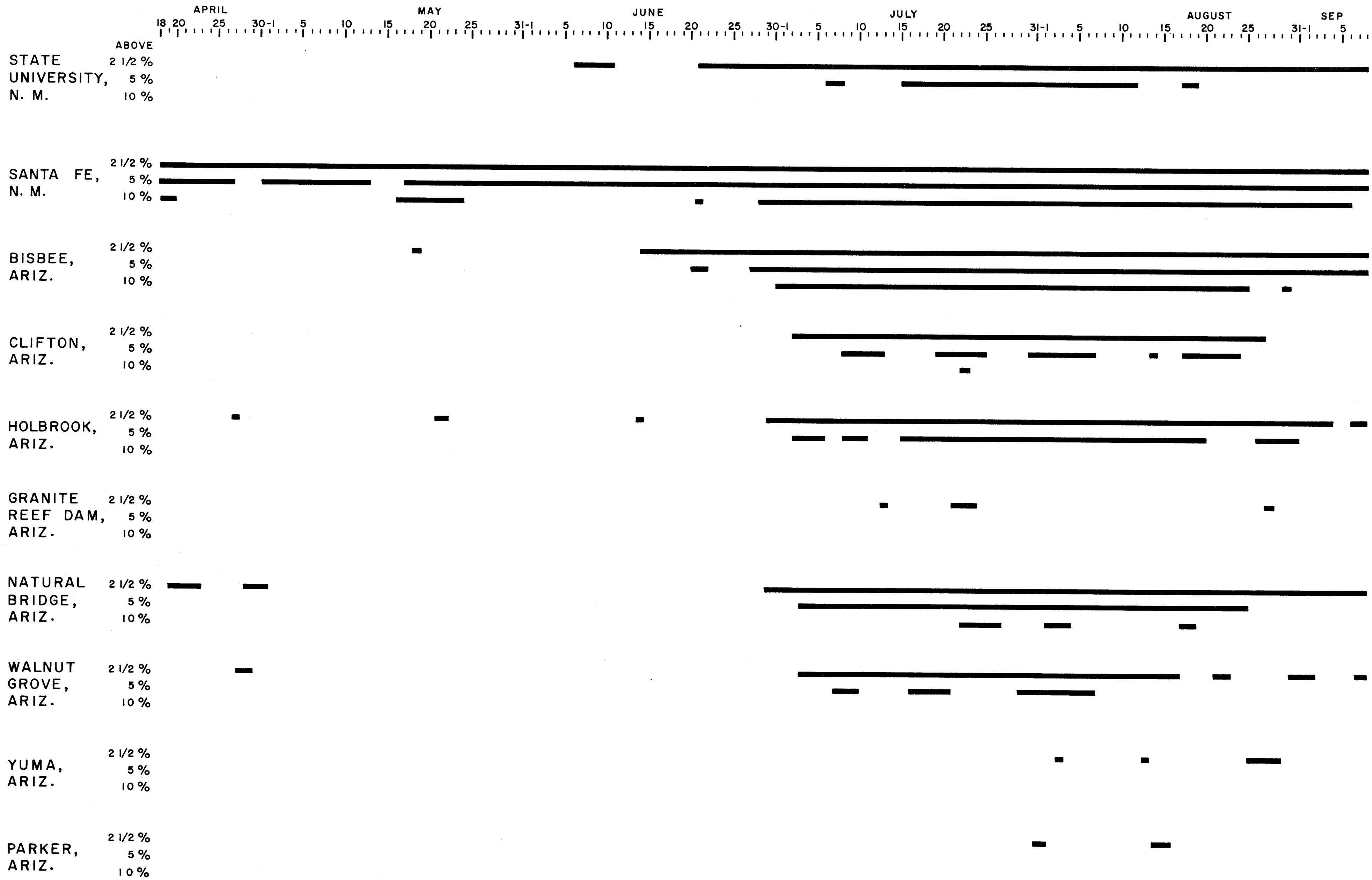

Figure 23

Last Early Summer Day on which the Probability of the Start of a 5 Day Drought Exceeds 50 Per Cent

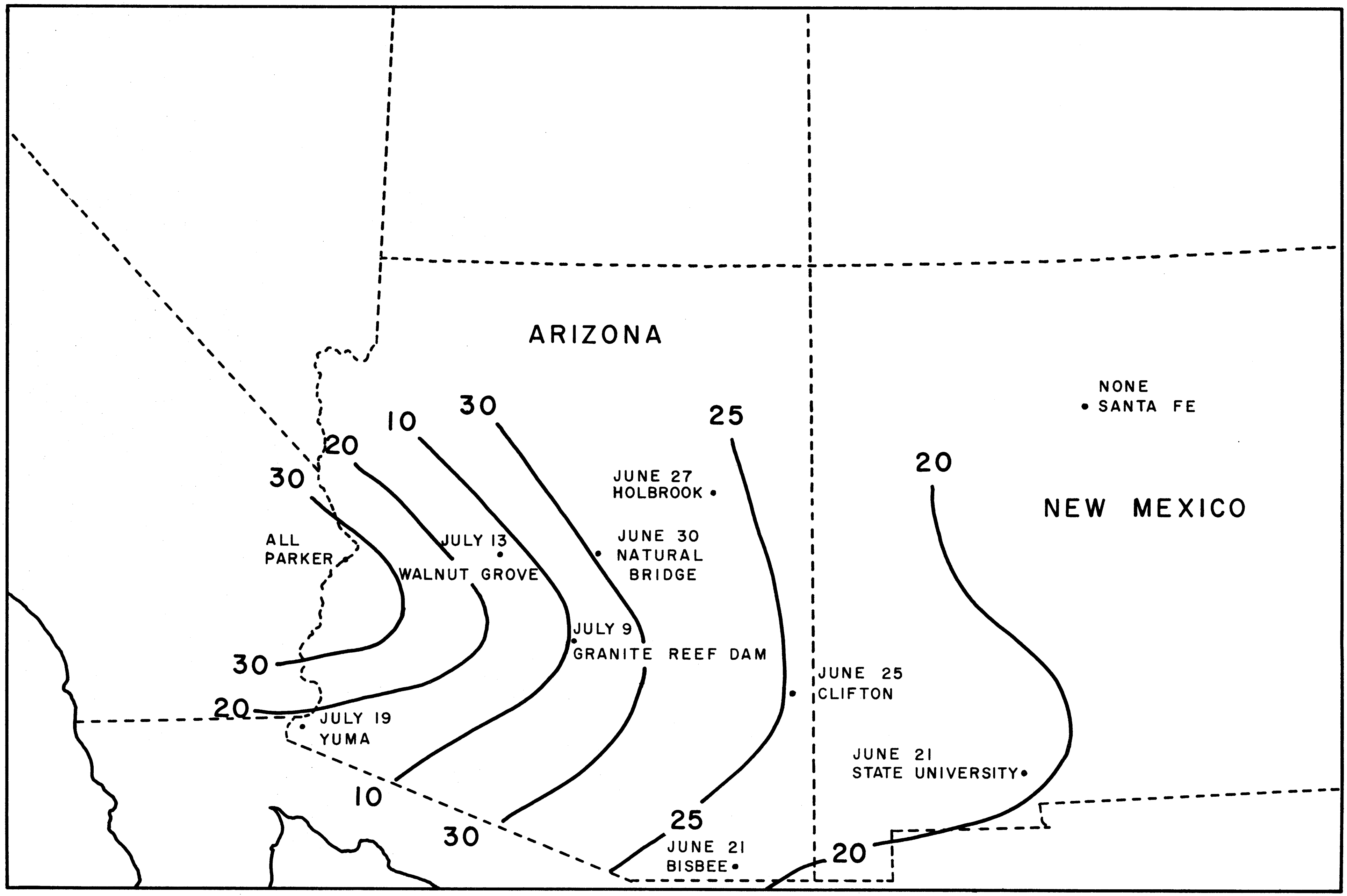

FIGURE 24

Average fraction (P) of seven Arizona weather stations reporting rainfall during each day in June, July, and August. Based on data for Tuba City, Holbrook, Tombstone, Bisbee, Globe, Jerome, and Snowflake, Arizona, for the sixty year period from 1898 through 1957.