HYDROLOGIC FREQUENCY STUDY AND ANALYSES FOR ALLERTON AGRICULTURAL WATERSHEDS

BY

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INTRODUCTION

Hydrologic data are basic to the accurate design of hydraulic structures. The design requires an estimate of rainfall and runoff rates that can be expected from watersheds for the design period. For this design, the amounts of water that have to be discharged must be known. If possible, these amounts should be assessed by direct measurements. If not, indirect methods, such as calculation of discharges from rainfall data, will have to be used (Stol, 1973).

The most common hydrologic data used for designing hydrologic structures are rainfall and streamflow records. The first step in designing a water control facility is to determine the probable recurrence of storms of different intensity and duration so that the most economical size structure can be provided (Schwab,1966).

The design of hydraulic structures requires an estimate of the peak runoff rate that can be expected from a watershed. It is physically and economically impossible to measure runoff from every watershed where an estimate of peak runoff rates may be needed. Rather, it is necessary to extend the results of runoff measurements from a small number of watersheds to ungaged areas.

Any watershed is unique with respect to runoff producing characteristics. Thus, difficulty is encountered in applying results of runoff studies to other watersheds. For small agricultural watersheds, the watershed characteristics, soil condition, and vegetal cover at the time of a storm has as important an effect on runoff as rainfall amounts and intensities. Without a thorough understanding of all the factors that affect runoff, the results of runoff studies must be limited to the area of similar physiography, soils, and land use represented by the measured watersheds.

To provide rainfall and runoff information applicable to a large area in Central Illinois, rainfall and runoff measurements were started in 1949 on four small agricultural watersheds in Allerton Park, Monticello, Illinois. The sizes of the watersheds range from 45.5 acres to 390 acres. The work was done by the Department of Agricultural Engineering, University of Illinois, in cooperation with the Soil Conservation Service, USDA.

The available data from these four small agricultural watersheds are rainfall, runoff, and, additionally, temperature, humidity, and wind speed. The rainfall data consist of monthly and annual total rainfall, and maximum rainfall intensities for various durations. The runoff data consist of monthly and annual runoff, annual maximum runoff depth, and maximum exceedances runoff depth, for various durations.

Similar projects have provided runoff data for the permeable deep loessal soils of northwestern Illinois, and the claypan region of southern Illinois. However, complete hydrologic data and its interpretation for small agricultural watersheds is not available in Central Illinois. The Allerton project covers soils between the above two soil types; a loessal soil over permeable calcareous till. The northwestern and southern Illinois studies were on watersheds of steep topography, whereas this study is from agricultural watersheds of very mild topography.

With these three projects, runoff data for most of the soils throughout Illinois are provided.

Objective and Scope of the Study

The objective of this study was to provide the best estimate of rainfall and runoff frequencies for four small agricultural watersheds. The specific objectives were:

- to obtain the depth-duration-frequency relationships for rainfall and runoff, and, additionally, to determine the probability relationships for temperature, humidity, and wind speed;
- to determine the generalized relationships between rainfall and runoff with a simple regression analysis; and
- to determine if the hydrologic records and the length of those records for this study are adequate for predicting future events.

HYDROLOGIC DATA ANALYSIS

Hydrologic data are random in nature depending on their magnitude and time of occurrence. When the data are arranged in the order of magnitude, a series of data which can be subjected to mathematical analysis is formed, and the distribution may be studied by the method of statistics (Chow,1953).

Statistical analysis as applied to hydrologic engineering consists of:

- estimating the future frequency or probability of hydrologic events based on the information contained in the hydrologic process, and
- correlating interrelated hydrologic variables.

In probability analysis, statistical methods permit coordination of observed data to yield a more accurate estimate of future frequencies than is indicated by the raw data. They also provide criteria for judging the reliability of the frequency estimates. In correlation analysis, statistical methods provide means for deriving the most likely relationship between two variables, and also provide criteria for judging the reliability of forecasts or estimates based on the derived relationship (Beard,1962).

Selection of Data

The available hydrologic data are generally arranged in chronological order. In order that the data have significant value, it is necessary to select the data and exclude the insignificant data. Hydrology is highly data dependent, and requires good data samples, both in time and space. The data must be representative and homogeneous (Linsley and Franzini,1973).

With respect to time, representative means that the data or the sample must be long enough to include an adequate range of the information to be used. The concept of homogeneity implies that the records should have a common meaning throughout the period of record. This means that the data for the study must measure the same aspect of each event (Beard,1962).

Many of the original data have practically no significant meaning in the analysis because the hydrologic design of a project is usually governed by a few critical conditions only. For this purpose, two types of data are generally selected from the complete duration series, namely the partial duration series and the extreme value series (Chow,1964). The problem in making probability estimates is essentially to determine the set of conditions that most likely generated the sample of data that has been recorded. This set of conditions is represented by a parent population which consists of all of the hydrologic events that would be generated if the record continues indefinitely and controlling conditions do not change. From this parent population, the partial duration series and the extreme value series are taken (Beard,1962).

Partial duration series or partial series is a series of data which are so selected that their magnitude is greater than a certain base value. If the base value is selected so that the number of values in the series is equal to the number of the record, the series is called an annual-exceedance series.

Extreme value series is a series of data that includes the highest or the lowest values with each value selected from an equal time interval in the record. The time interval is taken as one year and the series so selected is the annual series, which can be divided into annual maximum series for the largest annual events, and annual minimum series for the lowest annual events.

The annual exceedance and the annual maximum series give essentially identical results for recurrence intervals greater than about 10 years (Chow, 1953). The recurrence interval is defined as the number of years within which an event will be equalled or exceeded once on the average (Linsley and Franzini,1973).

Frequency Analysis

One of the primary goals of engineering hydrology is to determine design flows for hydraulic structures. If all the components which make up the hydrologic cycle were fully understood, and could be described, it might be possible to compute these flows entirely from a theoretical basis. Since this state of knowledge has not yet been achieved, one technique that can be used is the analysis of past events (historical data) with the purpose of using this data to predict future events. Such an approach involves examining the magnitude and frequency of occurrence of an event in the hope of finding some relationship between these variables. In this case, the past is extrapolated into the future, under the assumptions that future behavior of the hydrologic system will be similar to past behavior. The procedure involved in this work is known as frequency analysis (Chow,1964).

Hydrologic data most commonly analyzed in this way are rainfall and streamflow records. Because of our inability to consider all of the factors which might influence the magnitude of a hydrologic event, we must use statistics if we are to be able to say anything at all about the event. We cannot say with certainty that a certain magnitude of flood will occur next year or in a certain year in the future, but we might be able to say that there is a certain chance that a flood of that magnitude or larger will occur next year or in a certain year in the future. In this case, we are talking about the probability of an event occurring, which deals with the measure of chance or likelihood based on sampled data (Chow,1964).

An array may help the overall pattern of the data to be apparent. The purpose of the frequency is the primary consideration in selection of an array of data for frequency study. As examples, if we are considering using a frequency curve for estimating damages related to instantaneous peak flows in a stream, we should select the peak flows from the record. If the damages are related to maximum mean daily flows, this item should be selected (Beard, 1962).

In probability analysis, there are two basic approaches to estimate or infer the parent population from the sample data. The first approach is arranging the data in the order of magnitude to form a frequency array, and a graph of magnitude versus observed frequency plotted. The second approach is to derive general statistics from the data representing the average magnitude, the variability from that average, and other pertinent statistics relating frequency to magnitude as indicated by the data (Beard,1962; Huntsberger and Billingsley,1975).

For discrete random variables, the number of occurrences of a variate is called frequency. When the number of occurrences, or the frequency, is plotted against the variate as the abscissa, a pattern called frequency distribution is obtained. When the number of occurrences of a discrete variate is divided by the total number of occurrences, the result is the probability of the variate, and the distribution of the probabilities of all variates, instead of their frequencies, is called probability distribution. Both distributions may be called statistical distributions (Chow,1964; Huntsberger and Billingsley,1975).

Hydrologic data are treated as a statistical distribution for frequency analysis. The empirical frequency distribution of the data is then used to determine the magnitude of the variable to be expected in a given recurrence interval or return period (Chow,1951; McGuinness and Brakensiek,1964). The most commonly used distributions in hydrologic frequency analysis are the normal, extreme - value, and the log-normal distributions.

The best known of the frequency distributions is the normal distribution.

The normal frequency curve is bell-shaped and symmetrical about the mean. Special graph paper has been developed on which the normal distribution curve will plot as a straight line. This method has the advantage that different sets of data can be easily compared, and if justified, the line can be readily extended beyond the range of data for making probability estimates for the future events. The procedure for fitting frequency distribution is similar to the log-normal distribution which will be explained later. For the data that are skewed, or not normally distributed, the data have the tendency to plot as a curve instead of as a straight line.

The extreme-value theory was first investigated by Fisher and Tippett, and applied to hydrologic data by Gumbel (1954). The mean of the set of data is calculated from

$$\bar{x} = \Sigma\, x_i/n \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad [1]$$

and the standard deviation is calculated from

$$s = 1.067\ \Sigma\ (x_i-\bar{x})^2\ /\ \Sigma\ x_i\ K_y \quad \ldots\ldots\ldots\ldots \quad [2]$$

where n is the number of events, K_y is the frequency factor of Y or standardized normal deviate which is normally-distributed. The frequency factor K_y will be explained in more detail under the log-normal distribution. The data is then plotted on extreme-value probability paper. The procedure for fitting the distribution is similar to the log-normal distribution.

Most statistical data in hydrology form an extremely skewed frequency distribution, but their logarithms are nearly normally distributed. The distribution of such data is a logarithmico-normal or log-normal distribution (Chow,1954). The theoretical values for the normal, extreme value, and log-normal distributions are calculated from the general formula:

$$x_c = \bar{x} + s\,K_y \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad [3]$$

For the log-normal distribution, $\log_{10}x$ is used instead of x. The standard deviation (s) for normal and log-normal distribution is estimated from:

$$s = \Sigma\,(x_i-\bar{x})^2 / \,\Sigma\, x_i K_y \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad [4]$$

where $\log_{10}x_i$ is used instead of x_i for the log-normal distribution. The frequency factor K_y, read from a table, corresponds to the size of the sample or the number of years of data (n). The frequency factor K_y in this method depends not only on the probability (P), or return period (T), but also upon the coefficient of variation (c_v), and the coefficient of skewness (c_s). Computation of K_y for given c_v and c_s is mathematically complicated, and for simplicity of calculation, a normal probability function table has been prepared (Chow,1954; McGuinness and Brakensiek,1964). The K_y factors in the table were obtained by an approximate procedure, and are used as a means of drawing smooth curves, and do not replace, but are used as aid to, the purely graphical procedure (Chow,1954). The smoothing procedure has the advantage that it makes interpolation possible, and that it levels off random variations, to a certain extent. It has the disadvantage that it may suggest an accuracy for prediction that does not exist (Stol,1973).

The earliest uses of frequency methods were with data of floods and annual runoff. However, the methods can be used for a great variety of data, including all hydrologic and weather variables (USDA-SCS,1966).

Regression and Correlation

Correlation is the process of determining the manner in which the changes in one or more independent variables affect another (dependent) variable. The dependent variable is the value sought, and is to be related to various independent variables, which will be known in advance, and which will be physically related to the dependent variable. The function relating the variables is termed the regression equation. The proportion of the variance of the dependent variable that is explained by the regression equation is termed the coefficient of determination, which is the square of the correlation coefficient (Beard,1962; Huntsberger and Billingsley,1975).

To use a regression analysis, we must assume or know the functional form of the relationship between the variables. This is expressed in the form of a mathematical function, in which Y, the dependent variable, is set equal to some expressions which depend only on X, the independent variable, and on certain constants or parameters (Beard,1962; Huntsberger and Billingsley, 1975). One of the methods to arrive at the desired functional form is by studying scatter diagrams, obtained by plotting the pairs of values of X and Y as points in a plane, where Y is measured along the vertical axis and X along the horizontal axis. After the points have been plotted, observation of the diagram may reveal a pattern to the points that indicates what functional form may be used for the purpose of the analysis.

Because of sampling variations, the observed values or points will not all lie on the line, but will be scattered to some degree about the line. The regression line is the line that joins the means of the distributions corresponding to all possible values of X. Regression equations, the function relating the variables, can be linear or curvilinear, but linear regression suffices for most applications (Beard,1962).

In a simple correlation, the process of determining the manner in which the changes in one independent variable affect the dependent variable, the linear regression equation can be written as:

$$Y = A + B\ X \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad [5]$$

where Y is the dependent variable, X is the independent variable, A is the regression constant or the point of intercept in Y axis, and B is the regression coefficient or the slope of the regression line.

The correlation coefficient R is the square root of the coefficient of determination R^2, which is the proportion of the variance of the dependent variable that is explained by the regression equation. A positive correlation means that as one variable increases, the other increases. A negative correlation means that as one variable decreases, the other increases, or vice versa. If the correlation coefficient is zero, the variables are uncorrelated and there is no linear association between them (Huntsberger and Billingsley,1975). In the case of simple correlation, the coefficient of determination can be obtained from the equation:

$$R^2 = (\Sigma\ x_i y_i)^2\ /\ \Sigma\ x_i^2\ \Sigma\ y_i^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad [6]$$

and the correlation coefficient R is the square root of R^2.

A correlation coefficient of 1.0 would correspond to a coefficient of determination of 1.0, which is the highest theoretically possible, and indicates whenever the values of the independent variables are known exactly, the corresponding value of the dependent variables can be calculated exactly (Beard,1962).

If we assumed that the watershed conditions are the same during the periods of records, the regression line can be used to estimate runoff from rainfall, since there is a relationship between rainfall and runoff (Stol, 1973).

Temperature, Humidity, and Wind

Weather conditions have an important role in agricultural production. The estimated annual crop yield losses due to various weather conditions are summarized in Table 1. Although some of the disadvantages of weather conditions can be reduced with modern technology (heavy nitrogen applications, herbicides, pesticides, denser plant population, etc.), the role of the weather conditions still cannot be neglected (Changnon,1974).

Meteorological variables are purely physical variables which apply only to weather. To use them in non-meteorological applications, a means of conversion to the applied variable must be provided so that the climatological prediction can be transformed to the applied variable (Trent,1970). The farmer is concerned with the relationship problem, because tillage, planting, cultivating, harvesting, and in some cases, the processing of crops are influenced or controlled by the climate and the weather.

The climate and day-to-day weather are factors to consider in all outdoor activities, including those in agriculture, construction, and forestry. Man, machinery, livestock, crops, and structures are all affected by thermal extremes and their persistence (Trent,1970). Relative humidity is the amount of moisture in the air as compared with the greatest amount that the air could contain at the same temperature, expressed as percentage.

Wind is an important geological agent influencing soil erosion. It detaches, transports, deposits, and mixes soils, and is a factor in soil formation as well as soil erosion (Beasley,1976). Wind can also make the rain gage reading uncertain, by the deformation effect with respect to the rain gage itself. The effect is because wind reduces the amount of rain caught in the receiver by blowing the rain drops upward over the edge of the receiver (Stol,1973).

Table 1

Annual Estimated Crop Yield Losses Due to Various Weather Conditions in the Five-State Corn Belt Area[a]

	Average Annual Losses (bu/ac)					
	Western Corn Belt (Nebraska, Western Iowa)		Central Corn Belt (Eastern Iowa, Illinois)		Eastern Corn Belt (Indiana, Ohio)	
	Corn	Beans	Corn	Beans	Corn	Beans
Hail	3.50	2.36	1.88	1.38	1.25	0.88
Wind	3.67	1.01	3.88	0.94	3.79	1.19
Drought	7.30	2.67	5.40	2.72	8.74	3.67
Excessive Moisture	2.71	1.60	4.88	2.59	6.94	2.83
Excessive Heat	3.53	0.85	2.27	1.12	2.99	1.70
Excessive Coolness	0.30	0.33	1.47	0.37	1.51	0.73
Freeze or Frost	1.10	0.57	0.94	0.38	1.43	0.42
Total Loss	22.11	9.39	20.72	9.50	26.65	11.42
Total as Percent of Total Yield	38	32	28	31	36	38

[a] From Changnon (1974)

The rate of evaporation or transpiration increases with the rise in temperature as vapor pressure increases with increases in temperature. Wind also increases the rate of evaporation, particularly as it disperses the moist layer found directly over the evaporating water surface under stagnant conditions. As might be expected, from the decreased concentration of water molecules, which means lower humidity, evaporation increases with decreased barometric pressure (Schwab,1966).

Adequacy of the Length of Records

An observed frequency distribution of rainfall can be regarded as a sample of the frequency distribution of the rainfall that would occur in an infinitely long observation series or population. If the sample is representative of the population, one may expect that future observation periods will reveal a frequency distribution similar to the observed one. Hence, an observed frequency distribution may be used for recurrence predictions.

There is no general agreement among hydrologists and engineers as to the best method of frequency analysis for a given problem. No matter what method is used, the length of record available for the analysis affects the reliability of the final results. In hydrologic frequency analysis, it is assumed that the observed events represent true unbiased observations. The reliability of frequency analysis increases as the length of record increases. The length of record that is acceptable will depend on the return period that is of interest for design. Estimation of an event with a recurrence interval much greater than the period of record involves uncertainties that may cause considerable error. A period of record of 20 years usually produces a good approximation for practical purposes in design of many water control structures (Chow,1953).

Practice has been to assume that whatever frequency distribution was used, was suitable for the purpose at hand. However, frequency lines may vary considerably from sample to sample at the same station, or as sample size increases. We need some criterion by which we can judge when we have enough data for a frequency line that will remain relatively stable. This criterion is usually based on a statistical level of significance (Mockus, 1960). Where time trends exist in the data, we may confine the data selection to some definite period in order to improve short-term predictions.

It is a basic law of statistics that conclusions drawn for the population on grounds of a sample will be increasingly reliable as the size, or in this case, the length of records of the sample increases (Stol,1973).

One method to estimate whether the sample or the length of records is adequate is by calculating the minimum acceptable years of record for a given level of significance by the method of moments (Hersfield,1961). The formula, according to Schwab (1966), is:

$$Y = (4.30\ t\ \log_{10}R)^2 + 6 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad [7]$$

where Y is the minimum acceptable years of record, t is the student's statistical value at the known level of significance with (N-6) degrees of freedom, N is the total number of events in years, and R is the ratio of the magnitude of the 100-year event to the 2-year event.

The value of the 2-year event is a measure of the first moment, the central tendency of the distribution. The relationship of the 100-year to the 2-year events is a measure of the second moment, the dispersion of the distribution. These two parameters are used in conjunction with the return period diagram of the magnitude versus return period for estimating values for other return periods (Hersfield,1961).

A 10 percent level of significance is used for the criterion, which is about as high a level as can be used with hydrologic data. The significance may be interpreted as meaning that nine times out of ten, on the average, the test will be adequately representative of the long-term line (Mockus, 1960). A line failing to pass the test is either abandoned or additional data are estimated and added using data from nearby stations in making the estimates.

DATA BASE

Allerton Watersheds

The Allerton watersheds consist of four small agricultural watersheds, designated as watersheds A-1, B-1, W-1, and W-2. Watersheds A-1 and B-1 (82 acres and 45.5 acres, respectively) are located on agricultural land where the land use system consisted chiefly of a C-O-M-M rotation until 1959. Watershed W-2 (63 acres), located above Tomahawk Pond, was kept in permanent grass and legume mixture until 1959. Since 1959, most of these watersheds have been in row crop production. Watershed W-1 (390 acres) contains the first two smaller watersheds in addition to land under permanent grass and woodland cover.

Watershed A-1 has 3 soil types, with Flanagan silt loam soil the dominant one. The slopes consist of three classes, with 0-1.5% and 1.5-4% classes the dominant ones. This watershed has multiple flow patterns.

Watershed B-1 has 4 soil types, with Flanagan silt loam and Drummer silty clay loam soils the dominant ones. The slopes consist of two classes, with 0-1.5% class the dominant one. The watershed has a single flow pattern.

Watershed W-1 includes watersheds A-1 and B-1. It has 5 soil types, with Sunbury silt loam and Drummer silty clay loam soils the dominant ones. The watershed is rather compact, but with multiple flow patterns.

Watershed W-2 has 5 soil types, with Sunbury silt loam and Catlin silt loam soils the dominant ones. The watershed is compact, with a simple flow pattern.

Instruments have been installed in the watersheds since 1949 for regular measurements. The instruments consist of six recording rain gages, four standard rain gages, four runoff stage recording gages, a hygrothermograph for measuring temperature and humidity, and an anemometer. The location of the instruments in the watersheds is shown in Figure 1.

Rainfall Data

The data consist of monthly and annual total rainfall, and annual maximum intensities for various durations. The data were obtained from six recording rain gages, two of which are installed the year-round, and the other four which collect growing season data.

The rain gages were Friez Single Traverse Recording Rain and Snow Gages until the early 1970's. New Bendix Reversing Traverse Gages were installed at that time. The charts used on these rain gages are mostly 12-hour charts with one gage having a 7-day chart. The charts are normally changed at weekly intervals. For simplicity, a rain gage will be designated as RG.

Operation of RG-1 and RG-5 have been continuous since July and August 1949, respectively. Operation of RG-2 was for the period of April 1 to November 1 each year from 1949 to 1953. The operation was discontinued in June 1956 after the records were fragmentary from April 1956. The operation of RG-3, RG-4, and RG-6 began in August 1949, for the period of April 1 to November 1 each year. This period is considered as growing season or summer months data. In July 1965, RG-7 was installed, and in operation for the summer months period. The location of RG-7 is about 2,200 feet north of RG-3.

The basic data were rain gage charts that were transcribed to computer punch cards. These data were reduced and accumulated using a computer program (Mitchell,1965) to obtain monthly total rainfall (in inches), and maximum rainfall intensities (in inches per hour). The durations for the rainfall intensities are 2, 5, 10, 15, 20, 30, 60, 120, 240, 360, and 720 minutes.

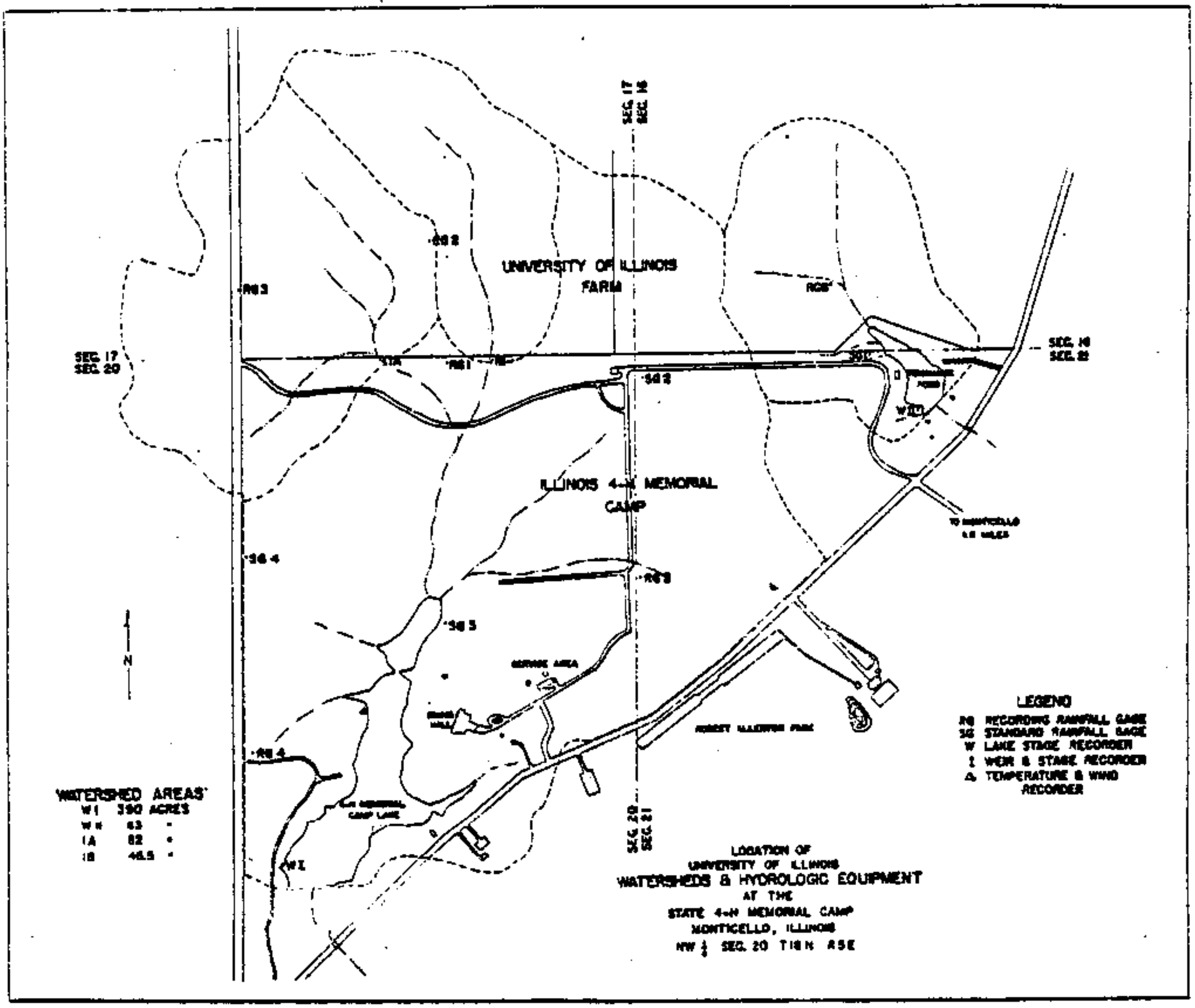

Figure 1. Location of the Allerton Watersheds and the Hydrologic Equipment

RG-1 and RG-5 provide year-round data, while the others are used to collect summer months rainfall data. The data from RG-2 and RG-7 are excluded since they are very short records (4 years, and 7 years of records, respectively).

The rainfall data from the individual rain gages were converted to area rainfall by means of Thiessen weighted averages using a watershed composite program (Mitchell,1968). The Thiessen method assumes that the recorded rainfall at a station is representative of the area half-way to the adjacent stations. Each station is therefore connected with its adjacent stations by straight lines, the perpendicular bisectors of which form a pattern of polygons. The area which each station is taken to represent is the area of its polygon, and this area is used as a weight factor for its rainfall. The sum of the products of station areas and rainfalls is divided by the total area covered by all stations to get the weighted average rainfall. The area average rainfall is computed as:

$$\bar{P} = \frac{A_1P_1 + A_2P_2 + A_3P_3 + \ldots\ldots + A_nP_n}{A_1 + A_2 + A_3 + \ldots. + A_n} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad [8]$$

where A is the station area, and P is the individual rainfall in that area. The program by Mitchell (1968) accumulates rainfall using the Thiessen method for each time increment. The individual rain gage data used with the program provided rainfall accumulations and maximum rainfall intensities for each of the four watersheds.

Runoff Data

The runoff data were from the four watersheds. It consists of monthly and maximum runoff depth for various durations, and maximum exceedance depth for various durations.

The runoff recording stage gages for measuring runoff from watershed A-1 and watershed B-1 were V-notch weirs, stilling wells, and recorders, which continuously monitor the runoff flows from the watersheds. The weirs are 16-inch broad crested, triangular concrete weirs having 5:1 side slopes. Each weir is equipped with a Friez Water Level Recorder model FW-1, used with a six-hour chart. The recorders from watershed A-1 and watershed B-1 have been in continuous operation since August and September 1949, respectively.

The outlet structure for measuring runoff from watershed W-1 consists of a large modified two-level concrete drop-inlet spillway. The lower level outlet has two triangular sharp edge weirs to provide accurate low flow calibrations. The upper level has a six by six foot pipe drop-inlet for flow at high stage. The structure has been in continuous operation since December 1951, but the data are mostly for the period of April 1 to September 1, each year.

The structure for measuring runoff from watershed W-2 is a tube-riser spillway. The structure has a 2-foot square concrete riser 10.8 feet high, and an 18-inch diameter concrete tube 49.6 feet long laid on a 1.03 percent slope.

The empirical equations for weir-flow control and pipe-flow control, respectively, were determined by Replogle _et al_ (1961) to be:

$$Q = 3.5 \; L \; H^{1.57} \quad \ldots\ldots \quad [9]$$

and

$$Q = 8.12 \; (h + 10.65)^{0.54} \quad \ldots\ldots \quad [10]$$

The structure has been in continuous operation since April 1950.

The basic runoff data were stage recorder charts that were transcribed to computer punch cards. These data were reduced and accumulated using a computer program (Woolhiser and Saxton,1965) to obtain total monthly and annual runoff, and maximum runoff depths for various durations. The runoff intensities were measured for durations of 1, 2, 6, 12, 24, 48, 72, 120, and 192 hours.

The monthly and annual runoff depth data are complete for watersheds A-1, B-1, and W-2. For watershed W-1, the data were for the summer months period, April 1 to August 31, each year. The length of records are 27 years for watersheds A-1, and B-1, 23 years for watershed W-1, and 24 years for watershed W-2.

Temperature, Humidity, and Wind

Temperature and relative humidity were measured using a Bendix Hygrothermograph Model 594 with a 7-day chart. The temperature unit consists of a Bourdon-type thermo-element filled with alcohol. The humidity measuring unit consists of a hygro-element (hair-element). The hair does not change uniformly at all percentages of humidity, and two cams are provided which change the non-linear action of the hair to the linear action of the pen. The basic temperature-humidity data were hygro-thermograph charts that were transcribed to computer punch cards. These data were reduced and accumulated using a computer program (Mitchell,1967) to obtain daily and monthly maximum, minimum, and average temperature and humidity. Urbana temperature and humidity data were used for those periods where the Allerton recorder malfunctioned.

The basic wind data and Urbana average wind data were transcribed to computer punch cards. These data were reduced and accumulated using a computer program (Mitchell,1967), that distributed the Allerton total wind distance in the same daily ratio as the Urbana daily average wind speed. Average daily, monthly, and annual wind speed, and monthly and annual maximum and minimum wind speed were determined. The wind speed was measured using a totalizing anemometer.

ANALYSES AND RESULTS

Rainfall

Procedure

The rainfall data analyzed consisted of monthly total rainfall depth, and maximum rainfall intensities for various durations. The data were from individual rain gages, and from each watershed.

The monthly total rainfall was divided into two different analyses according to the data sources, i.e. analysis for full-year data, and analysis for partial or summer-months data. The full-year data were from RG1, RG5, and from each watershed. The summer-months data were from RG3, RG4, RG6, in addition to data from RG1 and RG5. The basic data are presented in Appendix A, Tables A1 through A9. Urbana rainfall data are presented in Table A10.

The maximum rainfall intensities for various durations were from RG1, RG5, and from the four watersheds. The basic data are presented in Appendix A, Tables A11 through A16.

The analysis for the monthly total and rainfall intensities was made using the log-normal distribution described by McGuinness and Brakensiek (1964), which is summarized in Appendix B1. The plotting position used in the analysis is the method recommended by Chow (1953), using the Weibull formula:

$$T = (n + 1)/m \quad \text{...} \quad [11]$$

where T is the return period for the series in years, n is the number of years of record, and m is the rank of the data in decreasing order.

Computer programs were used in computing the descriptive statistics of the data, i.e. the logarithm-mean, and the standard deviation (s). The program list is presented in Appendix B2. The fitting equation is:

$$\log_{10}x = \overline{\log_{10}x} + sK_y \quad \text{[12]}$$

For drawing the lines of best fit, see the corresponding descriptive statistics for the data in Appendix B, Table B2, and the frequency factors K_y in Table B1.

Rainfall is measured at certain points. It is likely that the rainfall in the vicinity of a point measurement is approximately the same everywhere, but farther away from the point, this may not be true (Stol,1973). Since the data are from a number of individual rain gages, they were tested to determine if differences exist among those data. The purpose of the test is to determine whether the data from the gages can be combined or not.

The test may be made using the t-test for a selected level of significance. The procedure for a paired comparison test method is summarized in Appendix C1 and C2. If the calculated t falls in the rejection region R, we reject the null hypotheses that there is no difference in the two sets of data, in favor of the alternative hypotheses that the data are statistically different, and vice versa. Depending on the level of significance selected, the difference can be significant or highly significant (for 5% and 1% level of significance, respectively). If statistically there is no difference, the data can then be combined. If there is any difference, the data should be treated separately or individually.

<u>Results and Discussion</u>

RG-1 and RG-5 provided year-round data, both for monthly and annual total rainfall (Appendix A, Tables A1 and A2), and rainfall intensities for various durations (Appendix A, Tables A11 and A12). RG-3, RG-4, and RG-6 provided monthly total rainfall for the growing season April to October (Appendix A, Tables A3, A4, and A5). The calculated descriptive statistics for the monthly and annual total rainfall for the rain gages are presented in Appendix B, Table B2. Using the step by step procedure for fitting the log-normal frequency distribution (Appendix B1), the log-probability curves for the above data were constructed (Appendix D, Figures D1 through D5).

The curves show that they are similar in many respects for each corresponding month, but they do not have a specific pattern from month to month.

The test for differences among the above data reveals that statistically there is no difference between RG-1 and RG-5 data, for monthly and annual total rainfall. Testing RG-1 to Urbana data, and RG-5 to Urbana data, the results indicated that the data are significantly or highly significantly different (Appendix C, Table C1). These differences are probably caused by the difference in locality. Also, the Urbana weather condition is affected by urban activities while Allerton watersheds are not.

Since RG-1 and RG-5 monthly and annual total rainfall data are statistically the same, the data can be combined. The combined log-probability curves for the non-growing season monthly total rainfall, and annual rainfall are presented in Figure 2.

The tests for differences among the summer months data from RG-1, RG-3, RG-4, RG-5, and RG-6 reveal that statistically there are no differences (Appendix C, Table C2). Thus, the data from these rain gages for monthly total summer months can be combined. The descriptive statistics for the combined data are presented in Appendix B, Table B2, and the combined log-probability curves are presented in Figure 3.

For most of the data, the monthly total rainfall for January and December have zero values in their series. Since the logarithm of zero is undefined, the log-normal distribution method of analysis does not apply for these months. The January and December data were excluded for the analysis of monthly total rainfall.

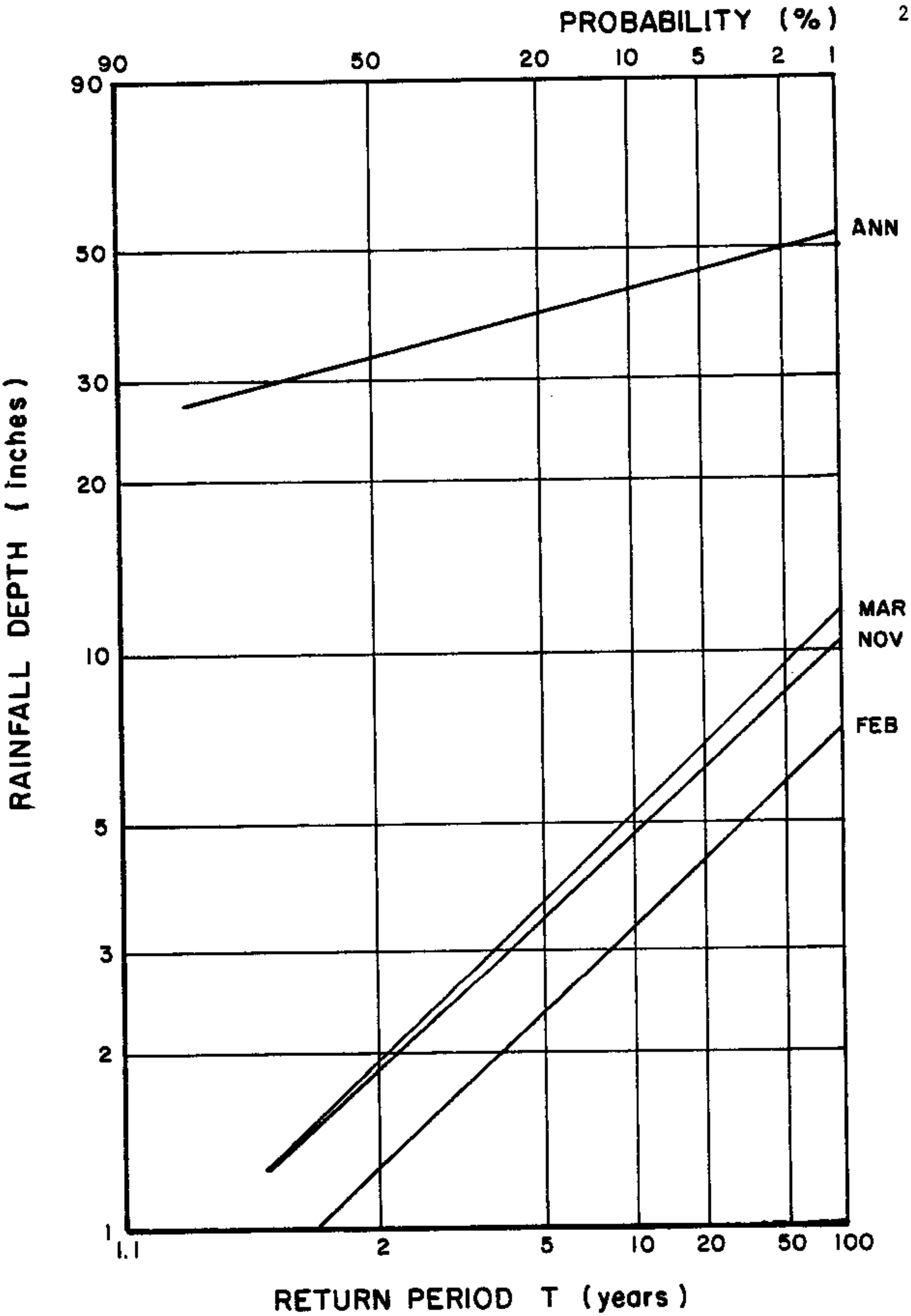

Figure 2. Log-Probability for Monthly and Annual Total Rainfall, Average of RG-1 and RG-5, Non-Growing Season

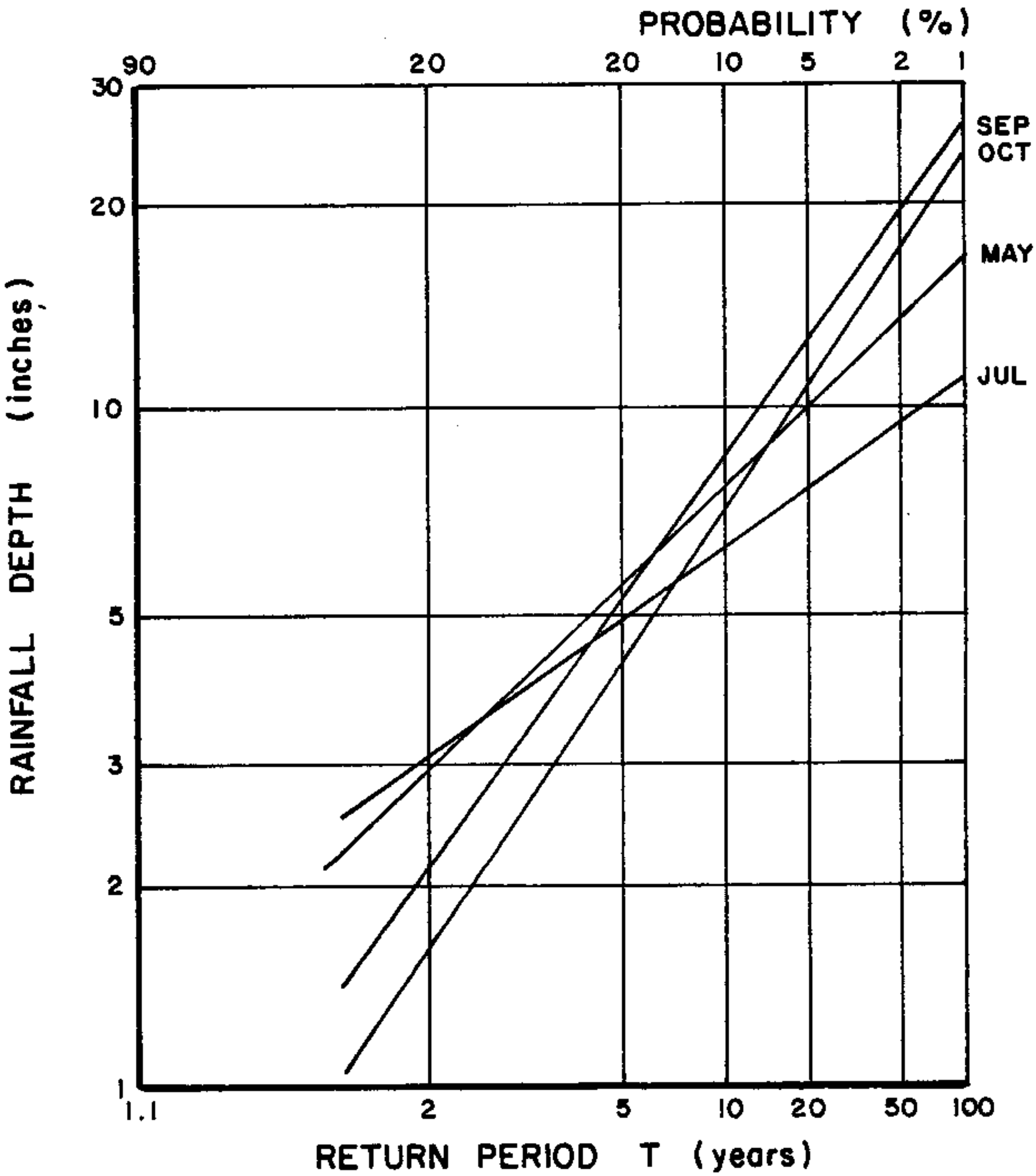

Figure 3. Log-Probability for Monthly Total Rainfall, Average Rain Gages, Growing Season

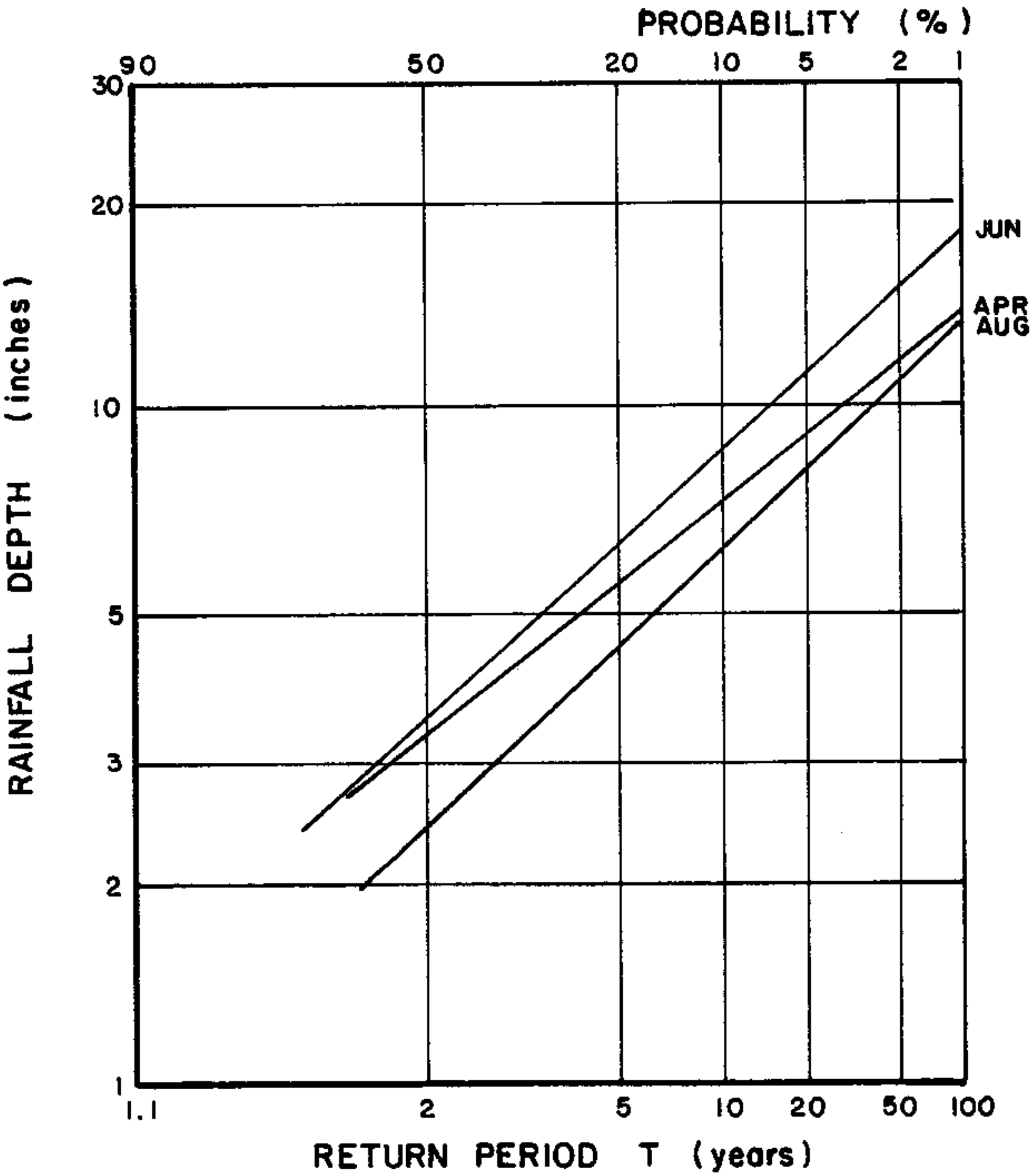

Figure 3. (continued)

The descriptive statistics for the rainfall intensities for various durations are presented in Appendix B, Table B3. The constructed log-probability curves for RG-1 and RG-5 are presented in Appendix D, Figures D6 and D7.

Testing the RG-1 and RG-5 data for rainfall intensities for various durations reveals that statistically there is no difference between the two sets of data (Appendix C, Table C4). Thus, RG-1 and RG-5 rainfall intensities data can be combined. The combined log-probability curves are presented in Appendix D, Figure D8, and the corresponding rainfall intensity-duration-frequency curves are presented in Figure 4.

A rainfall measurement is a point observation and may not a priori be representative of the area. Usually area rainfalls have a smaller variability than point rainfalls. For high return periods, this results in area rainfalls which are smaller than point rainfalls, and vice versa (Stol,1973). However, area rainfalls will differ less from point rainfalls if the duration is taken longer. Therefore, mean rainfalls taken over long periods will be approximately equal for points and for areas, if the area is homogeneous with respect to rainfall.

The Thiessen method which was used to develop watershed rainfall data, assumes that the recorded rainfall in a station is representative of the area halfway to the adjacent station. The Thiessen method can be used when the stations are not evenly distributed over the area, and is restricted in use to relatively flat areas, which applies to the Allerton watersheds.

The log-probability curves for monthly and annual total rainfall for each watershed were constructed using the descriptive statistics (Appendix B, Table B2), and are presented in Appendix D, Figures D9 through D12. Comparing the curves visually, the log-probability curves have the same pattern for

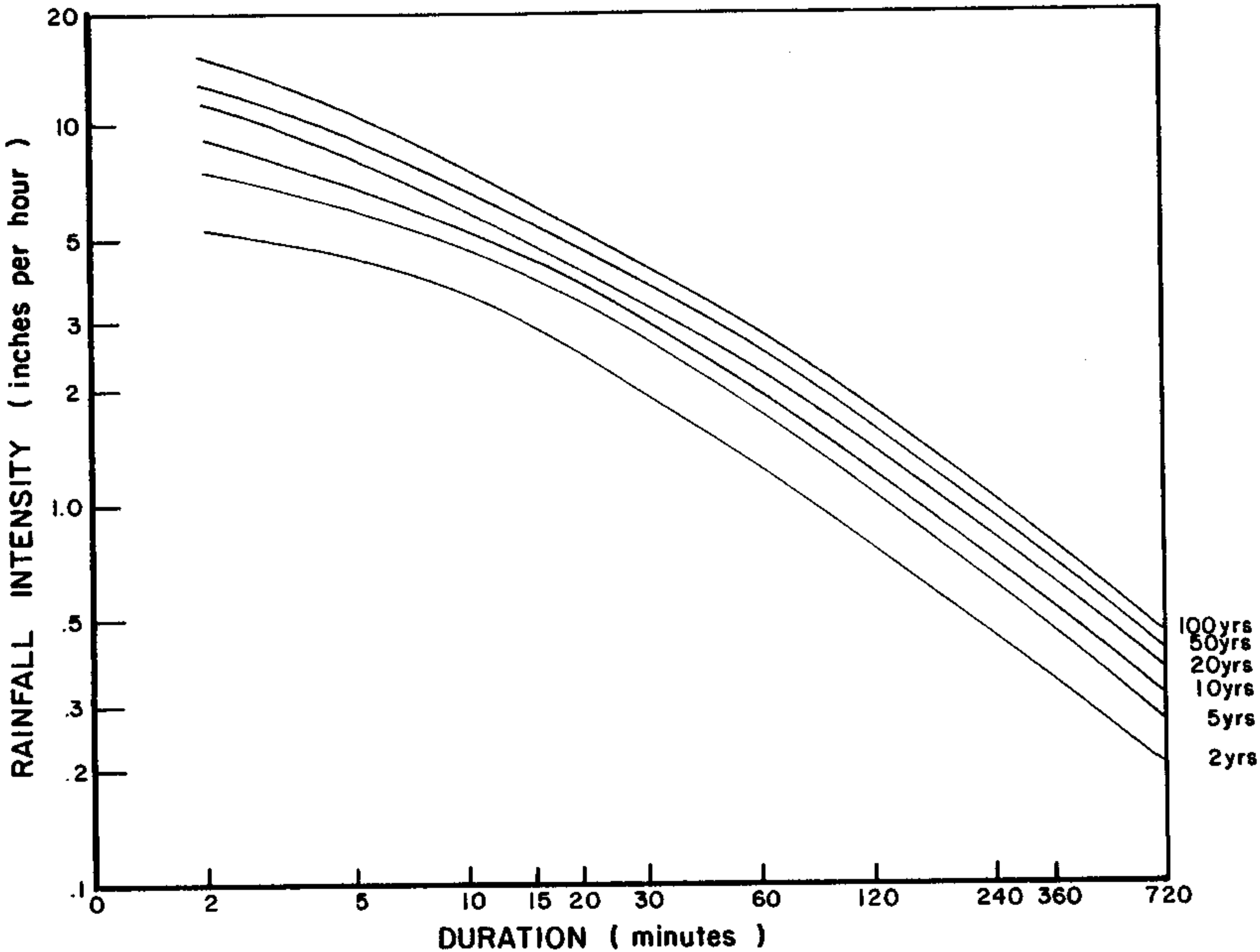

Figure 4. Rainfall Intensity-Duration-Frequency Curves for Various Return Periods, Average RG-1 and RG-5

each corresponding month, and the annual total rainfall.

Testing these monthly and annual total rainfall data from the four watersheds (Appendix C, Table C1) revealed that only 7 out of 78 tests data or about 9 percent are significantly or highly significantly different. It seems that involving the area in the weighted average by means of the Thiessen method does not enlarge the differences that already exist. Testing the RG-1 and RG-5 with each watershed (Appendix C, Table C3) reveal that only 17 out of 104 tests or about 16 percent are significantly or highly significantly different. The watersheds data are originally rain gage data converted to watershed data. From the previous tests among the rain gages, we know that there is statistically no difference. If we assume that we may accept a 16 percent difference, then we can say that the average of RG-1 and RG-5 for non-growing monthly and annual total rainfall (Figure 2), and average of RG-1, RG-3, RG-4, RG-5, and RG-6 for growing season monthly total rainfall (Figure 3) can be considered as representative of the monthly and annual total rainfall for the Allerton watersheds.

The descriptive statistics for rainfall intensities for each watershed are presented in Appendix B, Table B3. The constructed log-probability curves are presented in Appendix D, Figures D13 through D16. The corresponding rainfall intensity-duration-frequency curves are presented in Figures 5, 6, 7, and 8 for watersheds A-1, B-1, W-1, and W-2, respectively.

Testing the rainfall intensities data from the watersheds reveal that 34 out of 66 tests (Appendix C, Table C4) are significantly or highly significantly different. This indicates that the watersheds data for the rainfall intensities should be treated individually. The watersheds rainfall intensity data were originally rain gage data. Evidently, combining rain gage data by area and time increment enlarges the differences that already exist. Testing

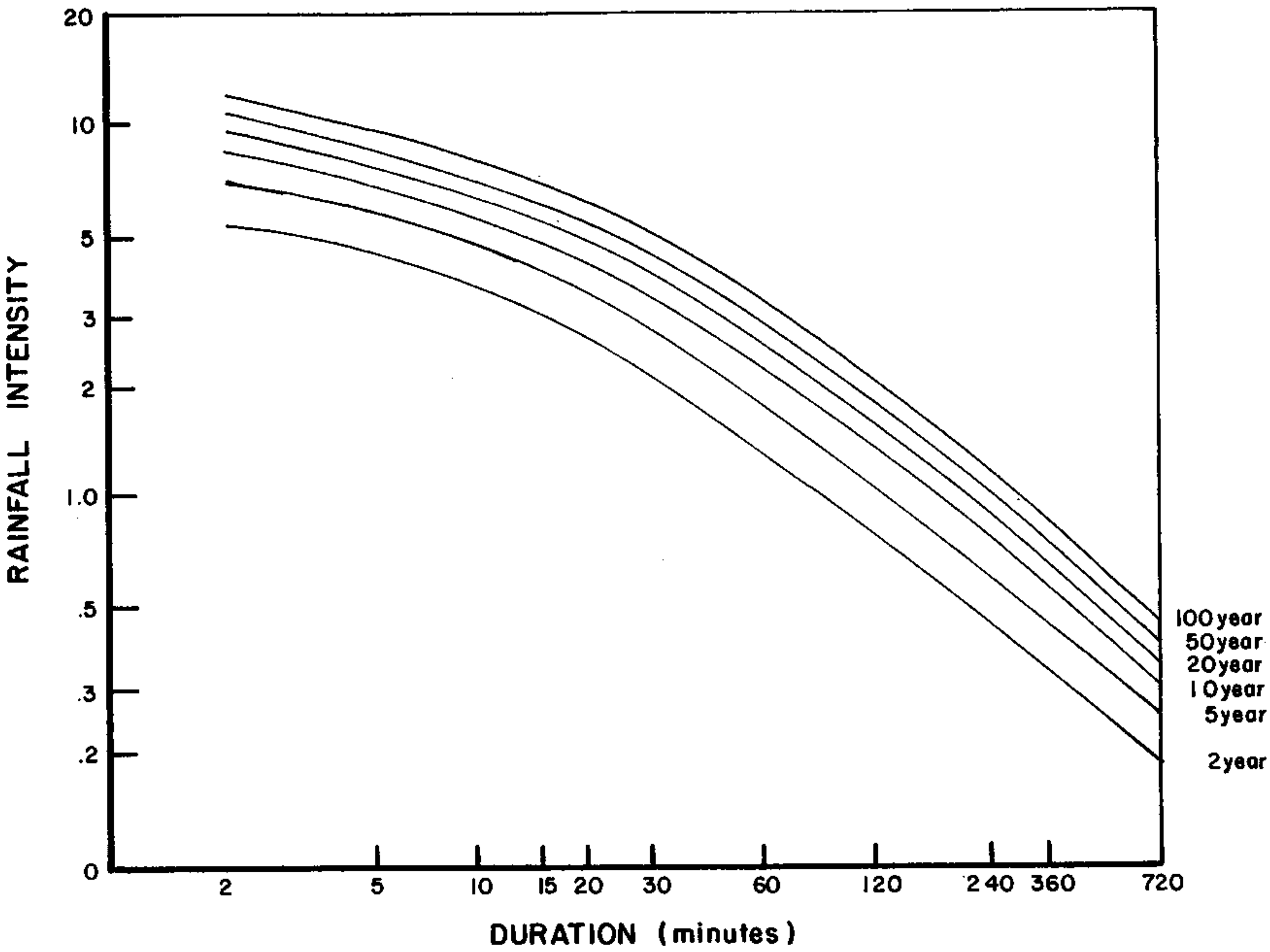

Figure 5. Rainfall Intensity-Duration-Frequency Curves for Various Return Periods, Watershed A-1

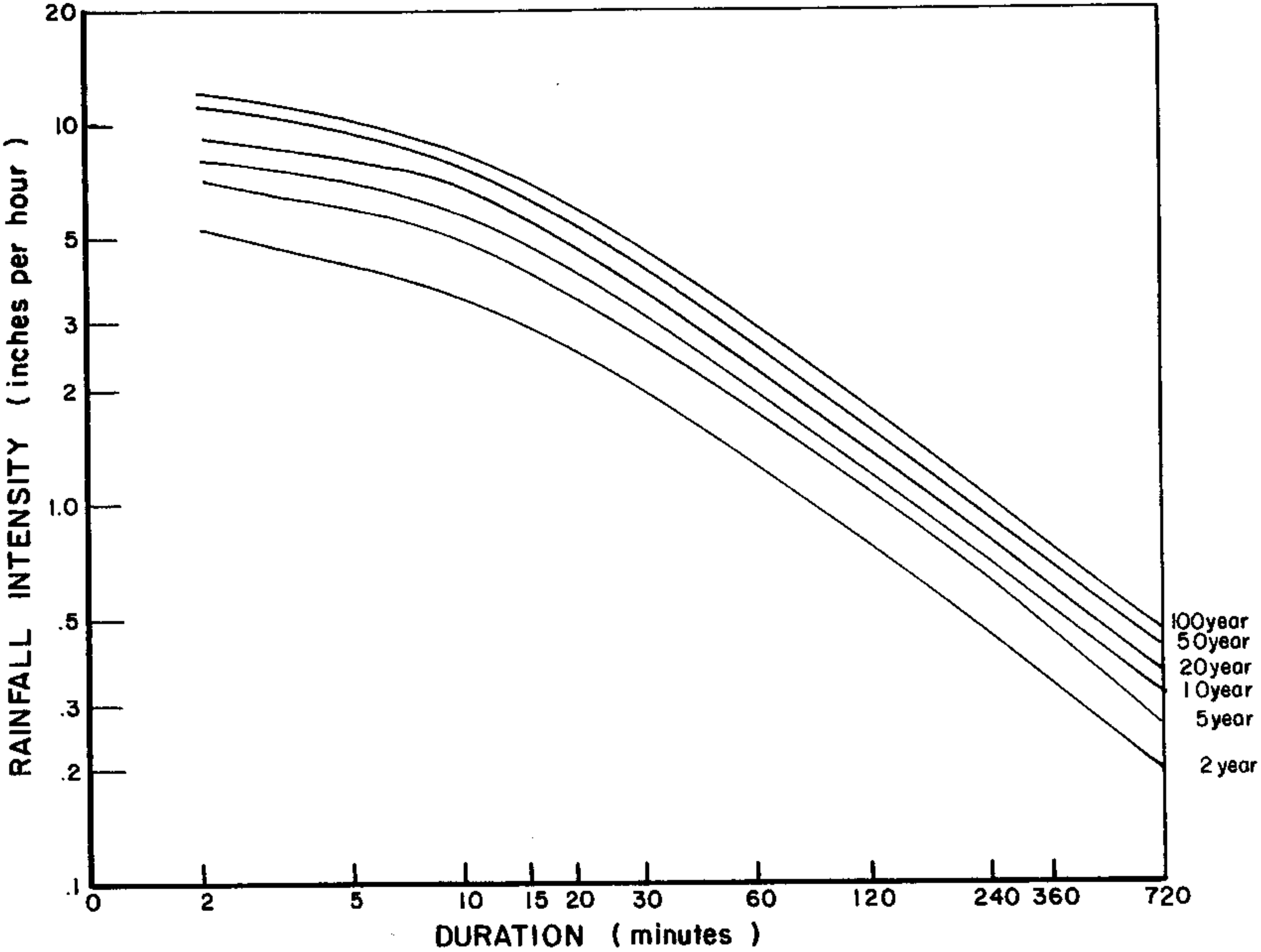

Figure 6. Rainfall Intensity-Duration-Frequency Curves for Various Return Periods, Watershed B-1

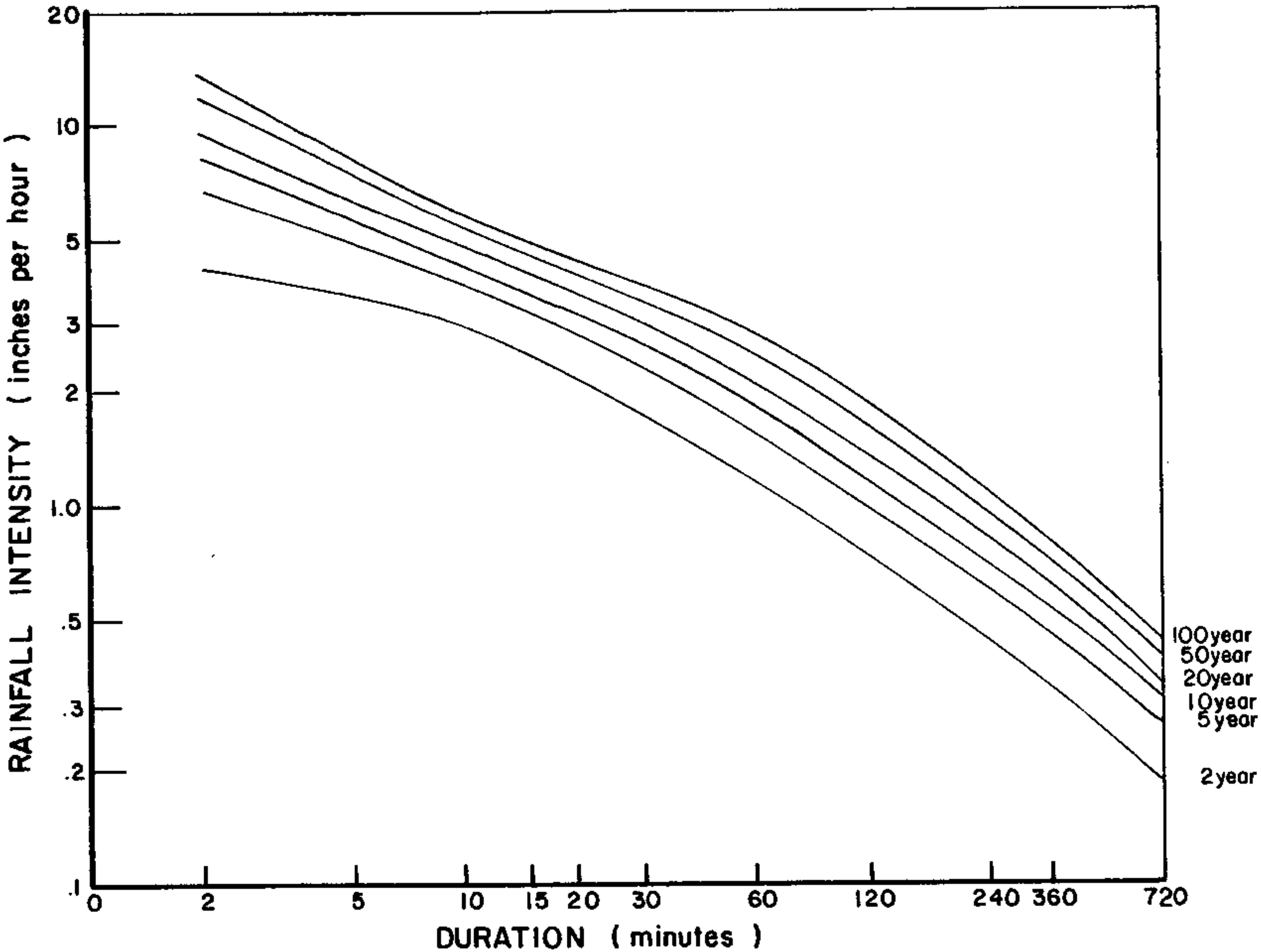

Figure 7. Rainfall Intensity-Duration-Frequency Curves for Various Return Periods, Watershed W-1

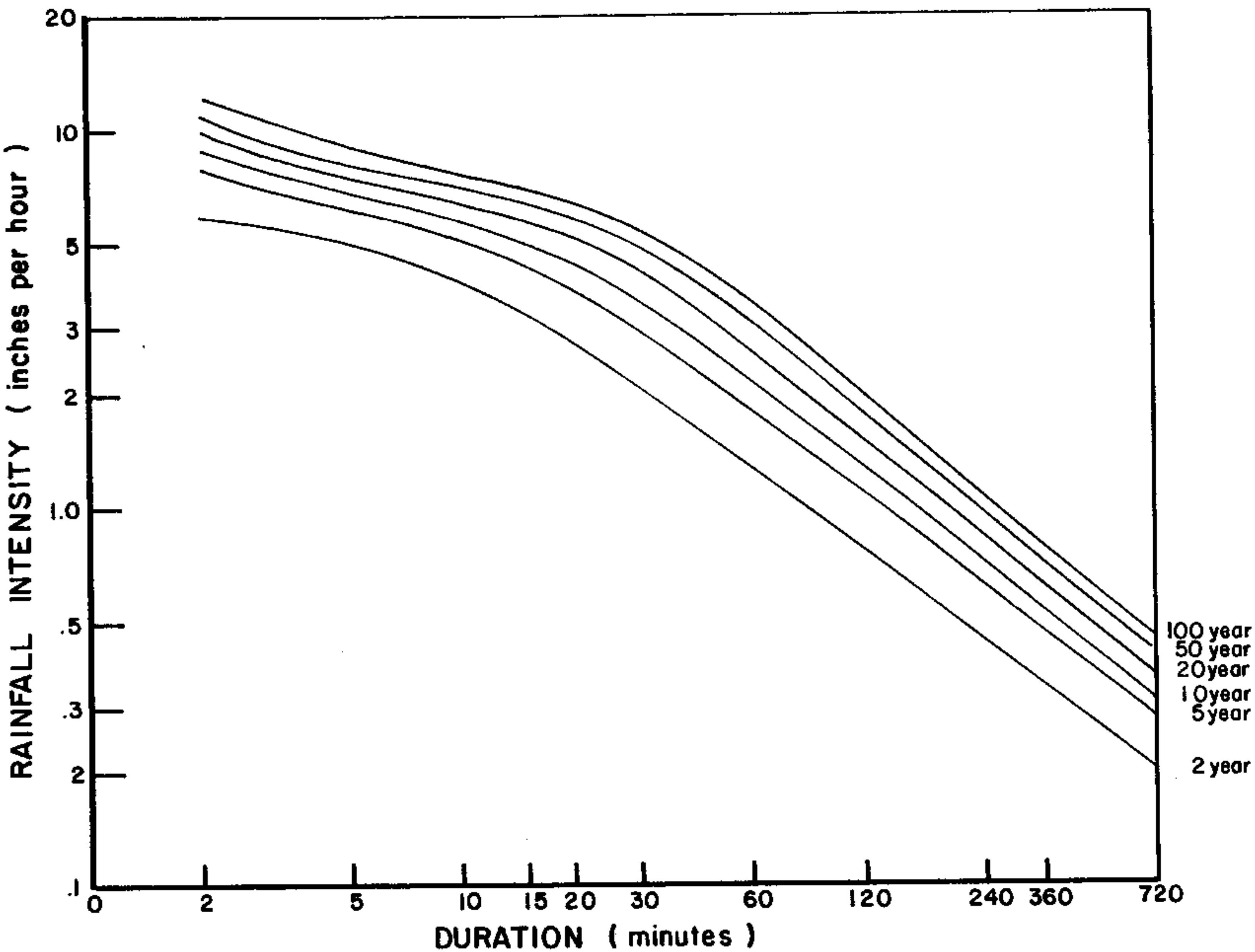

Figure 8. Rainfall Intensity-Duration-Frequency Curves for Various Return Periods, Watershed W-2

the RG-1 and RG-5 rainfall intensity with the watersheds data revealed that 25 out of 88 tests or about 28 percent are significantly or highly significantly different. The same reason for these differences applies.

From the rainfall intensity-duration-frequency curves for the watersheds, we can estimate that for watershed A-1, the 2-year event and 100-year event have the values of 5.4 and 13 inches per hour for 2-minute duration, respectively, and 1.9 and 4.4 inches per hour for 720-minute durations, respectively. For watershed B-1, these values are 5.2 and 12 inches per hour for 2-minute duration, and 1.9 and 4.6 inches per hour for 720-minute duration, respectively. For watershed W-1, these values are 4.2 and 14 inches per hour for 2-minute duration, and 1.8 and 4.5 inches per hour for 720-minute duration. For watershed W-2, these values are 6 and 12 inches per hour for 2-minute duration, and 1.9 and 4.6 inches per hour for 720-minute duration.

Runoff

Procedure

The data used in this study were the annual exceedance runoff depth for various durations. Many of the lower depths in the annual maximum series have values of practically zero (Appendix A, Tables A18 through A21). The data were from each watershed. These low values cause the standard deviations to be very high, making a frequency study using the annual maximum series for the runoff impractical. Thus, for the study, we used the annual exceedance data for durations from 1-hour to 192 hours (Appendix A, Tables A22 through A25).

The purpose of the study was to determine, within reasonable limits, the rates of runoff that can be expected during certain durations for various return periods. If a runoff depth-duration-frequency relationship can be reasonably defined, then the relationship may be used to select a runoff rate for the most critical duration period and design frequency (Kohnke,1961).

The procedure used is the same as that used in the rainfall studies, i.e. using the log-normal frequency distribution method described by McGuinness and Brakensiek (1964).

Results and Discussion

The basic data for the annual exceedance runoff for 1-hour to 192-hour durations are presented in Appendix A, Tables A22 through A25 for the four watersheds.

The descriptive statistics are presented in Appendix B, Table B4. The log-probability curves are presented in Appendix D, Figures D17 through D20. The corresponding runoff depth-frequency for various durations, where the depth is plotted against the durations for return periods from 2 to 100-years, are presented in Figures 9 through 12 for the four watersheds.

Examination of Figures 9 through 12 show that the results for the four watersheds are similar in many respects. For the durations of 1-hour and 192-hour, the runoff depths for the watersheds fall within a range of 0.15 to 0.23 inch, and 1.0 to 1.3 inches, respectively, for 2-year return period. For 100-year return period, the values for 1-hour and 192-hour durations are 0.8 to 1.2 inches, and 3.2 to 5.0 inches, respectively.

Although in general the results of the analysis are similar on the four watersheds, some differences exist. There are a number of possible reasons for this, including variations in soil, the type and extent of farming practices and vegetative cover, the degree to which topsoil has been removed by erosion, and other factors.

To know whether the differences are just chances or statistically different, the data were tested using the t-test. The tests (Appendix C,

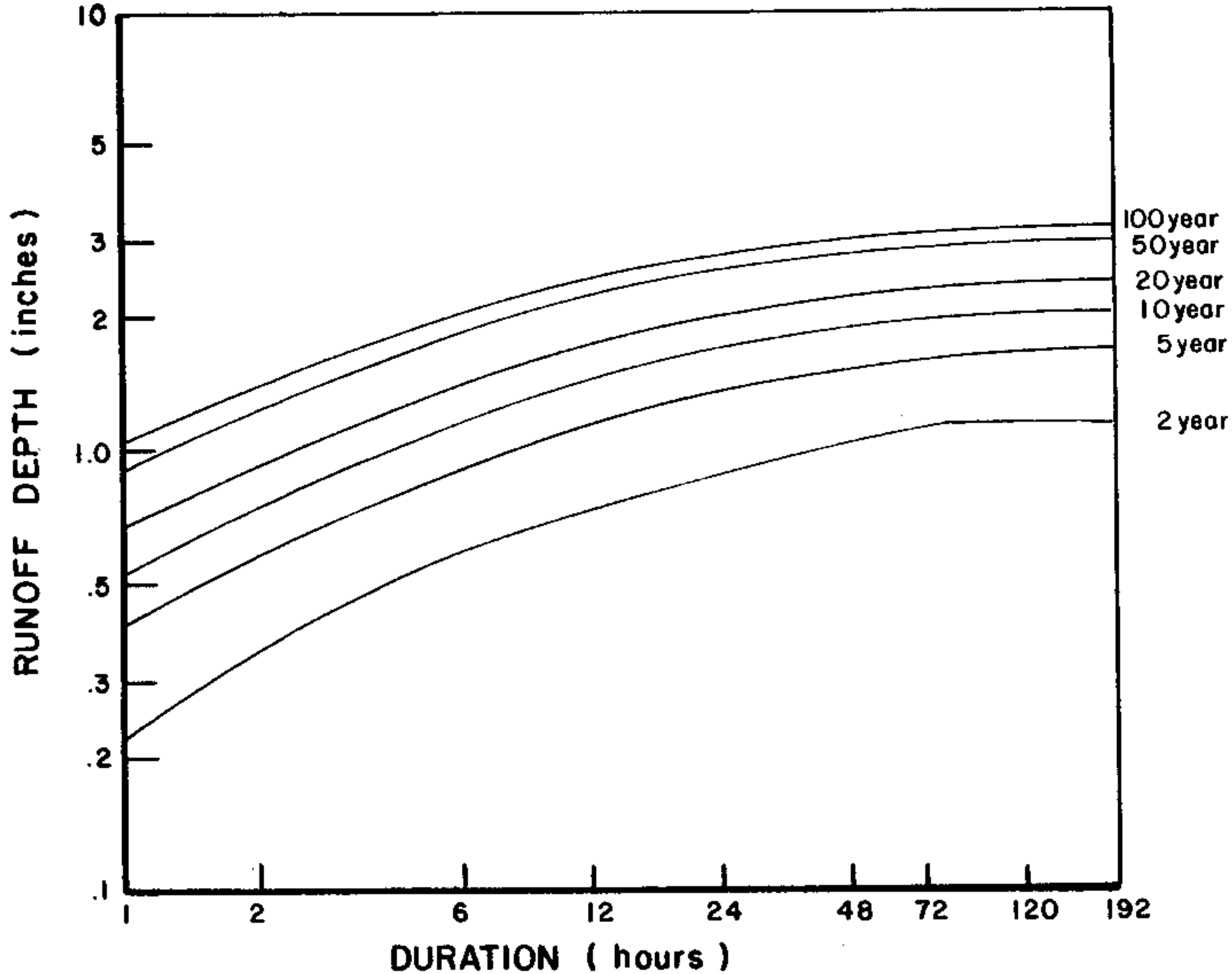

Figure 9. Runoff Depth-Duration-Frequency Curves for Various Return Periods, Watershed A-1

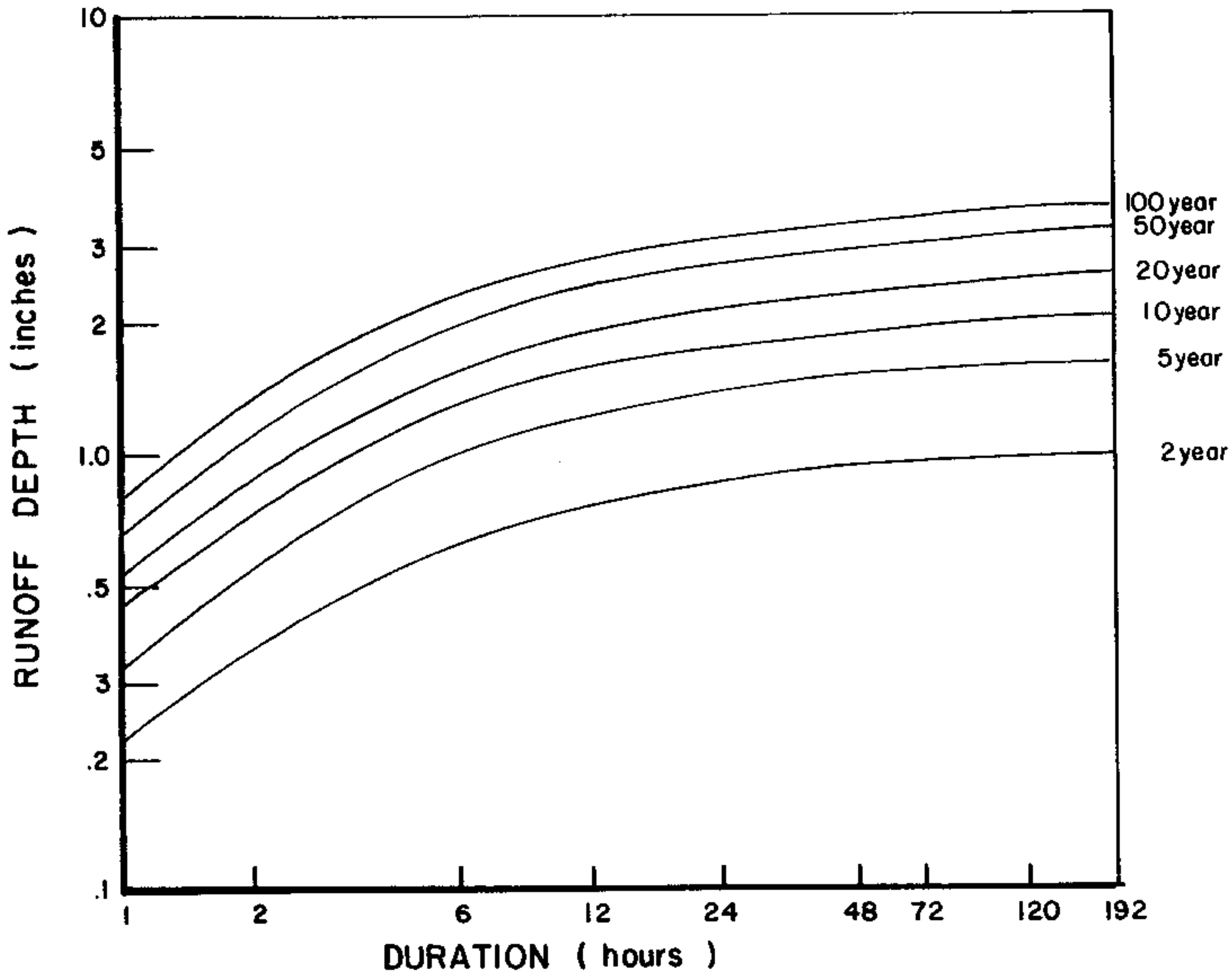

Figure 10. Runoff Depth-Duration-Frequency Curves for Various Return Periods, Watershed B-1

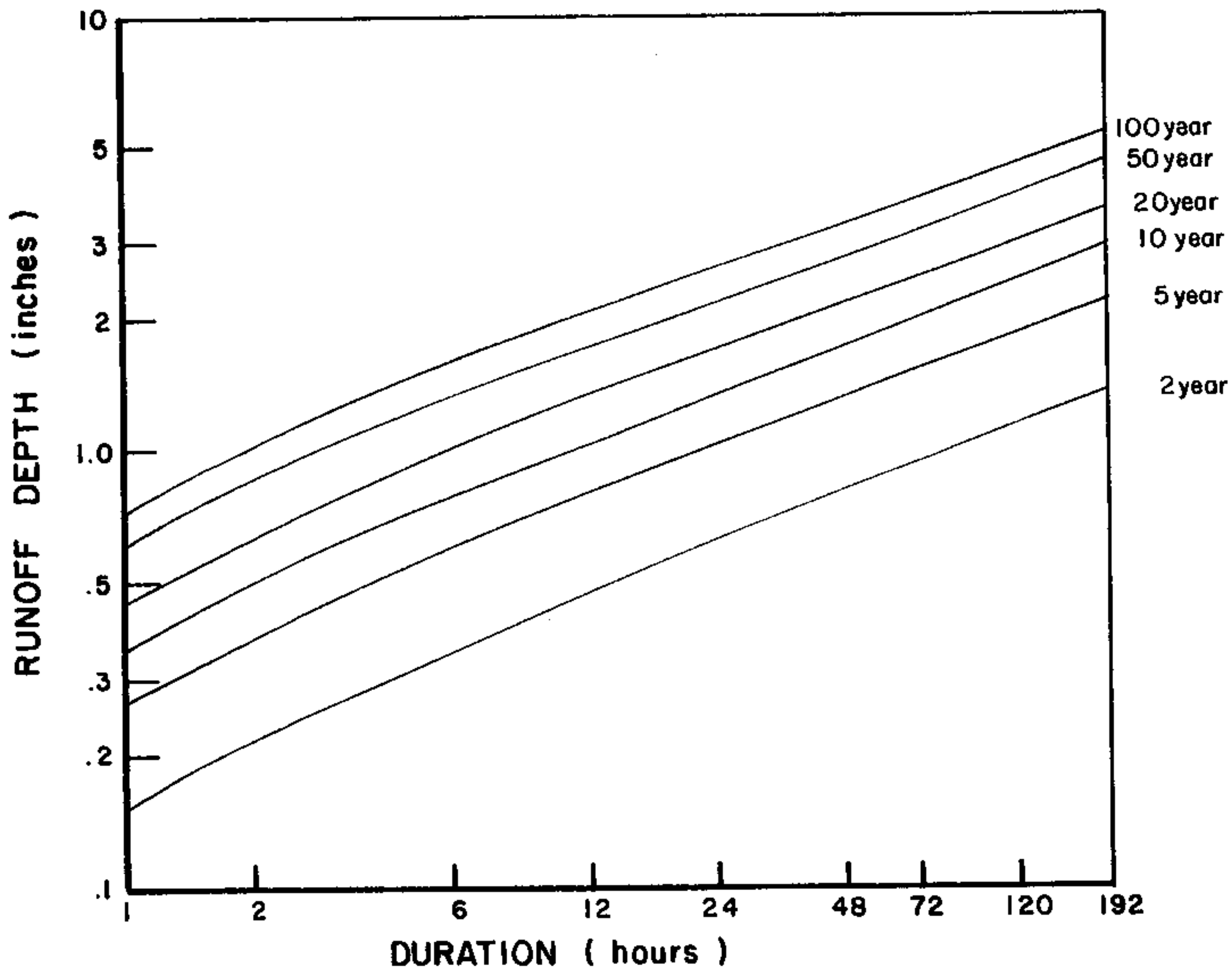

Figure 11. Runoff Depth-Duration-Frequency Curves for Various Return Periods, Watershed W-1 (summer months)

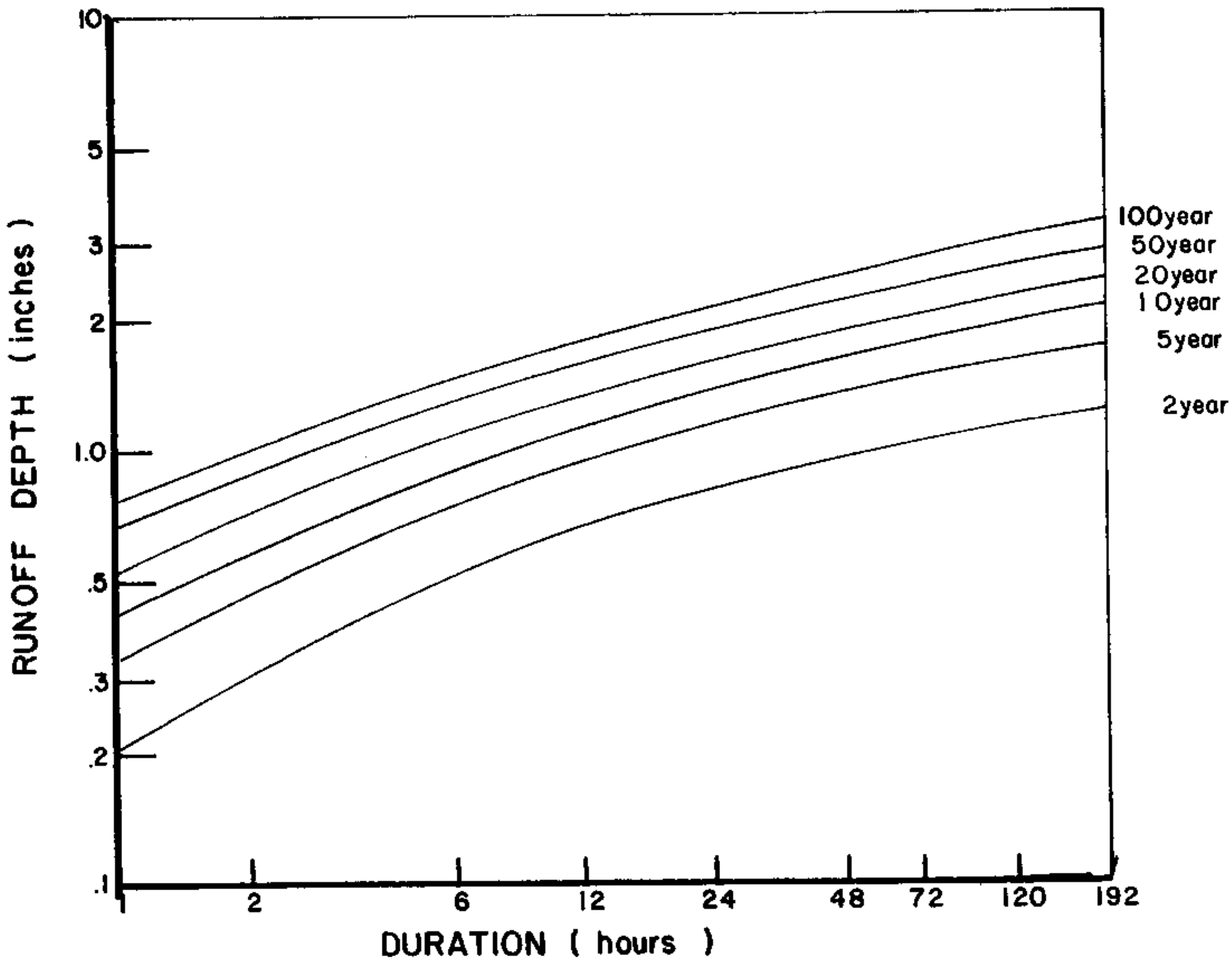

Figure 12. Runoff Depth-Duration-Frequency Curves for Various Return Periods, Watershed W-2

Table C5) shows that the basic data from the four watersheds are statistically different, for most of the durations. Thus, it is obvious that the runoff exceedances data should be treated individually for each watershed. Most of the differences are probably because each watershed has different dominant soil types.

The differences between watersheds A-1 and B-1 runoff are probably because of soils, topography, size and shape of the watersheds. Watershed A-1 has more slope classes than watershed B-1, but watershed A-1 has less soil types than watershed B-1. Also watershed A-1 has multiple patterns of flow, while watershed B-1 has a single pattern and is more compact.

The differences between watersheds A-1 and W-1 are probably because watershed A-1 is only a small part of watershed W-1, which contains both watersheds A-1 and B-1. Watershed W-1 runoff includes the accumulation of the tile flow from watersheds A-1 and B-1. The individual watershed has its own characteristics and agricultural practices. Similar reasons would apply to differences between watersheds B-1 and W-1.

The differences between watersheds A-1 and W-2 are probably because those two watersheds had different cropping practices from 1949 to 1959, although since 1959 they have similar cropping practices. Similar reasons would apply to differences between watersheds B-1 and W-2.

The differences between watersheds W-1 and W-2 are probably because watershed W-1 runoff includes the accumulation of tile flow from watersheds A-1 and B-1, while watershed W-2 is a single watershed with surface runoff.

As can be seen in Figures 9 to 12, and Appendix D, Figures D17 to D20, the curves for the longer durations (48-hour to 192-hour durations) are much higher for watershed W-1 than the other three watersheds. For watershed W-1, the curves show a stable rate of increase in depth with the increase in duration, while the other watersheds have a declining rate of increase in depth with an increase in duration.

Watershed A-1, B-1, and W-2 runoffs are surface flow which are much affected by the rainfall intensity and duration. With the decrease in intensity for longer durations, the surface runoff depths in these watersheds will decrease with longer durations. Watershed W-1 is a much larger watershed and hence a longer time of concentration. Also W-1 runoff has tile flow as well as surface runoff. The runoff depth is not directly affected by the decrease in rainfall intensity for longer durations.

Rainfall-Runoff Correlation

Procedure

The regression constant A, and regression coefficient B were calculated using the procedure in Appendix E1. These values were used to draw the lines of the best fit for each watershed. The correlation coefficient R, which is the square root of the coefficient of determination R^2, was also calculated as shown in Appendix E1.

There are two methods in testing the limits of the correlation coefficient R for rainfall-runoff relationships; the first method uses the confidence intervals for R, and the second uses three standard deviations of R on both sides of R (Snedecor,1956).

For the first method, the calculated R is compared with the R-table for (n-2) degrees of freedom for a certain level of significance. If the calculated R is higher, then we can infer that there is a linear relationship between the rainfall and runoff. If the calculated R is smaller, then we can infer that there is no relationship.

For the second method, the standard deviation of R is:

$$S_r = (1 - R^2)/\sqrt{n} \quad \text{[13]}$$

where S_r is the standard deviation of R, and n is the number of events. The limits are $(R \pm 3S_r)$. If both limits $(R - 3S_r)$ and $(R + 3S_r)$ are of the same sign as R, it is considered that R is statistically different from zero. If the limits have different signs, then R is not considered different from zero; in other words, there is no relationship between rainfall and runoff in that watershed (Chow,1964).

The simple linear regression analysis by the method of least squares used in this study was done by use of a computer program (Appendix E2). The basic data for annual total rainfall and runoff, and for summer months rainfall and runoff are presented in Appendix A, Tables A6 through A9 and Table A17.

Results and Discussion

The value of a rainfall-runoff relationship is to extend the length of runoff records from rainfall records. The varying watershed conditions that can exist with identical rainfall makes it logical to assume there cannot be a simple two-variable correlation between rainfall and runoff. The rainfall-runoff study conducted, assumed that the watershed conditions are the same during the period of record, and that the effects of some variables were neglected.

The simple linear regression analysis revealed that there is a linear relationship between the total annual rainfall and runoff for watersheds A-1, B-1, and W-2, and between the total summer-months rainfall and runoff for watershed W-1 (Appendix E, Table E1). The lines of the best fit for the relationship for each watershed with the corresponding descriptive statistics for each watershed are presented in Figures 13 to 16.

The correlation coefficient R for the four watersheds range from 0.5297

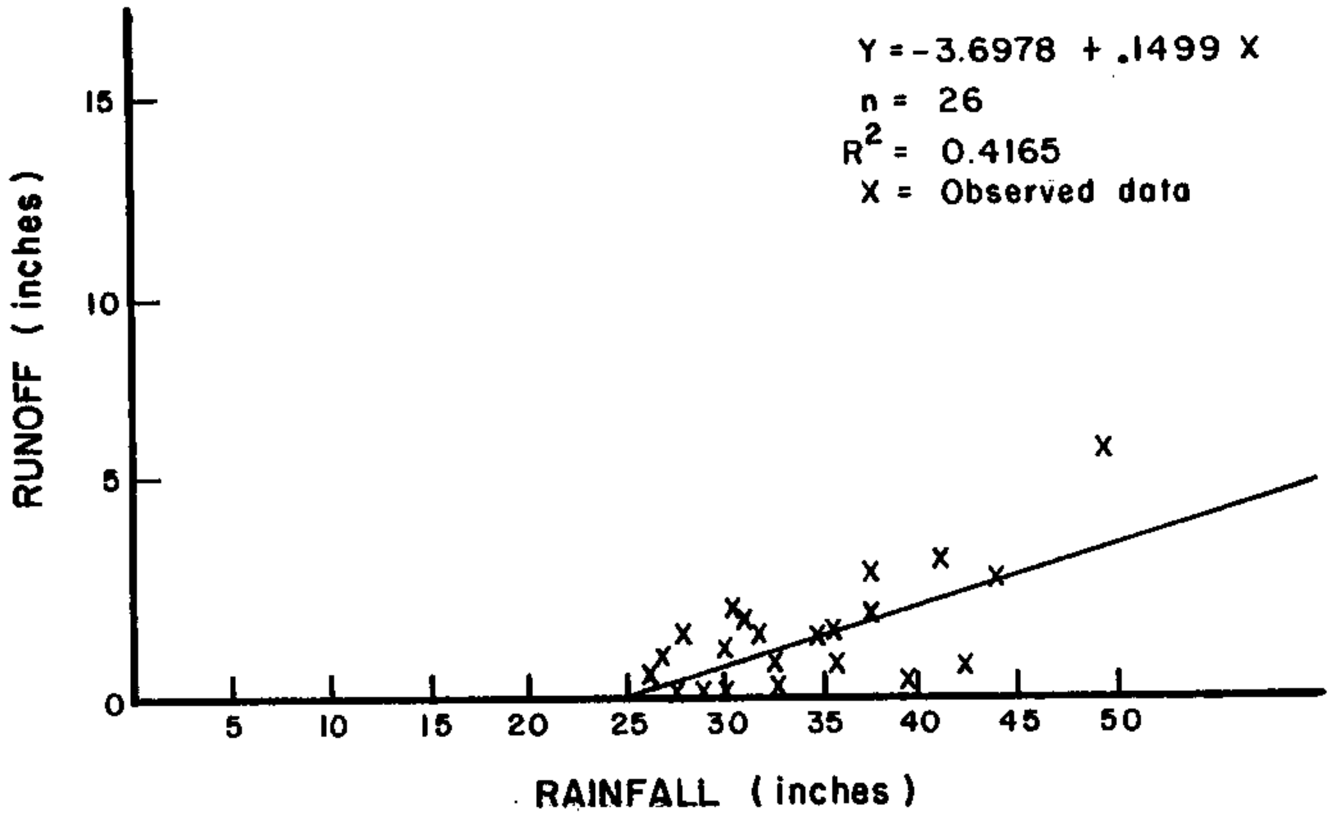

Figure 13. Annual Rainfall-Runoff Relationship, Watershed A-1

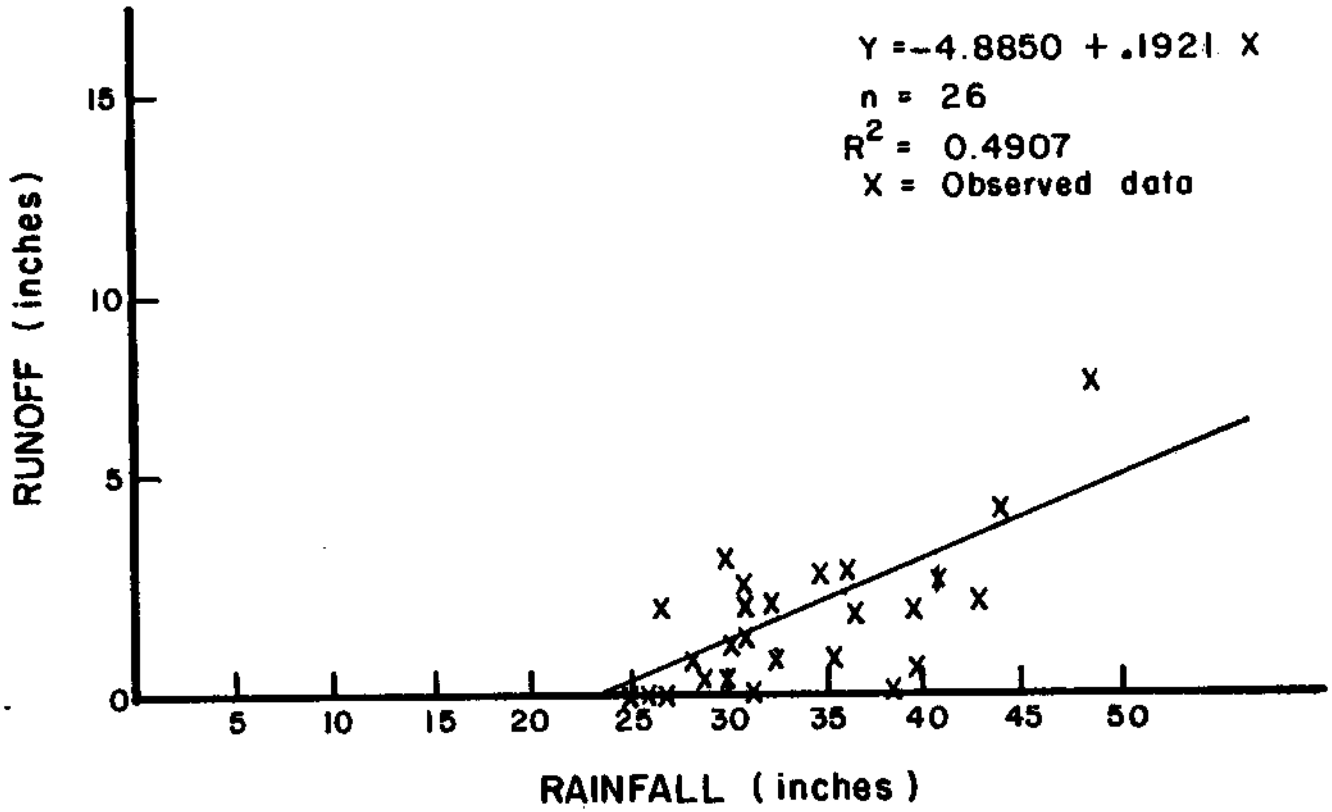

Figure 14. Annual Rainfall-Runoff Relationship, Watershed B-1

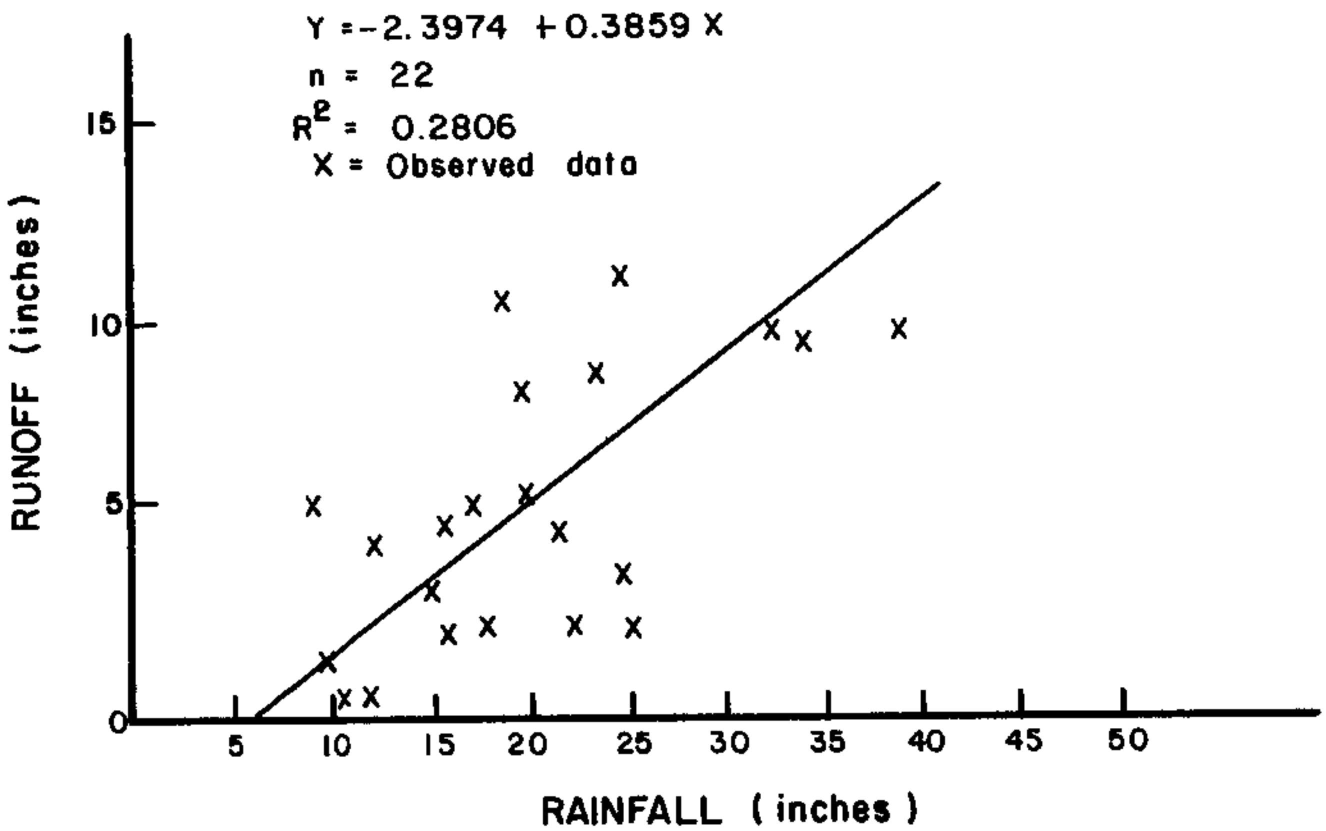

Figure 15. Summer Months Total Rainfall-Runoff Relationship, Watershed W-1

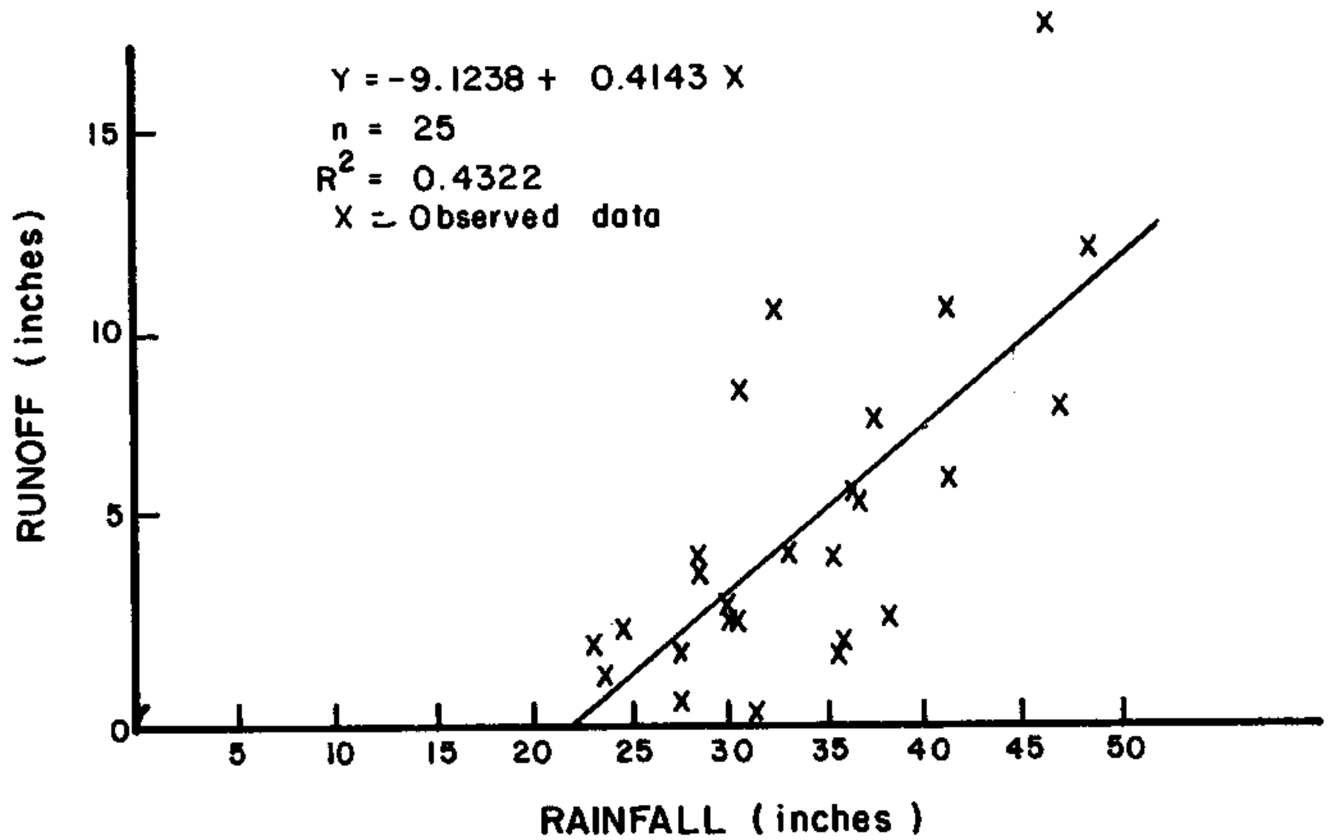

Figure 16. Annual Rainfall-Runoff Relationship, Watershed W-2

to 0.7005. The correlation coefficient is the statistical parameter for measuring the degree of association of the two linearly dependent variables.

The coefficient of determination R^2 of 0.4165 for watershed A-1 (Figure 14) indicates that 41 percent of the variance is accounted for, and 59 percent unaccounted for, which is the error variance. The standard error is the square root of 59 percent or 77 percent, which is the percentage of the original standard deviation of the dependent variable. Thus, with a coefficient of determination of 0.4165 (or correlation coefficient of 0.6454), the average error of estimate would be 77 percent of the average errors of estimate based simply on the mean observed value of the dependent variable without a regression analysis.

For watersheds B-1, W-1, and W-2 with coefficients of determination of 0.4907, 0.2806, and 0.4322, respectively (Figures 14, 15, and 16), the average error of estimates would be 71 percent, 85 percent, and 75 percent, respectively. These average error of estimate percentages indicate that the correlation between the total rainfall and runoff are very poor. Thus, the correlation may be used only for rough estimate of runoff from rainfall.

From the regression lines, we can conclude that for watershed A-1 (Figure 13) runoff occurs when the total annual rainfall exceeds 25 inches, for watershed B-1 (Figure 14) when annual rainfall exceeds 23 inches, and for watershed W-2 (Figure 16) when annual rainfall exceeds 22 inches. For watershed W-1 (Figure 15) runoff will occur when the total summer months rainfall exceeds 6 inches. For watershed W-1, the situation is different from the other three watersheds. The runoff in watershed W-1 includes tile flow in addition to surface runoff from watersheds A-1 and B-1. Also, some of the runoff is probably caused by the snow melt in spring, even when annual rainfall was low.

Testing the regression lines among the watersheds rainfall-runoff relationships (Appendix E, Table E2) reveal that statistically there is no difference for the four regression coefficients. This indicates that once the runoff began on each watershed, they have the same trend as the rainfall increases.

Testing the regression constants A using the same procedure as for the regression coefficient B (Appendix E, Table E2) reveal that the differences among them are highly significant. There are a number of reasons for this; those caused by the variations in soil, the type and extent of farming practices, and the degree to which topsoil has been removed by erosion, and other factors. Thus, the differences in the points of intercept are probably caused by the differences in time needed to reach the saturation point of each soil, especially for watersheds A-1, B-1, and W-2.

Temperature, Humidity, and Wind

Procedure

Using the same methods as for rainfall data, the log-probability curves for minimum and maximum temperature, humidity, and wind speed were constructed. The basic data used in the study are presented in Appendix A, Tables A26 through A31. The descriptive statistics for these data are presented in Appendix B, Table B5.

Results and Discussion

The constructed log-probability curves for the minimum and maximum daily average temperature, humidity, and wind speed for each month are presented in Appendix D, Figures D21 through D32.

From these curves, some inferences can be made. The highest temperatures for 2-year and 100-year return periods are 94°F and 108°F, respectively, which occur in July and June. The lowest minimum temperatures for 2-year and 100-year return periods are -5°F and -8°F, respectively, which occur in January.

The maximum humidity, which is 100 percent, occurs mostly at the 4-year return period for each month. For the 2-year return period, the maximum humidity is 98 percent and occurs every month each year. The lowest minimum humidities are 17 percent and 3 percent, for the 2-year and 100-year return periods, respectively, and both occur in October.

The highest maximum wind speeds are 16 miles per hour and 54 miles per hour for 2-year and 100-year return periods, respectively, which occur in February. The lowest minimum wind speeds are 1.8 miles per hour and zero, for 2-year and 100-year return periods, respectively, and both occur almost each month through the year.

The maximum and minimum temperature, humidity, and wind speed for each month are presented as diagrams in Figures 17, 18, and 19, respectively.

Adequacy of the Length of Records

The method of moments by Mockus (Mockus,1960; Hersfield,1961; Schwab et al,1966) was used to test the adequacy of the length of record. The results of these tests are presented in Appendix F, Tables F1 through F5, and are summarized in Table 2.

The results of the tests reveal that most of the monthly total rainfall data are inadequate in the length of records. For annual total rainfall (RG-1 and RG-5, and watersheds data), the tests reveal that they are adequate in the length of records.

For annual maximum rainfall intensities, the tests reveal that those data are adequate in the length of records, both for rain gage data and watershed data.

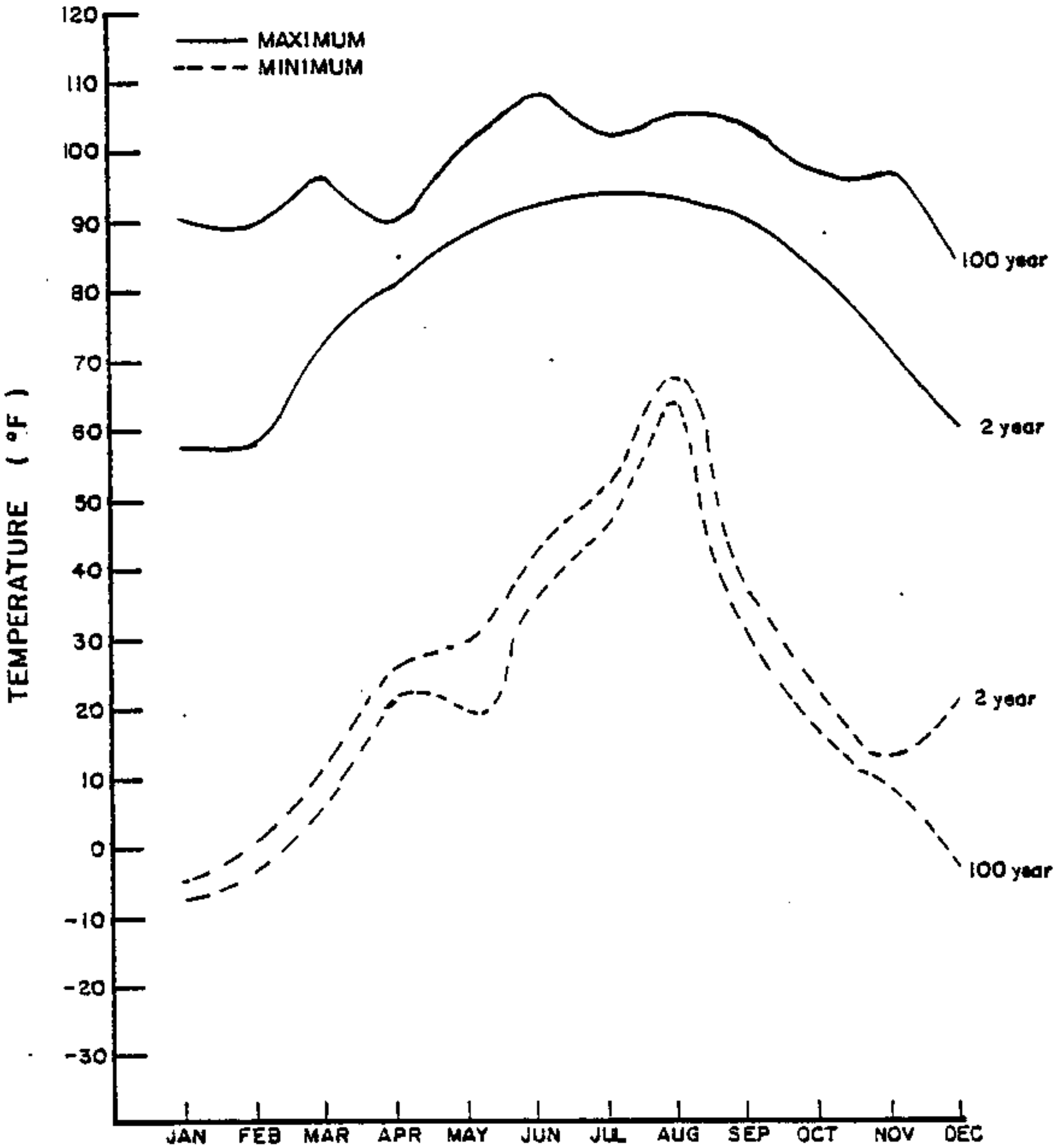

Figure 17. Frequency Relation for Maximum and Minimum Temperature (°F) for 2-year and 100-year Return Periods

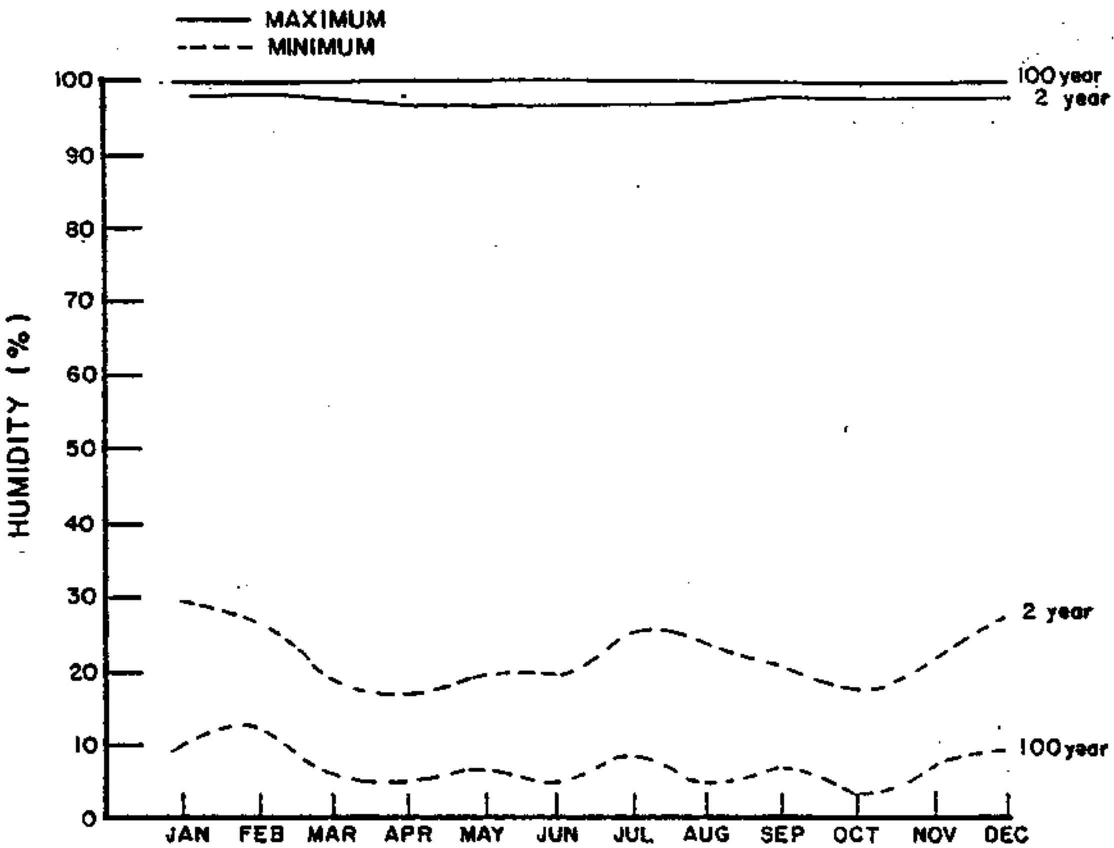

Figure 18. Frequency Relation for Maximum and Minimum Humidity (%) for 2-year and 100-year Return Periods

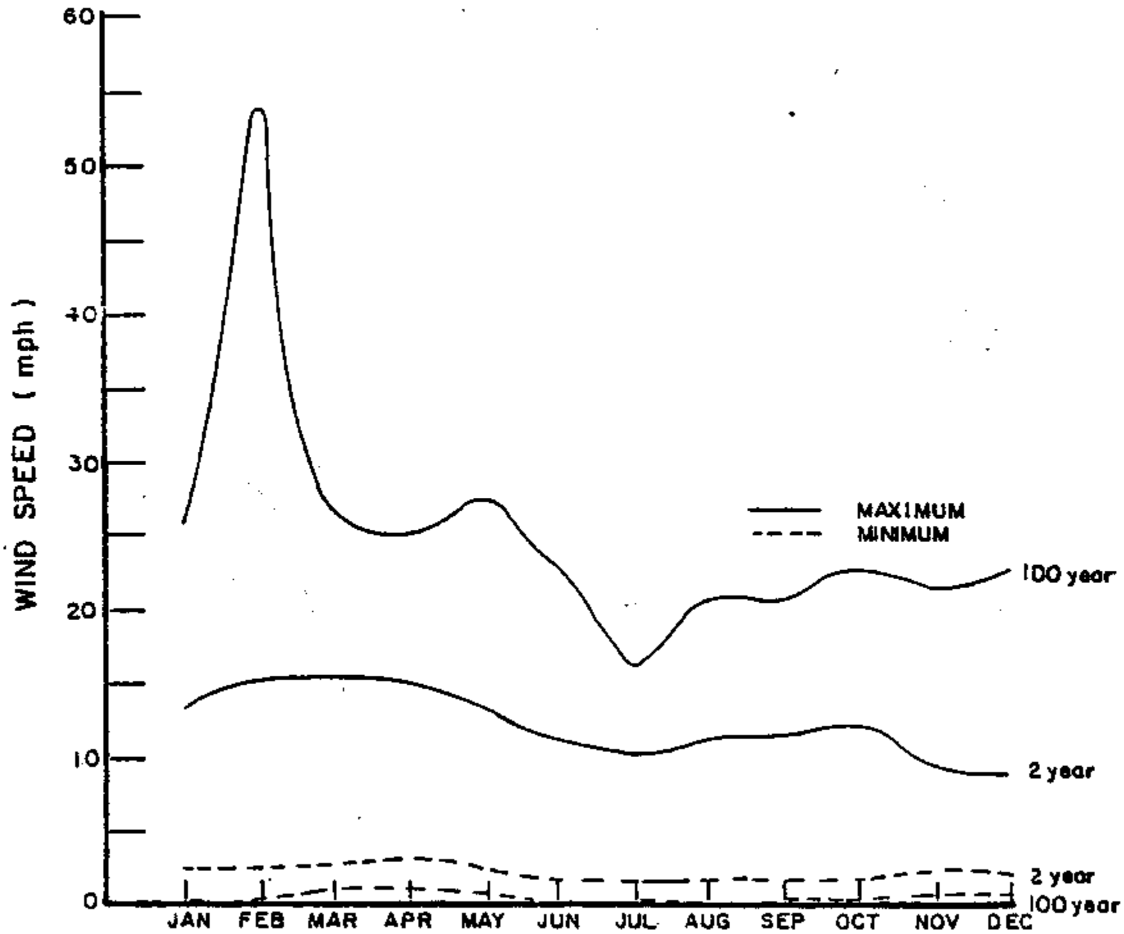

Figure 19. Frequency Relation for Maximum and Minimum Wind Speed (mph) for 2-year and 100-year Return Periods

Table 2

Summary of the Adequacy of the Length of Record Tests

Source of Data	Length of Record (Years) Available	Minimum Acceptable	Remark
Rain Gage Monthly Rainfall:			
RG-1 (full-year)	26	9-68	inadequate
RG-5 (full-year)	26	9-100	inadequate
RG-3 (growing season)	25	23-70	inadequate
RG-4 (growing season)	25	26-84	inadequate
RG-6 (growing season)	26	24-76	inadequate
Watershed Monthly and Annual Rainfall:			
A-1	26	9-100	inadequate
B-1	26	9-100	inadequate
W-1	26	9-104	inadequate
W-2	26	9-101	inadequate
Annual Maximum Rainfall Intensity:			
RG-1	27	12-19	adequate
RG-5	27	14-20	adequate
Watershed A-1	27	9-17	adequate
Watershed B-1	27	13-15	adequate
Watershed W-1	27	10-24	adequate
Watershed W-2	27	9-17	adequate
Annual Maximum Exceedances Runoff:			
Watershed A-1	27	17-27	adequate
Watershed B-1	27	21-27	adequate
Watershed W-1	23	26-32	inadequate
Watershed W-2	24	16-24	adequate
Other Weather Data:			
Maximum Temperature	15	7-9	adequate
Maximum Humidity	15	6	adequate
Maximum Wind Speed	20	8-23	adequate to inadequate

For annual maximum exceedances runoff data, the tests reveal that the data are adequate in the length of records, except for watershed W-1 which is the summer months data.

For maximum temperature, maximum humidity, and maximum wind speed, the tests reveal that the data are adequate in the length of records. The minimum temperature, minimum humidity, and minimum wind speed are not tested, because the test only applies to the data that is increasing with the longer return period.

The frequency distribution of the data series is only an estimate of the frequency distribution of the population, or the probability distribution. The degree to which an estimate can deviate from the population value is dependent on the sample size: the larger the sample, the smaller the deviation tends to be.

In the method we use in this study for fitting the distribution, the deviation from the population is designated as the standard deviation s. The larger the s, the steeper the slope. Since we used the method of moments for testing the adequacy of the length of record, the larger the s, the steeper the slope and the larger the ratio of 100-year event to the 2-year event. Thus, it will require the minimum acceptable years of record to be longer. The large standard deviation was caused by the wide range between the largest value and the smallest value in the data series. Thus, the wider the range in the data series, the longer the data needs to be recorded.

SUMMARY AND CONCLUSIONS

In this study, various hydrologic data were analyzed. They are rainfall depth (monthly and annual total), rainfall intensity for durations ranging from 2 minutes to 720 minutes, and runoff exceedance depths for durations ranging from 1 hour to 192 hours. In addition, maximum and minimum temperature, humidity, and wind speed were analyzed.

The rainfall data were from individual rain gages (for full-year and partial-year), and from individual watersheds. The watershed rainfall data were rain gage data converted by means of a Thiessen weighted average procedure. The runoff data were from the individual watersheds.

The data were tested among each other to see if there were differences. The test for monthly and annual total rainfall reveal that there are no differences among the rain gage data, among the watershed data, and between RG-1 and RG-5 and watershed data. This means that the monthly and annual total rainfall are from a homogeneous population.

The log probability curves from the average of RG-1 and RG-5 (Figure 2) are representative for the non-growing season monthly total and annual total rainfall for the Allerton watersheds. The log-probability curves from the average of RG-1, RG-3, RG-4, RG-5, and RG-6 (Figure 3) are representative for the growing season monthly total rainfall.

The test for the rainfall intensity data reveals that there are no differences between RG-1 and RG-5 data, but significant differences exist between RG-1 and RG-5 and watershed data, and among the watersheds. The rainfall intensity-duration-frequency curves for RG-1 and RG-5 are from homogeneous population and are representative for the Allerton watersheds (Figure 4). The differences between RG-1 and RG-5 and watershed data occur because combining the rain gage data by area and time increment enlarges the differences that already exist. The individual watershed rainfall intensity-duration-frequency curves are presented in Figure 5, Figure 6, Figure 7, and Figure 8.

The test for runoff depth for various durations reveal that the individual watershed data are different from each other, which means that the watersheds have different runoff producing characteristics.

The study on the relationships between annual rainfall and annual runoff for watersheds A-1, B-1, and W-2, and between summer months rainfall and summer months runoff from watershed W-1 reveal that there are linear relationships. However, the correlations are very poor when considering the standard error. The correlations can only be used for rough estimates of runoff from rainfall data.

The temperature, humidity, and wind speed analysis are summarized in Figures 17 through 19.

The tests for the adequacy of the length of records reveal that most of the data are adequate, except for monthly total rainfall.

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APPENDIX A

HYDROLOGIC DATA

TABLE A1

MONTHLY AND ANNUAL TOTAL RAINFALL (IN), RG-1

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1950	5.83	2.92	1.28	4.13	1.35	4.45	2.45	1.97	2.42	2.04	2.33	0.62	31.79
1951	1.53	5.03	3.01	4.07	3.19	5.47	5.68	5.26	2.80	2.72	1.17	1.67	41.60
1952	1.86	1.46	3.33	5.23	3.74	5.13	1.76	2.85	1.59	1.25	2.66	1.16	32.02
1953	1.48	1.92	6.20	1.42	1.86	5.23	3.65	1.26	0.72	2.05	0.60	1.09	27.48
1954	1.29	0.96	1.65	4.20	3.38	1.51	2.72	6.01	0.44	3.92	0.35	1.38	27.81
1955	2.75	2.55	1.23	3.04	4.56	3.82	4.45	1.12	3.28	8.69	1.52	0.26	37.27
1956	0.32	1.94	0.61	3.26	3.43	2.18	5.72	3.84	0.44	0.63	2.17	2.22	26.76
1957	1.51	1.83	1.23	7.07	4.41	7.47	1.97	1.11	1.65	2.95	2.97	4.09	38.26
1958	1.33	0.37	0.99	2.07	5.83	6.14	7.41	0.77	3.92	0.55	4.47	0.59	34.44
1959	2.20	2.52	3.19	2.77	3.64	0.97	1.47	1.43	3.61	3.53	2.41	2.03	29.77
1960	1.28	1.45	0.69	2.86	3.66	5.64	2.10	1.13	2.62	1.93	2.52	0.91	26.79
1961	0.00	1.59	2.99	4.54	5.26	4.86	3.09	2.12	3.84	3.59	3.20	2.26	37.34
1962	3.27	1.03	2.22	1.84	4.42	1.73	5.23	2.64	1.88	1.45	1.22	0.00	26.93
1963	0.50	0.36	4.67	3.39	0.69	0.83	3.33	5.35	0.22	1.86	1.61	0.40	23.21
1964	1.46	0.86	3.83	8.20	0.46	4.02	3.61	2.52	2.20	0.00	13.47	1.45	32.08
1965	3.15	1.07	2.10	5.27	1.70	3.91	3.13	5.90	7.04	1.21	1.00	2.66	38.14
1966	0.22	2.06	1.09	4.59	2.20	1.01	2.34	2.58	5.95	1.64	3.69	3.73	31.10
1967	2.52	1.06	2.49	1.74	5.40	2.65	2.74	2.75	2.75	4.11	2.11	6.16	36.48
1968	2.11	1.46	1.35	3.77	6.76	6.10	2.18	1.27	2.34	0.26	4.29	1.67	33.65
1969	3.00	1.02	0.40	3.29	1.46	1.09	3.08	1.84	6.93	4.93	2.73	0.55	30.49
1970	0.02	0.53	1.75	6.69	1.80	5.15	2.70	2.08	6.38	2.66	1.02	0.69	31.42
1971	0.00	2.54	1.03	0.66	2.99	3.19	9.93	1.70	5.62	1.45	1.63	7.20	38.09
1972	0.48	0.50	2.86	5.93	2.11	1.97	1.51	3.89	7.32	1.35	4.33	5.54	37.79
1973	1.43	0.53	7.20	2.78	3.15	8.92	7.44	1.11	2.58	2.99	2.73	2.82	43.68
1974	3.65	3.17	2.75	4.05	7.61	8.31	1.49	7.34	1.63	1.50	3.90	2.76	48.32
1975	3.39	1.06	2.61	3.23	3.87	4.76	4.55	7.16	3.10	2.52	2.34	2.75	42.40

TABLE A2

MONTHLY AND ANNUAL TOTAL RAINFALL (IN), RG-5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1950	5.46	2.97	1.32	4.12	1.28	4.17	2.13	1.68	2.73	1.74	2.11	0.76	30.47
1951	1.02	4.99	2.82	4.09	3.58	5.73	5.47	5.07	3.06	2.61	1.32	1.64	41.40
1952	1.89	1.42	3.33	5.29	3.64	5.13	1.64	2.72	1.27	1.16	2.73	1.20	31.42
1953	1.47	1.89	6.27	1.57	1.51	4.98	3.31	1.20	0.64	1.89	0.53	1.35	26.61
1954	1.27	0.96	1.74	3.93	3.24	1.27	2.80	5.95	0.53	4.16	0.46	1.42	27.73
1955	2.68	2.56	1.36	3.01	4.55	4.01	4.47	0.99	3.27	8.83	1.53	0.21	37.47
1956	0.25	1.70	0.43	3.16	2.88	2.02	4.67	3.94	0.47	0.66	2.15	2.07	24.40
1957	1.31	1.72	1.28	6.77	4.60	7.29	2.07	0.95	1.81	2.78	2.41	4.04	37.03
1958	1.33	0.37	0.97	1.94	4.96	6.34	7.17	0.67	3.88	0.53	4.24	0.51	32.91
1959	2.16	2.52	3.40	2.73	3.59	0.96	1.39	1.52	3.52	3.50	2.37	1.95	29.61
1960	1.29	1.60	1.02	2.87	3.86	6.30	2.13	1.10	2.31	1.96	2.50	1.06	28.00
1961	0.00	1.59	2.81	4.54	5.26	4.86	2.80	2.23	3.75	3.48	3.22	1.95	36.49
1962	3.13	1.03	2.22	1.66	6.43	2.00	5.03	2.62	1.89	1.44	1.30	0.00	28.75
1963	0.50	0.50	6.50	2.24	0.87	1.04	3.64	3.64	0.18	1.17	1.73	0.58	22.59
1964	1.45	0.69	3.88	8.33	0.50	4.28	3.78	2.71	2.53	0.04	3.60	1.39	33.18
1965	3.28	1.12	1.99	4.51	2.16	4.01	3.39	6.21	7.16	1.23	1.15	2.60	38.81
1966	0.21	2.02	1.33	4.86	2.07	1.19	1.99	2.48	6.25	1.17	4.06	3.86	31.49
1967	3.02	1.11	2.35	1.72	5.24	2.37	3.15	3.09	2.52	4.09	1.78	6.26	36.70
1968	1.40	1.56	1.20	3.38	6.91	5.96	2.16	1.58	2.24	0.18	4.15	1.74	32.45
1969	2.61	0.98	1.22	4.03	1.49	0.97	2.94	1.52	6.97	5.12	2.73	0.66	31.34
1970	0.02	0.52	1.39	6.36	1.88	1.97	2.96	2.18	6.36	2.53	0.91	0.69	30.77
1971	0.00	2.77	1.32	0.66	3.08	3.31	10.09	1.47	5.53	1.35	1.37	7.42	38.37
1972	0.39	0.55	2.98	5.70	2.23	2.02	1.80	4.16	7.51	1.62	3.72	5.43	38.19
1973	1.56	0.73	8.99	6.15	3.15	9.28	6.86	0.96	2.94	2.96	2.64	2.88	49.09
1974	1.96	3.02	3.56	4.75	8.63	8.89	1.43	6.64	1.54	1.35	3.96	2.90	48.65
1975	4.20	2.16	2.50	2.98	3.72	4.33	3.98	6.37	2.78	2.12	2.38	2.75	40.27

TABLE A3

MONTHLY TOTAL RAINFALL (APRIL-OCTOBER)

RG-3

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
1950	4.12	1.30	4.17	2.26	1.67	2.66	1.88
1951	4.22	3.11	5.62	5.46	5.13	2.70	2.66
1952	5.04	3.50	4.93	1.67	2.96	1.53	1.23
1953	1.29	1.71	5.10	2.98	1.19	0.57	1.95
1954	3.99	3.17	1.34	2.54	5.87	0.44	3.92
1955	1.97	4.46	4.01	4.22	1.51	3.18	8.64
1956	2.99	3.26	2.09	5.09	4.24	0.52	0.65
1957	6.57	4.36	7.45	2.07	1.07	0.98	3.26
1958	1.32	4.89	5.92	7.42	0.67	3.91	0.38
1959	2.89	3.51	0.90	1.51	1.03	3.50	3.29
1960	2.82	3.64	5.88	2.00	0.98	2.48	1.62
1961	3.99	5.13	3.81	3.04	2.14	3.67	3.15
1962	2.47	3.74	1.37	4.58	2.28	1.86	1.20
1963	2.22	0.90	2.26	4.32	5.34	0.32	0.99
1964	9.55	0.58	5.20	3.76	2.57	2.35	0.17
1965	5.09	1.77	4.02	3.07	5.88	6.85	1.17
1966	4.81	2.47	1.10	2.42	2.58	5.88	1.65
1967	2.39	4.79	2.38	2.60	2.72	2.63	3.91
1968	3.54	6.48	5.85	2.25	1.49	2.12	0.21
1969	6.00	1.36	1.14	3.04	2.12	6.92	4.74
1970	5.70	1.80	4.98	2.70	2.07	5.87	2.47
1971	0.71	2.86	3.01	9.50	1.40	5.28	1.44
1972	4.71	6.69	2.08	1.56	3.64	6.67	1.92
1974	4.02	7.19	8.31	1.64	7.59	0.82	1.63
1975	3.11	3.92	4.79	4.46	7.26	3.15	2.52

TABLE A4

MONTHLY TOTAL RAINFALL (APRIL-OCTOBER)

RG-4

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
1950	4.04	1.22	4.33	2.62	1.96	2.45	1.97
1951	4.04	3.17	5.76	5.10	5.44	3.03	2.53
1952	3.89	3.55	4.84	1.71	2.80	1.20	1.19
1953	1.57	1.50	4.87	2.66	0.98	0.58	1.79
1954	4.10	3.12	1.30	2.44	5.88	0.43	3.61
1955	3.41	4.45	4.00	4.18	0.91	3.24	7.50
1956	3.00	3.23	2.02	5.09	4.26	0.42	0.62
1957	6.62	4.40	7.28	2.18	1.03	1.28	2.76
1958	1.26	5.17	6.22	7.61	0.78	3.99	0.42
1959	2.89	3.61	0.80	1.44	1.24	3.33	3.52
1960	2.89	3.80	5.95	2.07	1.05	2.46	1.87
1961	4.24	5.11	4.26	2.82	2.21	3.92	3.14
1962	2.97	3.77	1.50	4.32	1.90	1.23	1.89
1963	2.22	0.90	2.26	2.01	4.76	0.28	0.84
1964	5.85	0.49	4.75	3.23	2.66	0.21	0.16
1965	4.81	1.35	3.72	2.63	6.14	6.70	1.96
1967	1.84	5.44	2.52	3.07	3.06	2.61	4.12
1968	3.31	5.68	5.91	2.23	1.42	2.24	0.22
1969	6.00	1.51	1.20	3.12	1.70	6.99	4.88
1970	5.58	2.23	5.17	2.64	2.09	6.14	2.50
1971	0.72	2.88	3.04	9.67	1.31	5.19	1.50
1972	5.43	2.32	1.93	1.78	4.23	7.44	1.53
1973	4.80	6.44	4.72	6.69	1.08	2.63	2.91
1974	4.30	7.58	8.31	1.26	6.33	1.34	1.30
1975	3.11	4.35	4.51	4.34	6.01	2.76	2.36

TABLE A5

MONTHLY TOTAL RAINFALL (APRIL-OCTOBER)

RG-6

YEAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
1950	3.98	1.36	4.40	2.36	1.66	2.49	1.80
1951	3.91	3.43	5.39	5.69	4.99	2.70	2.59
1952	3.82	3.21	5.11	1.50	2.72	1.55	1.16
1953	1.57	1.56	4.80	3.33	1.21	0.61	1.83
1954	3.74	3.15	1.47	2.86	5.70	0.45	4.04
1955	2.94	4.39	3.85	4.49	1.07	3.17	10.33
1956	2.35	2.92	2.02	4.67	3.94	0.39	0.58
1957	6.58	4.25	6.83	2.02	1.12	1.74	2.66
1958	1.72	4.73	6.97	7.22	0.81	4.22	0.47
1959	2.82	3.69	1.04	1.49	1.70	3.70	3.53
1960	2.92	3.93	5.99	2.16	1.01	2.30	1.93
1961	3.66	5.35	4.88	3.25	2.42	3.88	3.25
1962	2.97	4.65	2.07	5.36	2.83	2.19	1.33
1963	2.22	0.86	0.92	3.16	4.23	0.18	0.65
1964	5.03	0.49	4.09	3.82	2.35	2.25	0.17
1965	3.28	1.75	3.51	2.59	5.30	6.90	1.16
1966	4.93	2.37	1.09	2.61	2.74	4.90	1.73
1967	2.59	4.66	2.35	2.74	2.92	2.75	3.65
1968	3.61	7.02	6.27	2.32	1.37	2.22	0.19
1969	6.00	1.60	1.29	3.09	1.92	6.82	4.95
1970	5.58	1.72	4.86	2.78	2.09	5.92	2.45
1971	0.75	2.86	3.15	9.79	1.43	4.96	1.24
1972	5.56	2.53	1.98	1.54	3.66	7.47	1.55
1973	4.23	2.96	8.92	6.90	0.92	2.62	2.53
1974	4.49	7.97	8.37	1.43	6.42	1.49	1.24
1975	2.85	3.95	3.99	4.60	6.93	3.10	2.23

TABLE A6

MONTHLY AND ANNUAL TOTAL RAINFALL (IN), WATERSHED A-1

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1950	5.40	2.94	1.26	4.42	1.28	4.28	2.38	1.72	2.57	1.83	2.17	0.79	31.04
1951	0.97	5.05	2.80	4.18	3.18	6.00	5.32	5.21	2.85	2.65	1.18	1.65	41.04
1952	1.88	1.35	3.38	5.04	3.57	5.21	1.58	2.65	1.52	1.22	2.72	1.20	31.39
1953	1.47	1.92	6.27	1.40	1.88	5.04	3.50	1.24	0.56	1.94	0.60	1.44	27.26
1954	1.29	0.96	2.53	4.13	3.38	1.31	2.56	5.96	0.42	3.93	0.48	1.38	28.33
1955	3.22	2.55	1.36	3.40	4.38	3.99	4.19	1.39	3.23	7.80	1.47	0.26	37.24
1956	0.32	1.97	0.61	3.27	1.91	2.34	5.72	3.85	0.58	0.65	2.17	2.22	25.61
1957	1.49	1.83	1.33	6.79	4.21	7.53	2.43	1.18	1.51	2.92	4.37	4.22	39.81
1958	1.33	0.37	1.07	1.97	3.43	4.80	7.59	0.75	3.89	0.42	4.24	0.59	30.45
1959	2.20	2.51	3.29	2.86	3.48	0.91	1.52	1.35	3.56	2.69	1.24	2.03	27.64
1960	1.28	1.65	0.81	2.84	3.86	5.67	1.92	0.93	3.72	1.66	2.51	1.06	27.91
1961	0.00	1.59	2.99	3.95	4.97	3.88	3.25	2.45	3.73	3.33	3.07	2.26	35.47
1962	3.27	1.03	2.22	1.76	4.24	1.46	4.98	2.49	1.87	1.39	1.22	0.00	25.93
1963	0.50	0.36	6.17	3.38	0.69	1.05	3.44	6.72	0.38	0.47	1.65	0.48	25.30
1964	1.46	0.86	3.77	6.48	0.46	4.18	3.41	2.76	2.33	0.04	3.47	1.38	30.60
1965	3.15	1.03	1.99	5.64	1.77	4.03	2.74	5.92	6.87	1.20	1.00	2.66	38.04
1966	0.22	1.90	1.09	3.53	2.25	1.14	2.41	2.58	5.82	1.67	3.74	4.17	30.52
1967	2.66	1.08	2.55	1.62	4.91	2.39	2.72	2.76	2.65	3.95	2.11	6.50	35.90
1968	2.23	1.46	1.35	3.45	6.45	5.89	2.09	1.61	2.06	0.22	4.29	1.67	32.71
1969	3.00	1.02	1.52	4.07	1.46	1.04	2.96	2.04	6.92	4.75	2.73	1.06	32.57
1970	0.02	0.65	2.00	6.98	1.82	5.01	2.72	2.07	6.31	2.47	1.02	0.69	31.76
1971	0.00	2.54	1.10	0.68	2.91	3.64	9.53	1.49	5.21	1.43	1.63	7.25	37.46
1972	0.40	0.91	3.12	5.13	1.99	2.12	1.39	3.68	6.91	1.92	2.86	5.53	35.56
1973	1.44	0.57	7.17	2.87	2.88	9.12	7.44	1.11	2.86	2.93	2.73	2.82	43.99
1974	3.70	3.27	2.75	4.02	7.19	3.32	1.60	7.72	1.42	1.61	3.65	3.01	48.26
1975	3.54	2.13	2.68	3.16	3.91	4.81	4.33	7.19	3.02	2.52	2.38	2.75	42.47

TABLE A7

MONTHLY AND ANNUAL TOTAL RAINFALL (IN), WATERSHED B-1

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1950	5.88	2.94	1.26	4.51	1.13	4.26	2.40	1.78	2.52	1.86	2.14	0.79	31.47
1951	1.56	5.05	2.87	3.98	3.28	5.75	5.20	5.17	2.92	2.56	1.19	1.65	41.18
1952	1.89	1.41	3.38	5.21	3.63	5.22	1.41	2.69	1.63	1.24	2.74	1.65	31.66
1953	1.48	1.92	6.30	1.48	1.87	4.77	3.61	1.27	0.53	1.97	0.60	1.44	27.29
1954	1.29	0.96	2.52	4.19	3.38	1.33	2.64	5.00	0.43	3.94	0.44	1.38	28.50
1955	3.22	2.55	1.36	3.46	4.52	3.97	4.27	1.20	3.24	7.90	1.47	0.26	37.57
1956	0.32	1.97	0.61	3.28	1.99	2.34	5.72	3.85	0.49	0.64	2.17	2.22	25.60
1957	1.49	1.83	1.33	6.97	4.33	7.47	2.18	1.11	1.49	2.92	4.37	4.22	39.71
1958	1.33	0.37	1.07	2.03	3.82	5.51	8.06	0.76	3.99	0.51	4.38	0.59	32.42
1959	2.20	2.51	3.29	2.81	3.58	0.95	1.49	1.54	3.58	2.83	1.24	2.03	28.05
1960	1.28	1.65	0.81	2.79	3.86	5.50	1.72	0.80	2.99	1.84	2.51	1.06	26.81
1961	0.00	1.59	2.99	3.99	4.98	4.03	3.25	2.50	3.80	3.46	3.20	2.26	36.05
1962	3.27	1.03	2.22	1.79	4.24	1.28	5.21	2.52	1.88	1.37	1.22	0.00	26.03
1963	0.50	0.36	6.17	3.38	0.69	1.05	3.42	6.95	0.38	1.45	1.66	0.48	26.49
1964	1.46	0.86	3.77	6.48	0.46	4.24	3.44	2.70	2.24	0.04	3.47	1.38	30.60
1965	3.15	1.07	1.99	5.52	1.73	3.93	2.95	5.95	6.92	1.25	1.00	2.66	38.11
1966	0.22	1.90	1.09	3.53	2.31	1.11	2.41	2.61	5.71	1.58	3.74	4.17	30.38
1967	2.52	1.08	2.55	1.56	5.02	2.47	2.65	2.70	2.65	3.98	2.11	6.50	35.82
1968	2.23	1.46	1.35	3.54	6.43	5.97	1.98	1.64	2.08	0.24	4.29	1.54	32.75
1969	3.00	1.02	1.52	4.05	1.67	1.23	3.01	1.95	6.97	4.75	2.73	1.06	32.96
1970	0.02	0.65	2.00	6.78	1.90	4.86	2.58	2.06	6.48	2.46	1.02	0.69	31.50
1971	0.00	2.54	1.10	0.60	2.96	3.54	9.52	1.64	5.14	1.39	1.69	7.25	37.41
1972	0.41	0.50	3.12	5.44	2.09	2.07	1.36	3.84	7.13	1.98	2.86	5.53	36.33
1973	1.44	0.57	7.17	2.90	3.29	9.12	7.44	1.11	2.99	2.98	2.73	2.82	44.56
1974	3.70	3.27	2.75	4.02	7.44	8.32	1.51	7.43	1.30	1.55	3.65	3.01	47.95
1975	3.49	2.13	2.63	3.23	4.03	4.77	4.61	7.33	3.11	2.52	2.38	2.75	43.03

TABLE A8

MONTHLY AND ANNUAL TOTAL RAINFALL (IN), WATERSHED W-1

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1950	5.46	2.97	1.32	4.12	1.28	4.25	2.41	1.77	2.29	1.83	2.18	0.76	30.64
1951	1.02	4.99	2.82	4.08	3.32	6.03	5.15	5.24	3.00	2.61	1.32	1.64	41.22
1952	1.89	1.42	3.33	5.19	3.65	4.85	1.63	2.63	1.39	1.18	2.73	1.20	31.09
1953	1.47	1.92	6.27	1.41	1.83	4.93	3.36	1.19	0.60	1.90	0.60	1.41	26.89
1954	1.29	0.97	2.49	4.17	3.24	1.32	2.64	5.91	0.46	4.04	0.46	1.43	28.42
1955	2.85	2.56	1.39	3.46	4.41	3.92	4.37	1.09	3.25	7.88	1.49	0.26	36.93
1956	0.29	1.99	0.58	3.28	1.75	2.25	5.40	3.94	0.45	0.64	2.17	2.19	24.93
1957	1.47	1.80	1.31	6.88	4.35	7.34	2.44	1.08	1.69	2.82	4.21	4.03	39.42
1958	1.33	0.37	1.03	1.97	4.82	5.86	7.32	0.76	3.95	0.48	4.28	0.55	32.72
1959	2.18	2.51	3.33	2.82	3.57	0.90	1.46	1.55	3.52	2.71	1.44	1.99	27.98
1960	1.28	1.58	0.89	2.87	3.96	5.74	1.96	0.93	3.50	1.85	2.50	1.06	28.12
1961	0.00	1.59	2.92	4.20	4.95	4.40	3.15	2.50	3.82	3.34	3.20	2.14	36.21
1962	3.21	1.03	2.22	1.79	4.18	1.46	5.01	2.39	1.71	1.20	1.25	0.00	25.45
1963	0.50	0.42	6.31	3.34	0.76	1.03	3.36	6.66	0.33	1.13	1.69	0.52	26.05
1964	1.46	0.79	3.72	6.58	0.44	4.32	3.41	2.79	2.33	0.04	3.52	1.38	30.78
1965	3.16	1.11	1.99	4.97	1.82	3.91	2.88	6.02	6.87	1.23	1.07	2.64	37.67
1966	0.22	1.89	1.19	3.75	2.19	1.15	2.17	2.53	5.95	1.64	3.88	4.20	30.76
1967	2.56	1.10	2.47	1.73	5.51	2.48	2.96	2.90	2.68	4.01	1.98	6.42	36.80
1968	1.78	1.52	1.28	3.43	6.75	6.17	2.05	1.70	2.12	0.22	4.24	1.69	32.95
1969	2.84	1.00	1.40	4.06	1.58	1.14	2.99	1.82	6.94	4.89	2.73	0.90	32.29
1970	0.02	0.60	1.84	6.57	1.90	5.01	2.70	2.10	5.13	2.49	0.98	0.69	30.62
1971	0.00	2.63	1.18	0.68	2.97	3.42	9.64	1.51	5.14	1.36	1.53	7.35	37.41
1972	0.37	0.52	3.05	5.51	2.42	2.01	1.57	3.91	7.28	1.53	2.81	5.54	36.51
1973	1.49	0.63	7.80	4.05	2.99	9.12	7.52	1.03	2.98	2.91	2.69	2.82	46.06
1974	2.98	3.16	3.05	4.30	7.58	8.51	1.24	6.76	1.66	1.47	3.74	2.95	47.40
1975	3.78	2.15	2.59	3.17	3.97	4.55	4.24	7.03	3.19	2.36	2.38	2.75	42.16

TABLE A9

MONTHLY AND ANNUAL TOTAL RAINFALL (IN), WATERSHED W-2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1950	5.40	2.94	1.26	3.97	1.32	4.37	2.27	1.67	2.39	1.77	2.09	0.79	30.24
1951	1.20	5.05	2.80	3.91	3.40	5.84	5.65	5.08	2.86	2.60	1.42	1.67	41.48
1952	1.86	1.46	3.28	5.25	3.60	4.71	1.68	2.48	1.49	1.16	2.66	1.16	30.79
1953	1.48	1.92	6.19	1.24	1.81	4.79	3.44	1.23	0.58	1.81	0.61	1.39	26.49
1954	1.27	0.99	2.57	3.60	2.94	1.66	2.81	5.59	0.45	4.04	0.41	1.46	27.79
1955	2.57	2.57	1.41	3.36	4.16	3.82	4.62	1.05	3.03	7.57	1.51	0.27	35.94
1956	0.27	2.00	0.57	3.26	1.38	2.03	4.67	4.08	0.41	0.58	2.19	2.17	23.61
1957	1.47	1.76	1.28	6.62	4.20	6.83	2.62	1.15	1.95	2.66	4.09	3.92	38.55
1958	1.33	0.37	1.00	1.74	4.52	7.04	7.15	0.80	4.17	0.54	4.24	0.53	33.43
1959	2.17	2.51	3.37	2.90	3.43	1.03	1.48	1.89	3.73	2.73	1.58	1.98	28.80
1960	1.29	1.54	0.95	1.98	4.16	5.83	2.15	0.98	3.77	1.92	2.50	1.06	29.13
1961	0.00	1.59	2.86	4.23	5.15	4.95	3.26	2.42	3.48	3.50	3.21	2.05	36.70
1962	3.17	1.03	2.22	1.98	4.67	2.05	5.37	2.83	2.19	1.06	1.28	0.00	27.85
1963	0.50	0.46	6.40	2.92	0.80	0.92	3.00	5.87	0.18	0.81	1.71	0.55	24.12
1964	1.45	0.74	3.69	7.54	0.40	4.13	3.51	2.61	2.40	0.04	3.55	1.39	31.65
1965	3.18	1.14	1.99	4.56	1.79	3.55	2.51	5.62	6.87	1.30	1.10	2.62	36.23
1966	0.21	1.88	1.26	4.03	2.36	1.17	2.03	2.48	4.97	1.66	3.97	4.24	30.26
1967	2.60	1.10	2.40	1.71	5.27	2.40	2.86	2.93	2.78	3.38	1.88	6.32	35.63
1968	1.56	1.55	1.23	3.52	7.00	6.29	1.93	1.51	2.13	0.19	4.19	1.72	32.82
1969	2.72	0.99	1.23	4.06	1.65	1.29	3.08	1.85	6.82	4.90	2.73	0.77	32.17
1970	0.02	0.56	1.73	6.47	1.71	4.35	2.94	2.07	6.31	2.55	0.94	0.64	31.00
1971	0.00	2.71	1.27	0.75	2.87	3.08	9.50	1.48	4.73	1.19	1.44	7.44	36.46
1972	0.34	0.54	3.02	5.84	2.50	1.98	1.39	3.59	7.38	1.55	2.77	5.55	36.45
1973	1.52	0.68	3.23	4.23	3.29	9.11	8.72	0.92	3.14	2.53	2.65	2.82	47.84
1974	2.45	3.07	3.31	4.49	7.97	8.37	1.41	6.20	1.53	1.45	3.81	2.91	46.97
1975	3.97	2.16	2.56	2.85	4.04	3.98	4.55	6.69	2.83	2.23	2.37	2.75	40.98

MONTHLY AND ANNUAL TOTAL RAINFALL (IN), URBANA

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1950	7.62	3.71	1.77	4.53	1.80	4.32	5.09	1.65	4.36	2.89	3.67	2.18	42.99
1951	2.07	3.91	3.69	3.07	2.49	4.98	3.66	4.71	2.13	2.76	2.41	2.51	38.39
1952	1.94	1.79	3.66	3.82	5.02	5.70	2.09	2.76	1.67	1.34	2.62	1.46	33.87
1953	2.34	1.49	7.13	1.57	1.94	2.92	3.83	0.68	0.59	1.71	0.72	1.17	26.09
1954	1.81	1.56	1.94	4.15	3.05	2.73	2.92	4.69	0.25	4.46	0.53	1.61	29.70
1955	2.82	2.18	2.29	3.25	2.94	3.01	5.47	1.83	3.15	7.42	2.51	0.30	37.17
1956	0.63	2.43	1.07	2.35	2.92	1.89	5.82	3.79	1.25	0.39	2.11	2.65	27.30
1957	1.61	1.84	1.41	7.49	4.08	6.46	5.09	1.53	0.98	3.26	3.00	4.89	41.64
1958	1.53	0.44	1.37	2.36	4.29	7.50	7.17	3.27	2.84	0.42	4.85	0.59	36.63
1959	2.78	2.79	3.53	3.04	6.56	1.09	1.54	2.44	3.36	4.53	2.61	2.33	36.60
1960	1.54	2.82	1.97	3.28	4.14	6.23	2.77	1.32	2.82	2.30	2.05	1.62	32.86
1961	0.51	2.17	4.59	5.71	5.46	6.47	2.80	1.27	3.92	3.47	3.37	2.36	42.10
1962	4.21	2.74	2.74	2.47	5.27	2.23	9.57	2.81	1.59	2.41	1.53	0.41	37.98
1963	0.95	0.96	6.84	2.22	0.96	2.26	4.32	3.55	0.30	1.69	2.02	0.88	26.89
1964	1.89	1.74	3.97	9.55	0.58	5.20	2.41	2.59	2.18	0.16	3.42	1.79	35.48
1965	4.13	1.66	2.50	5.64	3.66	3.05	5.12	6.89	5.91	1.96	1.24	2.88	44.44
1966	0.40	2.07	1.91	4.64	2.99	3.02	1.34	2.97	6.29	1.03	3.52	5.66	35.84
1967	3.05	1.39	2.51	2.39	4.66	1.55	2.66	1.46	1.54	4.47	2.49	6.63	34.80
1968	2.31	1.41	1.69	3.31	6.97	6.97	2.83	4.80	1.78	0.64	4.68	2.38	39.72
1969	3.60	1.02	2.23	6.00	1.71	1.82	2.98	3.30	5.74	5.39	1.88	1.38	37.05
1970	0.52	0.86	2.30	7.71	1.72	3.26	4.58	3.12	6.99	3.07	1.34	1.01	36.48
1971	1.03	3.27	1.46	0.70	3.84	1.22	10.96	1.43	4.77	0.72	1.59	6.16	37.15
1972	0.98	0.83	3.28	4.81	1.40	3.44	2.58	5.71	8.69	2.13	4.17	4.93	42.95
1973	1.11	0.67	6.55	5.14	3.23	7.05	9.21	3.04	3.01	2.91	2.47	4.81	49.20
1974	3.08	3.33	3.86	4.74	6.31	5.71	1.47	5.94	1.52	1.30	3.78	2.54	43.58
1975	4.64	2.85	2.59	3.08	3.85	6.21	4.90	6.43	2.97	2.20	3.32	2.85	45.89

TABLE A11

ANNUAL MAXIMUM RAINFALL INTENSIY (IPH), RG-1

YEAR	DURATION (MINUTES)										
	2	5	10	15	20	30	60	120	240	360	720
1949	4.94	4.94	4.33	3.53	2.97	2.11	1.13	0.67	0.40	0.27	0.15
1950	2.03	2.03	2.03	1.67	1.67	1.42	0.90	0.46	0.23	0.19	0.11
1951	4.02	4.02	4.02	4.02	3.63	3.19	2.10	1.13	0.60	0.40	0.23
1952	3.32	3.32	3.32	2.47	2.07	1.67	1.32	0.71	0.41	0.29	0.15
1953	2.84	2.84	2.84	2.11	2.11	1.69	0.95	0.62	0.42	0.35	0.22
1954	5.46	4.17	4.17	4.17	4.17	3.21	1.62	0.82	0.47	0.43	0.21
1955	3.89	3.02	3.02	3.02	3.01	2.26	1.76	1.35	1.05	0.83	0.42
1956	3.54	3.54	3.54	2.37	1.78	1.23	0.96	0.56	0.33	0.23	0.12
1957	13.65	6.27	3.31	2.71	2.71	1.82	0.94	0.65	0.35	0.32	0.19
1958	3.47	3.47	3.47	3.47	2.89	2.37	1.38	0.75	0.49	0.35	0.23
1959	2.86	2.86	2.22	2.15	1.89	1.58	0.82	0.57	0.34	0.27	0.18
1960	1.88	1.88	1.88	1.88	1.88	1.45	0.75	0.61	0.37	0.24	0.12
1961	5.05	5.05	4.79	3.91	3.11	2.18	1.20	1.00	0.65	0.45	0.26
1962	7.50	3.59	3.59	2.42	1.83	1.50	1.26	0.72	0.36	0.24	0.13
1963	3.66	3.66	3.66	3.07	3.07	2.05	1.02	0.62	0.39	0.26	0.15
1964	5.99	4.43	4.19	3.22	2.85	2.35	1.43	0.79	0.45	0.43	0.22
1965	5.45	4.24	3.43	3.13	2.81	2.45	1.89	0.97	0.51	0.40	0.21
1966	4.77	4.71	2.93	2.57	2.43	1.67	1.03	0.62	0.40	0.32	0.24
1967	5.92	5.53	3.94	2.93	2.66	2.08	1.17	0.69	0.37	0.26	0.13
1968	6.16	4.93	2.47	2.03	1.74	1.37	0.83	0.63	0.40	0.36	0.23
1969	3.08	3.08	3.08	3.08	2.77	2.22	1.60	1.12	0.67	0.47	0.31
1970	9.99	8.59	7.26	5.94	4.99	4.00	2.23	1.21	0.67	0.45	0.25
1971	9.39	9.24	5.86	4.73	3.76	2.56	1.39	0.95	0.76	0.54	0.31
1972	7.62	4.61	2.72	2.20	1.91	1.54	1.10	0.80	0.53	0.36	0.18
1973	6.83	6.11	4.56	3.83	2.99	2.04	1.62	0.32	0.48	0.34	0.21
1974	4.75	3.73	3.68	2.89	2.89	2.76	1.59	0.97	0.62	0.48	0.27
1975	8.54	8.45	5.36	4.58	4.16	3.40	2.15	1.16	0.50	0.39	0.19

TABLE A12

ANNUAL MAXIMUM RAINFALL INTENSIY (IPH), RG-5

YEAR	DURATION (MINUTES)										
	2	5	10	15	20	30	60	120	240	360	720
1949	7.33	6.68	4.55	3.71	2.99	2.13	1.16	0.68	0.42	0.28	0.14
1950	5.63	4.19	2.09	1.40	1.05	0.80	0.41	0.33	0.21	0.19	0.11
1951	5.21	5.00	4.74	3.90	3.08	2.65	1.98	1.16	0.59	0.40	0.22
1952	5.22	5.22	3.19	2.58	2.75	2.45	1.27	0.66	0.41	0.27	0.14
1953	5.14	4.80	4.37	3.05	2.37	1.65	0.92	0.58	0.40	0.36	0.21
1954	6.44	6.06	5.26	4.94	4.21	3.18	1.82	0.91	0.47	0.43	0.22
1955	7.13	6.55	6.12	5.14	4.47	3.31	1.82	1.28	1.02	0.68	0.34
1956	8.47	5.53	4.10	3.00	2.44	1.83	1.00	0.58	0.30	0.23	0.12
1957	8.53	6.87	4.17	3.30	2.51	1.68	0.84	0.51	0.34	0.30	0.19
1958	7.43	5.20	4.46	4.28	3.68	2.87	1.77	0.93	0.48	0.34	0.24
1959	7.79	5.52	4.09	2.76	2.07	1.38	1.17	0.66	0.35	0.35	0.18
1960	5.83	3.52	3.18	2.57	2.08	1.54	0.84	0.56	0.33	0.23	0.15
1961	5.49	5.05	4.79	3.91	3.11	2.18	1.27	1.00	0.65	0.45	0.26
1962	10.05	10.05	7.93	5.85	4.58	3.31	1.75	0.97	0.49	0.32	0.16
1963	3.78	3.03	2.96	2.35	2.02	1.51	0.88	0.49	0.27	0.19	0.14
1964	5.46	5.46	4.93	3.33	2.53	1.73	1.16	0.75	0.42	0.30	0.18
1965	4.48	4.48	2.96	2.96	2.96	2.96	2.02	1.01	0.54	0.42	0.22
1966	4.07	4.07	4.07	2.81	2.17	1.88	1.00	0.56	0.43	0.34	0.25
1967	2.42	2.42	2.42	2.42	2.42	2.03	1.25	0.69	0.39	0.27	0.14
1968	2.99	2.99	2.99	2.12	1.68	1.51	0.94	0.69	0.43	0.36	0.22
1969	2.45	2.45	2.44	2.44	2.44	2.44	1.87	1.22	0.74	0.52	0.34
1970	3.06	3.06	3.06	3.06	3.06	3.06	2.10	1.14	0.63	0.43	0.22
1971	30.80	13.20	6.60	4.47	3.35	2.24	1.82	1.18	0.76	0.60	0.31
1972	6.21	6.14	5.83	3.92	2.95	1.97	1.02	0.74	0.48	0.33	0.17
1973	7.06	6.30	3.95	2.79	2.33	1.88	1.55	0.88	0.51	0.35	0.31
1974	6.19	6.19	3.19	2.17	1.75	1.75	1.24	0.81	0.49	0.37	0.22
1975	4.27	3.24	3.24	2.23	1.72	1.48	1.48	1.07	0.56	0.37	0.19

TABLE A13

ANNUAL MAXIMUM RAINFALL INTENSIY (IPH), WATERSHED A-1

YEAR	DURATION (MINUTES)										
	2	5	10	15	20	30	60	120	240	360	720
1949	5.99	5.04	4.13	3.62	2.96	2.10	1.13	0.67	0.42	0.28	0.15
1950	3.50	2.07	1.87	1.72	1.50	1.20	0.81	0.43	0.22	0.19	0.12
1951	6.39	6.04	5.43	4.32	3.83	2.93	2.14	1.21	0.61	0.41	0.23
1952	4.66	4.56	3.42	2.95	2.83	2.26	1.37	0.73	0.39	0.26	0.15
1953	5.55	4.72	3.55	2.93	2.45	1.72	0.95	0.60	0.41	0.36	0.21
1954	5.77	5.11	4.36	3.54	3.10	2.39	1.54	0.79	0.47	0.43	0.21
1955	5.60	5.35	5.06	5.49	3.90	2.94	1.75	1.42	1.01	0.69	0.34
1956	5.19	3.47	3.47	2.37	1.78	1.23	0.96	0.56	0.33	0.23	0.12
1957	5.75	5.53	2.84	2.25	2.24	1.62	0.93	0.52	0.35	0.31	0.20
1958	3.73	3.73	3.60	3.18	2.74	2.07	1.15	0.65	0.46	0.35	0.18
1959	3.82	3.82	3.82	2.79	2.21	1.54	0.99	0.59	0.34	0.23	0.13
1960	5.24	3.32	2.52	2.09	1.80	1.33	0.75	0.61	0.37	0.24	0.12
1961	4.90	4.90	4.90	4.18	3.31	2.32	1.25	1.06	0.67	0.47	0.27
1962	8.74	5.52	3.45	2.66	2.27	1.90	1.27	0.73	0.37	0.25	0.13
1963	3.59	3.59	3.59	2.55	2.52	1.70	1.30	0.63	0.31	0.21	0.14
1964	6.00	4.40	4.18	3.19	2.79	2.35	1.41	0.79	0.42	0.31	0.16
1965	4.40	4.00	3.57	3.29	2.98	2.56	1.90	0.98	0.52	0.40	0.21
1966	4.60	4.40	2.87	2.16	2.02	1.57	0.98	0.60	0.41	0.33	0.24
1967	5.80	4.39	3.84	2.93	2.55	2.03	1.19	0.69	0.38	0.26	0.13
1968	5.76	3.92	2.46	1.89	1.70	1.35	0.84	0.63	0.40	0.36	0.23
1969	3.23	3.23	2.94	2.91	2.69	2.27	1.64	1.11	0.65	0.47	0.30
1970	9.99	8.60	7.23	5.88	4.93	3.98	2.22	1.21	0.67	0.44	0.25
1971	7.95	5.00	4.26	3.76	3.13	2.22	1.34	0.92	0.75	0.53	0.31
1972	10.28	7.80	6.13	4.67	3.94	2.72	1.36	0.80	0.41	0.27	0.14
1973	6.83	6.16	4.53	3.84	3.00	2.04	1.62	0.82	0.48	0.34	0.21
1974	3.81	3.81	3.69	2.70	2.39	2.36	1.44	0.94	0.60	0.50	0.28
1975	6.55	6.55	4.71	4.48	4.19	3.59	2.20	1.17	0.59	0.39	0.20

TABLE A14

ANNUAL MAXIMUM RAINFALL INTENSIY (IPH), WATERSHED B-1

YEAR	DURATION (MINUTES)										
	2	5	10	15	20	30	60	120	240	360	720
1949	5.20	5.12	4.49	3.69	2.98	2.12	1.16	0.69	0.42	0.28	0.15
1950	5.18	2.77	2.36	2.12	1.80	1.32	0.78	0.41	0.21	0.19	0.12
1951	5.63	5.63	5.45	3.98	3.80	2.93	2.05	1.16	0.58	0.39	0.22
1952	4.90	4.80	3.61	3.19	2.98	2.34	1.40	0.75	0.40	0.27	0.15
1953	6.50	6.30	3.71	2.84	2.38	1.68	0.94	0.57	0.39	0.35	0.21
1954	5.12	3.61	3.07	3.06	3.04	2.46	1.59	0.82	0.47	0.43	0.21
1955	3.82	3.53	3.26	2.92	2.71	2.11	1.71	1.38	1.02	0.74	0.37
1956	5.19	3.47	3.47	2.37	1.78	1.23	0.96	0.56	0.33	0.23	0.12
1957	6.00	5.56	2.94	2.09	2.06	1.53	0.93	0.52	0.35	0.30	0.19
1958	4.51	3.73	3.48	3.10	2.65	1.84	1.00	0.54	0.46	0.34	0.19
1959	2.53	2.53	2.53	2.18	1.99	1.57	0.98	0.58	0.34	0.23	0.13
1960	2.50	2.03	1.38	1.32	1.32	1.08	0.75	0.61	0.37	0.24	0.12
1961	4.90	4.90	4.79	4.04	3.25	2.28	1.24	1.05	0.67	0.47	0.27
1962	6.24	3.36	2.59	1.96	1.72	1.48	1.09	0.72	0.36	0.24	0.13
1963	3.59	3.59	3.59	2.44	2.31	1.54	1.04	0.63	0.34	0.23	0.14
1964	6.00	4.40	4.18	3.19	2.79	2.35	1.41	0.79	0.42	0.32	0.16
1965	4.10	3.84	3.21	2.98	2.71	2.39	1.83	0.95	0.51	0.40	0.21
1966	4.60	4.13	2.73	2.04	1.69	1.37	0.81	0.55	0.41	0.33	0.24
1967	5.28	5.00	3.64	2.75	2.49	1.99	1.19	0.70	0.37	0.25	0.13
1968	4.00	3.36	2.03	1.79	1.55	1.31	0.81	0.60	0.40	0.35	0.23
1969	5.90	3.02	3.02	3.01	2.70	2.19	1.63	1.11	0.67	0.48	0.31
1970	8.49	7.57	6.65	5.48	4.64	3.68	2.09	1.14	0.64	0.43	0.22
1971	7.68	6.93	5.29	4.16	3.49	2.42	1.30	0.91	0.75	0.53	0.30
1972	10.28	7.80	6.13	4.67	3.94	2.72	1.36	0.80	0.49	0.33	0.16
1973	6.83	6.16	4.53	3.84	3.00	2.04	1.62	0.82	0.48	0.34	0.21
1974	4.25	3.81	3.69	2.74	2.70	2.58	1.54	0.95	0.61	0.49	0.28
1975	5.66	5.66	4.82	4.40	4.04	3.44	2.23	1.20	0.61	0.41	0.20

TABLE A15

ANNUAL MAXIMUM RAINFALL INTENSIY (IPH), WATERSHED W-1

YEAR	DURATION (MINUTES)										
	2	5	10	15	20	30	60	120	240	360	720
1949	5.00	4.84	4.20	3.63	2.96	2.10	1.14	0.67	0.42	0.28	0.14
1950	2.60	2.22	1.86	1.72	1.53	1.21	0.63	0.44	0.22	0.19	0.11
1951	9.70	4.86	4.32	3.80	3.17	2.70	2.01	1.15	0.58	0.40	0.22
1952	4.30	3.96	2.71	2.50	2.42	2.12	1.27	0.70	0.39	0.26	0.14
1953	3.47	3.31	2.96	2.52	2.23	1.62	0.92	0.54	0.39	0.36	0.21
1954	4.00	3.91	3.40	3.04	2.65	2.11	1.59	0.83	0.47	0.43	0.21
1955	4.30	3.81	3.24	2.92	2.56	2.40	1.67	1.36	0.99	0.69	0.35
1956	3.42	2.18	2.18	1.49	1.12	0.77	0.61	0.52	0.33	0.22	0.12
1957	6.61	5.24	3.14	2.17	1.68	1.44	0.88	0.46	0.33	0.28	0.19
1958	3.96	2.91	2.73	2.52	2.29	1.78	1.22	0.69	0.40	0.35	0.21
1959	3.43	3.36	3.07	2.64	2.15	1.52	0.77	0.46	0.30	0.20	0.13
1960	3.25	2.60	2.21	1.73	1.43	1.05	0.71	0.61	0.37	0.24	0.13
1961	3.43	3.42	3.33	2.82	2.31	1.70	1.06	0.89	0.65	0.46	0.27
1962	4.61	3.48	2.96	2.36	1.88	1.50	1.09	0.70	0.35	0.23	0.13
1963	2.60	2.24	2.12	1.64	1.45	1.29	0.96	0.59	0.30	0.20	0.14
1964	3.80	3.12	2.90	2.26	1.73	1.49	1.17	0.71	0.41	0.28	0.15
1965	3.65	3.52	3.19	3.02	2.81	2.50	1.84	0.95	0.50	0.39	0.21
1966	4.60	4.46	2.95	2.11	1.77	1.38	0.87	0.53	0.42	0.34	0.25
1967	4.04	3.92	3.22	2.62	2.09	1.57	1.03	0.64	0.37	0.26	0.13
1968	2.05	2.03	1.97	1.72	1.45	1.27	0.81	0.63	0.41	0.36	0.23
1969	13.95	5.80	3.15	2.46	2.22	1.90	1.61	1.15	0.69	0.49	0.31
1970	6.29	5.85	5.39	4.72	4.13	3.32	2.08	1.13	0.63	0.43	0.21
1971	7.64	3.45	3.22	2.92	2.38	1.67	1.11	0.85	0.71	0.51	0.30
1972	6.19	4.72	3.64	2.77	2.35	1.63	0.98	0.73	0.48	0.32	0.16
1973	6.83	6.16	4.65	3.84	3.00	2.05	1.54	0.80	0.41	0.27	0.19
1974	2.56	2.53	2.24	1.99	1.98	1.90	1.25	0.85	0.55	0.44	0.25
1975	4.66	4.57	3.47	3.02	2.78	2.58	1.62	0.95	0.55	0.37	0.19

TABLE A16

ANNUAL MAXIMUM RAINFALL INTENSIY (IPH), WATERSHED W-2

YEAR	DURATION (MINUTES)										
	2	5	10	15	20	30	60	120	240	360	720
1949	5.70	5.70	4.56	3.69	2.98	2.12	1.16	0.69	0.42	0.28	0.14
1950	3.60	4.36	3.04	2.56	2.10	1.56	0.84	0.43	0.21	0.18	0.09
1951	8.31	6.24	5.54	4.36	3.67	3.03	2.08	1.20	0.60	0.40	0.21
1952	6.83	5.82	3.95	2.98	2.69	2.34	1.26	0.68	0.38	0.25	0.14
1953	8.44	7.10	4.27	3.08	2.36	1.64	0.91	0.54	0.36	0.34	0.20
1954	8.40	5.71	5.71	5.09	4.46	3.35	1.83	0.92	0.46	0.43	0.21
1955	6.24	6.24	6.24	5.47	4.68	5.02	2.67	1.61	0.81	0.54	0.27
1956	8.38	5.33	4.06	2.97	2.42	1.82	0.99	0.58	0.30	0.23	0.12
1957	7.12	6.92	4.08	3.25	2.51	1.69	0.85	0.49	0.33	0.30	0.18
1958	6.26	5.12	4.63	4.11	3.65	2.81	1.70	0.90	0.53	0.38	0.24
1959	7.64	5.52	4.50	3.28	2.46	1.64	1.10	0.65	0.35	0.23	0.13
1960	5.04	3.56	3.17	2.58	2.05	1.49	0.77	0.61	0.37	0.24	0.14
1961	5.00	5.00	4.60	3.89	3.28	2.36	1.36	1.06	0.68	0.48	0.27
1962	10.60	7.32	4.66	3.64	2.73	1.88	1.36	0.68	0.34	0.23	0.13
1963	3.70	3.70	2.99	2.36	2.04	1.54	0.79	0.44	0.27	0.20	0.14
1964	5.40	4.14	3.16	2.90	2.43	1.72	1.60	0.67	0.43	0.34	0.21
1965	5.37	3.89	3.61	3.18	2.87	2.46	1.81	0.91	0.49	0.38	0.20
1966	5.50	5.30	2.88	2.04	1.71	1.15	0.82	0.52	0.43	0.35	0.26
1967	4.47	4.47	4.47	3.06	2.40	1.66	1.14	0.72	0.38	0.27	0.14
1968	7.54	6.72	3.36	2.24	1.96	1.49	0.91	0.63	0.39	0.36	0.23
1969	4.22	4.22	3.65	3.39	3.09	2.62	1.88	1.21	0.71	0.51	0.31
1970	6.31	6.31	5.98	5.44	4.81	3.69	2.04	1.10	0.61	0.41	0.20
1971	6.22	5.27	4.35	3.76	3.03	2.18	1.31	0.89	0.72	0.50	0.29
1972	4.70	3.54	3.10	2.51	2.08	1.83	1.27	0.85	0.54	0.36	0.18
1973	6.83	6.16	4.53	3.84	3.00	2.04	1.62	0.89	0.51	0.35	0.31
1974	6.42	5.43	2.93	2.10	1.60	1.20	0.85	0.71	0.50	0.40	0.23
1975	5.45	5.45	5.45	5.45	5.03	3.73	2.42	1.52	0.76	0.51	0.25

TABLE A17

ANNUAL TOTAL RUNOFF DEPTH (INCHES)

YEAR	ANNUAL TOTAL RUNOFF DEPTH (INCHES)			
	WATERSHED A-1	WATERSHED B-1	WATERSHED W-1	WATERSHED W-2
1950	2.0554	0.0908	0.0000	2.7736
1951	3.4845	2.7472	0.7054	10.2612
1952	1.0552	2.7223	12.2263	2.5718
1953	0.9455	0.8241	3.7925	2.6916
1954	0.0002	0.0106	1.0800	2.0853
1955	2.0091	2.1496	3.6104	1.9023
1956	0.0059	0.0721	2.5161	2.1157
1957	0.4751	1.2105	4.8370	2.7816
1958	1.2154	1.1357	7.8055	4.5178
1959	1.4594	0.2854	1.1385	4.4560
1960	0.0390	0.5069	2.9329	3.9791
1961	1.5609	3.2419	9.0838	5.8590
1962	0.5846	2.1983	9.6295	0.8009
1963	0.6808	0.0777	1.3824	1.2673
1964	2.2926	2.8613	0.9353	0.2969
1965	0.2121	0.3217	4.3585	2.1592
1966	0.3135	0.6638	5.5905	3.0860
1967	0.9095	2.3995	6.4936	4.2712
1968	0.6654	2.2250	10.4171	10.4737
1969	0.1687	0.8820	0.6743	4.7852
1970	1.4160	1.2360	10.8439	8.3867
1971	2.9771	1.8203	5.8070	5.6126
1972	1.4859	0.8818	4.7240	3.7079
1973	2.6732	4.4403	9.9550	8.0603
1974	6.3947	7.7575	9.0768	17.0000

NOTE= WATERSHED W-1 DATA ARE FOR SUMMER MONTHS ONLY

TABLE A18

ANNUAL MAXIMUM RUNOFF DEPTH (IN), WATERSHED A-1

YEAR	DURATION (HOURS)								
	1	2	6	12	24	48	72	120	192
1949	0.148	0.236	0.557	0.692	0.766	0.772	0.772	0.790	0.790
1950	0.064	0.111	0.264	0.504	0.652	0.658	0.658	0.658	0.957
1951	0.464	0.646	0.841	1.188	1.218	1.218	1.218	1.218	1.218
1952	0.142	0.238	0.433	0.617	0.634	0.634	0.634	0.634	0.634
1953	0.115	0.201	0.320	0.348	0.442	0.522	0.523	0.523	0.523
1955	0.366	0.610	1.192	1.299	1.301	1.301	1.301	1.301	1.301
1956	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.006	0.006
1957	0.138	0.239	0.366	0.366	0.366	0.366	0.366	0.366	0.366
1958	0.374	0.565	0.687	0.687	0.687	0.687	0.687	0.687	0.680
1959	0.289	0.462	0.669	1.285	1.425	1.430	1.430	1.430	1.430
1960	0.049	0.078	0.089	0.089	0.089	0.089	0.089	0.089	0.089
1961	0.690	0.975	1.504	1.559	1.560	1.561	1.561	1.561	1.561
1962	0.134	0.231	0.430	0.458	0.458	0.458	0.458	0.458	0.458
1963	0.132	0.230	0.461	0.651	0.667	0.675	0.675	0.675	0.675
1964	0.552	0.798	1.328	1.554	1.765	1.966	1.966	1.966	1.966
1965	0.034	0.066	0.117	0.119	0.119	0.119	0.119	0.119	0.119
1966	0.057	0.096	0.225	0.250	0.254	0.283	0.283	0.283	0.283
1967	0.152	0.234	0.323	0.626	0.631	0.631	0.631	0.631	0.631
1968	0.107	0.168	0.333	0.336	0.527	0.529	0.529	0.529	0.529
1969	0.021	0.040	0.081	0.093	0.093	0.121	0.121	0.121	0.121
1970	0.347	0.434	0.648	0.707	0.710	0.710	0.710	0.710	0.710
1971	0.334	0.538	0.848	1.014	1.051	0.169	1.169	1.892	2.221
1972	0.128	0.243	0.548	0.671	0.678	0.688	0.761	0.761	0.761
1973	0.568	0.740	1.051	1.118	1.130	1.198	1.198	1.198	1.198
1974	0.515	0.779	1.224	2.298	2.511	3.579	3.594	3.594	3.594
1975	0.053	0.099	0.246	0.295	0.298	0.298	0.298	0.298	0.298

TABLE A19

ANNUAL MAXIMUM RUNOFF DEPTH (IN), WATERSHED B-1

YEAR	DURATION (HOURS)								
	1	2	6	12	24	48	72	120	192
1949	0.208	0.390	0.897	1.163	1.283	1.307	1.307	1.389	1.389
1950	0.006	0.009	0.020	0.026	0.040	0.040	0.042	0.051	0.054
1951	0.305	0.547	0.829	0.851	0.851	0.851	0.851	0.851	0.904
1952	0.170	0.310	0.654	1.028	1.153	1.177	1.177	1.177	1.177
1953	0.141	0.232	0.356	0.387	0.557	0.644	0.651	0.651	0.651
1954	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.004
1955	0.389	0.739	1.557	1.684	1.685	1.685	1.685	1.685	1.685
1956	0.020	0.025	0.036	0.042	0.043	0.043	0.043	0.043	0.043
1957	0.088	0.129	0.297	0.385	0.466	0.468	0.468	0.484	0.513
1958	0.151	0.266	0.482	0.505	0.506	0.506	0.506	0.683	0.683
1959	0.016	0.032	0.094	0.169	0.212	0.212	0.212	0.212	0.212
1960	0.063	0.124	0.242	0.329	0.417	0.417	0.418	0.494	0.501
1961	0.350	0.641	1.255	1.672	1.879	2.095	2.118	2.118	2.118
1962	0.115	0.168	0.456	0.628	0.725	0.727	0.727	0.727	0.727
1963	0.018	0.024	0.029	0.029	0.029	0.029	0.029	0.029	0.036
1964	0.485	0.809	1.373	1.691	2.166	2.675	2.694	2.694	2.694
1965	0.043	0.071	0.117	0.144	0.149	0.150	0.150	0.150	0.260
1966	0.084	0.151	0.327	0.396	0.423	0.650	0.653	0.655	0.655
1967	0.238	0.378	0.537	0.961	0.981	0.981	0.981	0.981	0.981
1968	0.134	0.219	0.368	0.645	0.871	0.887	0.889	0.955	0.956
1969	0.038	0.076	0.184	0.263	0.305	0.412	0.413	0.413	0.413
1970	0.318	0.367	0.430	0.432	0.655	0.655	0.655	0.655	0.655
1971	0.257	0.416	0.880	0.990	1.011	1.011	1.011	1.011	1.011
1972	0.134	0.263	0.521	0.595	0.715	0.749	0.863	0.863	0.866
1973	0.674	1.234	1.798	2.029	2.039	2.040	2.040	2.040	2.040
1974	0.426	0.536	1.041	1.146	1.188	1.739	1.880	2.383	2.383
1975	0.131	0.233	0.492	0.726	0.752	1.333	1.336	1.336	1.340

TABLE A20

ANNUAL MAXIMUM RUNOFF DEPTH (IN), WATERSHED W-1

YEAR	DURATION (HOURS)								
	1	2	6	12	24	48	72	120	192
1951	0.018	0.035	0.063	0.105	0.190	0.306	0.335	0.377	0.435
1952	0.108	0.188	0.473	0.754	0.981	1.345	1.442	1.611	1.765
1953	0.085	0.144	0.298	0.434	0.725	1.084	1.270	1.531	1.752
1954	0.098	0.106	0.125	0.128	0.134	0.160	0.172	0.181	0.221
1955	0.081	0.140	0.227	0.285	0.390	0.535	0.604	0.717	0.799
1956	0.052	0.099	0.142	0.189	0.240	0.347	0.459	0.593	0.639
1957	0.067	0.132	0.307	0.438	0.547	0.667	0.733	0.824	1.005
1958	0.126	0.230	0.436	0.504	0.594	0.718	0.821	1.091	1.398
1959	0.016	0.024	0.037	0.055	0.075	0.105	0.125	0.191	0.288
1960	0.064	0.112	0.235	0.320	0.452	0.589	0.656	0.828	0.978
1961	0.724	1.131	1.652	1.891	2.140	2.476	2.629	2.905	3.151
1962	0.117	0.217	0.493	0.703	0.910	1.153	1.324	1.547	1.741
1963	0.033	0.047	0.070	0.116	0.190	0.379	0.553	0.698	0.744
1964	0.049	0.089	0.183	0.285	0.409	0.558	0.626	0.724	0.763
1965	0.068	0.122	0.287	0.417	0.512	0.668	0.746	0.971	1.357
1966	0.150	0.209	0.244	0.291	0.476	0.722	0.916	1.300	1.689
1967	0.283	0.318	0.318	0.318	0.380	0.583	0.743	0.916	1.311
1968	0.121	0.141	0.319	0.439	0.686	1.071	1.522	2.090	2.453
1969	0.020	0.037	0.045	0.045	0.051	0.054	0.082	0.136	0.204
1970	0.111	0.201	0.437	0.558	1.096	1.431	1.639	1.920	2.575
1971	0.237	0.344	0.394	0.527	0.869	0.954	0.958	0.954	0.995
1972	0.397	0.404	0.418	0.452	0.522	0.662	0.923	1.050	1.762
1973	0.250	0.480	1.139	1.162	1.208	1.308	1.712	2.087	2.315
1974	0.279	0.492	0.800	1.342	1.601	2.312	2.519	2.815	3.020

TABLE A21

ANNUAL MAXIMUM RUNOFF DEPTH (IN), WATERSHED W-2

YEAR	DURATION (HOURS)								
	1	2	6	12	24	48	72	120	192
1950	0.036	0.049	0.133	0.199	0.237	0.307	0.309	0.389	0.517
1951	0.416	0.617	1.052	1.390	1.481	1.481	2.190	2.458	3.014
1952	0.126	0.209	0.399	0.571	0.672	0.739	0.739	0.739	0.739
1953	0.132	0.218	0.361	0.415	0.436	0.443	0.451	0.501	0.564
1954	0.060	0.098	0.153	0.197	0.217	0.240	0.256	0.264	0.406
1955	0.057	0.101	0.179	0.205	0.318	0.448	0.460	0.495	0.518
1956	0.027	0.050	0.122	0.189	0.289	0.345	0.377	0.464	0.559
1957	0.035	0.065	0.116	0.182	0.194	0.220	0.281	0.468	0.561
1958	0.402	0.553	0.673	0.696	0.733	0.743	0.804	1.169	1.304
1959	0.021	0.042	0.112	0.183	0.309	0.612	0.845	0.907	0.933
1960	0.169	0.256	0.377	0.462	0.584	0.586	0.633	0.715	0.722
1961	0.571	0.835	1.306	1.515	1.659	1.744	1.849	1.880	1.914
1962	0.042	0.072	0.127	0.152	0.171	0.216	0.216	0.216	0.216
1963	0.016	0.026	0.046	0.076	0.136	0.256	0.376	0.616	0.976
1964	0.022	0.029	0.053	0.057	0.057	0.080	0.080	0.109	0.149
1965	0.050	0.078	0.160	0.236	0.290	0.377	0.377	0.377	0.517
1966	0.056	0.103	0.288	0.546	0.970	1.435	1.449	1.453	1.460
1967	0.060	0.102	0.261	0.408	0.529	0.592	0.678	0.723	1.063
1968	0.101	0.184	0.403	0.558	1.047	1.273	1.648	2.186	2.283
1970	0.336	0.457	0.583	0.596	0.833	0.993	1.309	1.369	1.450
1971	0.617	0.624	0.643	0.752	0.768	0.768	0.768	0.990	1.221
1972	0.139	0.251	0.482	0.519	0.531	0.568	0.780	1.105	1.592
1973	0.242	0.344	0.511	0.604	0.647	0.735	0.835	1.072	1.200
1974	0.316	0.492	0.817	1.455	1.644	2.277	2.448	2.789	2.973

Table A22

Maximum Exceedance Runoff Depth (In.) Watershed A-1

Date	Duration (hours)								
	1	2	6	12	24	48	72	120	192
10-21-49	0.148	0.189	0.219	0.223	0.223	0.224	0.224	0.224	0.224
12-22-49	0.134	0.236	0.557	0.692	0.766	0.772	0.772	0.772	0.772
1-04-50	0.064	0.110	0.264	0.504	0.652	0.658	0.658	0.658	0.658
2-21-51	0.183	0.350	0.841	1.188	1.218	1.218	1.218	1.218	1.218
6-28-51	0.301	0.423	0.552	0.559	0.559	0.560	0.560	0.560	0.560
7-09-51	0.464	0.646	0.814	0.828	0.828	0.828	0.828	0.828	0.828
4-23-52	0.142	0.238	0.433	0.617	0.634	0.634	0.634	0.634	0.634
3-16-53	0.115	0.201	0.320	0.348	0.355	0.356	0.356	0.356	0.356
4-02-53	0.105	0.172	0.266	0.293	0.442	0.522	0.522	0.522	0.522
5-27-55	0.290	0.367	0.463	0.474	0.477	0.477	0.477	0.477	0.477
10-07-55	0.366	0.610	1.192	1.299	1.301	1.301	1.301	1.301	1.301
6-28-57	0.138	0.239	0.366	0.366	0.366	0.366	0.366	0.366	0.366
6-11-58	0.374	0.565	0.687	0.687	0.687	0.687	0.687	0.687	0.687
7-11-58	0.156	0.292	0.380	0.380	0.380	0.380	0.380	0.380	0.380
2-10-59	0.289	0.462	0.669	1.285	1.425	1.430	1.430	1.430	1.430
5-09-61	0.690	0.975	1.504	1.559	1.561	1.561	1.561	1.561	1.561
3-21-62	0.134	0.231	0.430	0.458	0.458	0.458	0.458	0.458	0.458
4-20-64	0.552	0.798	1.328	1.554	1.765	1.966	1.966	1.966	1.966
6-21-64	0.134	0.154	0.168	0.170	0.170	0.170	0.170	0.170	0.170
12-21-67	-.152	0.234	0.323	0.626	0.631	0.631	0.631	0.631	0.631
6-15-68	0.107	0.168	0.333	0.336	0.527	0.529	0.529	0.529	0.529
4-19-70	0.096	0.176	0.324	0.409	0.594	0.695	0.695	0.695	0.695
6-16-70	0.347	0.434	0.648	0.707	0.710	0.710	0.710	0.710	0.710
7-04-71	0.147	0.269	0.445	0.501	0.503	0.503	0.503	0.503	0.503
12-10-71	0.334	0.538	0.848	1.014	1.051	1.051	1.051	1.051	1.051
12-15-71	0.098	0.164	0.340	0.591	0.968	1.170	1.170	1.170	1.170
4-23-72	0.128	0.243	0.548	0.671	0.678	0.688	0.761	0.761	0.761
12-30-72		0.068	0.171	0.292	0.540	0.665	0.665	0.665	0.665
6-07-73	0.568	0.740	1.051	1.118	1.130	1.198	1.198	1.198	1.198
6-19-73	0.142	0.197	0.440	0.488	0.489	0.489	0.489	0.489	0.489

Table A22 (continued)

Date	Duration (hours)								
	1	2	6	12	24	48	72	120	192
7-23-73	0.274	0.397	0.502	0.506	0.506	0.506	0.506	0.506	0.506
1-23-74	0.136	0.253	0.470	0.790	1.055	1.065	1.142	1.158	1.158
5-22-74	0.105	0.179	0.253	0.255	0.459	0.492	0.676	0.679	0.679
6-23-74	0.515	0.779	1.224	2.298	2.511	3.579	3.594	3.594	3.594

Table A23

Maximum Exceedance Runoff Depth (In.) Watershed B-1

Date	Duration (hours)								
	1	2	6	12	24	48	72	120	192
10-22-49	0.199	0.285	0.385	0.403	0.406	0.411	0.411	0.411	0.411
12-22-49	0.208	0.390	0.897	1.163	1.283	1.307	1.307	1.307	1.307
1-03-51	0.113	0.202	0.380	0.472	0.571	0.580	0.580	0.580	0.580
6-28-51	0.193	0.222	0.327	0.340	0.349	0.349	0.349	0.349	0.349
7-09-51	0.305	0.547	0.829	0.851	0.851	0.851	0.851	0.851	0.851
4-13-52	0.107	0.213	0.438	0.514	0.586	0.610	0.610	0.610	0.610
4-24-52	0.170	0.310	0.654	1.028	1.153	1.177	1.177	1.177	1.177
4-23-53	0.141	0.232	0.356	0.387	0.557	0.644	0.651	0.651	0.651
10-07-55	0.389	0.739	1.577	1.684	1.685	1.685	1.685	1.685	1.685
6-11-58	0.142	0.195	0.354	0.366	0.367	0.367	0.367	0.367	0.367
7-12-58	0.151	0.266	0.482	0.505	0.506	0.506	0.506	0.506	0.506
4-25-61	0.314	0.470	0.740	0.990	1.035	1.035	1.035	1.035	1.035
5-09-61	0.350	0.641	1.255	1.672	1.879	2.095	2.118	2.118	2.118
3-21-62	0.085	0.168	0.456	0.628	0.725	0.727	0.727	0.727	0.727
4-21-64	0.485	0.809	1.373	1.691	2.166	2.675	2.694	2.692	2.694
12-08-66	0.840	0.151	0.327	0.396	0.423	0.650	0.653	0.655	0.655
3-23-67			0.125	0.243	0.391	0.572	0.644	0.650	0.650
12-21-67	0.238	0.378	0.537	0.961	0.981	0.981	0.981	0.981	0.981
2-07-68	0.106	0.181	0.342	0.645	0.871	0.887	0.889	0.995	0.957
5-26-68	0.131	0.173	0.199	0.215	0.216	0.216	0.216	0.216	0.216
6-16-68	0.134	0.219	0.368	0.391	0.704	0.712	0.712	0.712	0.712
6-16-70	0.318	0.367	0.430	0.432	0.655	0.655	0.655	0.655	0.655
7-05-71	0.257	0.319	0.416	0.469	0.469	0.469	0.469	0.469	0.469
4-22-72	0.134	0.263	0.521	0.595	0.715	0.749	0.863	0.863	0.863
4-21-73	0.151	0.242	0.330	0.332	0.333	0.333	0.333	0.333	0.333
6-07-73	0.674	1.234	1.798	2.029	2.039	2.040	2.040	2.040	2.040
6-19-73	0.187	0.336	0.594	0.624	0.624	0.624	0.624	0.624	0.624
7-23-73	0.242	0.406	0.485	0.486	0.486	0.486	0.486	0.486	0.486
2-22-74	0.151	0.281	0.663	0.916	0.948	0.984	1.109	1.109	1.109

Table A23 (continued)

Date	Duration (hours)								
	1	2	6	12	24	48	72	120	192
3-12-74	0.070	0.141	0.408	0.704	0.926	1.039	1.044	1.072	1.072
5-22-74	0.279	0.534	1.041	1.123	1.125	1.127	1.880	2.383	2.383
5-30-74	0.149	0.254	0.345	0.346	0.346	0.346	0.346	0.346	0.346
6-23-74	0.426	0.529	0.593	1.146	1.188	1.739	1.739	1.739	1.739
1-11-75	0.131	0.233	0.369	0.391	0.603	0.604	0.604	0.604	0.604
2-04-75	0.119	0.207	0.492	0.726	0.752	1.333	1.336	1.336	1.336

Table A24

Maximum Exceedance Runoff Depth (In.) Watershed W-1

Date	Duration (hours)								
	1	2	6	12	24	48	72	120	192
7-17-52	0.108	0.188	0.473	0.754	0.981	1.345	1.442	1.611	1.765
6-18-53	0.085	0.144	0.298	0.434	0.725	1.084	1.270	1.531	1.752
8-21-54	0.098	0.106							
5-07-55						0.315	0.385	0.447	0.533
7-05-55	0.081	0.140	0.227	0.285	0.390	0.535	0.604	0.717	0.799
8-28-56	0.052	0.099	0.142		0.240	0.347	0.459	0.593	0.639
8-12-57	0.067	0.132	0.307	0.438	0.547	0.667	0.733	0.824	1.005
8-19-58	0.126	0.230	0.436	0.504	0.594	0.718	0.821	1.091	1.398
8-15-60	0.064	0.112	0.235	0.320	0.452	0.589	0.656	0.828	0.978
7-14-61	0.724	1.131	1.652	1.891	2.140	2.476	2.629	2.905	3.151
4-17-62	0.117	0.217	0.493	0.703	0.910	1.153	1.324	1.547	1.741
6-24-62		0.073	0.213	0.346	0.358	0.368	0.377	0.391	0.502
5-18-63						0.379	0.553	0.698	0.744
4-11-64	0.049	0.089	0.183	0.285	0.409	0.558	0.626	0.724	0.763
7-13-65	0.068	0.122	0.287	0.417	0.521	0.668	0.746	0.871	1.357
6-28-66	0.099	0.118	0.195	0.291	0.476	0.722	0.916	1.300	1.689
7-29-66	0.108	0.134	0.163						
8-11-66	0.064	0.119	0.159	0.228	0.228				
8-15-66	0.137	0.309	0.210						
9-03-66	0.111	0.138	0.142						
7-11-67	0.070	0.071		0.217	0.380	0.583	0.743	0.916	1.311
7-31-67	0.227	0.227	0.227	0.227	0.227				
8-19-67	0.139	0.146	0.146						
8-26-67	0.160	0.160	0.160						
9-20-67	0.283	0.318	0.318	0.318	0.318	0.337	0.337	0.337	0.337
8-18-68	0.121	0.141	0.319	0.439	0.686	1.071	1.522	2.090	2.453
7-24-70	0.111	0.201	0.437	0.558	1.096	1.431	1.639	1.920	2.575
5-05-71	0.156	0.191	0.214	0.215	0.217				0.335

Table A24 (continued)

Date	Duration (hours)								
	1	2	6	12	24	48	72	120	192
5-17-71	0.046	0.080	0.152	0.223	0.295	0.306	0.311	0.450	0.508
5-25-71	0.051	0.086	0.228	0.441	0.869	0.954	0.954		
8-14.71	0.237	0.344	0.394	0.527	0.523	0.679	0.695	0.799	0.995
7-18-72	0.397	0.404	0.418	0.452	0.522	0.622	0.923	1.050	1.762
8-14-73	0.250	0.480	1.139	1.162	1.208	1.308	1.712	2.087	2.315
7-28-74	0.279	0.492	0.800	1.342	1.601	2.312	2.519	2.815	3.020

Table A25

Maximum Exceedance Runoff Depth (In.) Watershed W-2

Date	Duration (hours)								
	1	2	6	12	24	48	72	120	192
2-19-51	0.143	0.231	0.472	0.647	0.719	0.850	0.993	1.431	1.533
3-03-51	0.169	0.333	0.886	1.390	1.481	1.481	1.481	1.481	1.481
6-30-51	0.217	0.357	0.529	0.583	0.615	0.655	0.659		
7-10-51	0.416	0.617	1.052	1.260	1.291	1.291	1.291	1.291	
8-30-51	0.109	0.193	0.413	0.608	0.704	0.725	0.725	0.922	
11-13-51	0.062	0.119	0.316	0.499	0.708	0.829	0.839	0.839	
12-31-51	0.066	0.122	0.253	0.391					
4-23-52	0.128	0.209	0.399	0.571	0.672				
3-15-53	0.132	0.218	0.361	0.415	0.436	0.443			
5-28-55	0.150	0.199	0.218						
5-02-56						0.503	0.589	0.630	0.662
6-18-58	0.402	0.553	0.673	0.696	0.733	0.733	0.784	0.838	0.873
7-31-58	0.347	0.390	0.554	0.604	0.668	0.743	0.804	1.169	1.304
3-06-59						0.529	0.646	0.724	0.824
5-23-59						0.612	0.848	0.907	0.933
4-17-60	0.155	0.182	0.229	0.355	0.470	0.742	0.800	0.917	1.074
7-13-60	0.169	0.256	0.377	0.462	0.584	0.586	0.633	0.710	0.710
5-09-61	0.571	0.835	1.306	1.516	1.659	1.744	1.849	1.880	1.914
3-19-63								0.616	0.976
2-12-66	0.049	0.098	0.288	0.546	0.970	1.435	1.449	1.453	1.460
4-24-66	0.056	0.103	0.213	0.301	0.419	0.512	0.512		
2-22-67	0.053	0.102	0.261	0.408	0.529	0.592	0.678	0.723	1.063
8-01-67	0.060	0.075				0.494	0.581	0.679	0.727
8-29-67									0.710
2-06-68	0.071	0.137	0.320	0.535	0.917	1.266	1.648	2.186	2.283
5-27-68	0.071	0.139	0.311	0.383	0.447	0.549	0.749		
7-07-68	0.101	0.184	0.403	0.558	1.047	1.273	1.356	1.465	1.630
1-31-69	0.045	0.083	0.198	0.277	0.373	0.660	0.660		
4-21-70	0.054	0.108	0.324	0.568	0.646	0.993	1.309	1.369	1.450

Table A25 (continued)

Date	Duration (hours)								
	1	2	6	12	24	48	72	120	192
6-21-70	0.336	0.457	0.583	0.596	0.833	0.854	0.955	1.004	1.074
2-05-71	0.146	0.268	0.562	0.752	0.768				
7-05-71	0.180	0.321	0.550	0.687	0.742	0.742	0.742	0.742	
9-20-71	0.264	0.265	0.269	0.275					
9-26-71	0.614	0.624	0.643	0.651					
12-11-71	0.143	0.225	0.376	0.514	0.561	0.586	0.601		
4-29-72	0.139	0.251	0.482	0.519	0.531	0.568	0.780	1.105	1.592
3-23-73	0.082	0.157	0.309	0.395	0.502	0.558	0.659	1.072	1.200
6-05-73	0.164	0.248	0.511	0.604	0.647	0.735	0.736	0.757	0.866
7-05-73	0.047	0.091	0.245	0.312	0.377	0.507	0.575		0.640
7-24-73	0.242	0.344	0.426	0.436	0.436	0.442	0.835		
7-04-74	0.316	0.492	0.817	1.455	1.644	2.277	2.448	2.789	2.973
	0.073	0.130	0.333	0.454	0.613	0.821	0.886	1.033	1.429

TABLE A26

DAILY AVERAGE MINIMUM TEMPERATURE (DEGREES FAHRENHEIT)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1955	-8.0	-9.0	6.0	30.0	39.0	46.0	59.0	50.0	41.0	32.0	8.0	2.0
1956	1.0	13.0	16.0	28.0	29.0	39.0	48.0	46.0	29.0	26.0	12.0	12.0
1957	-11.0	11.0	9.0	20.0	30.0	44.0	53.0	46.0	30.0	23.0	14.0	3.0
1958	5.0	0.0	18.0	28.0	30.0	45.0	57.0	45.0	34.0	18.0	4.0	0.0
1959	0.0	0.0	18.0	25.0	38.0	40.0	48.0	58.0	40.0	22.0	3.0	16.0
1960	1.0	3.0	-2.0	26.0	35.0	50.0	51.0	51.0	43.0	21.0	18.0	-11.0
1961	-5.0	5.0	20.0	19.0	33.0	44.0	45.0	43.0	37.0	25.0	16.0	-2.0
1962	-10.0	1.0	2.0	21.0	44.0	49.0	53.0	52.0	30.0	6.0	16.0	0.0
1963	-14.0	-6.0	6.0	25.0	27.0	47.0	50.0	46.0	31.0	26.0	14.0	-6.0
1964	4.0	10.0	12.0	26.0	5.0	42.0	48.0	46.0	40.0	19.0	9.0	2.0
1965	-5.0	-6.0	11.0	30.0	29.0	48.0	51.0	47.0	47.0	35.0	17.0	5.0
1966	-12.0	2.0	16.0	20.0	26.0	37.0	56.0	51.0	39.0	21.0	14.0	8.0
1967	-6.0	-5.0	13.0	32.0	29.0	24.0	43.0	41.0	31.0	27.0	15.0	-10.0
1968	-13.0	3.0	13.0	30.0	36.0	51.0	53.0	49.0	46.0	31.0	20.0	-3.0
1969	-5.0	-14.0	7.0	34.0	15.0	43.0	55.0	50.0	41.0	22.0	13.0	5.0

TABLE A27

DAILY AVERAGE MAXIMUM TEMPERATURE (DEGREES FAHRENHEIT)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1955	58.0	57.0	72.0	80.0	88.0	91.0	95.0	96.0	98.0	84.0	76.0	58.0
1956	52.0	64.0	74.0	80.0	91.0	94.0	94.0	92.0	92.0	84.0	72.0	67.0
1957	54.0	64.0	69.0	82.0	80.0	90.0	94.0	95.0	91.0	76.0	64.0	58.0
1958	50.0	63.0	56.0	83.0	85.0	92.0	89.0	94.0	93.0	82.0	73.0	52.0
1959	56.0	63.0	79.0	83.0	92.0	96.0	94.0	95.0	93.0	79.0	66.0	61.0
1960	62.0	45.0	71.0	84.0	84.0	91.0	91.0	93.0	96.0	82.0	72.0	61.0
1961	88.0	65.0	70.0	74.0	85.0	99.0	93.0	92.0	94.0	80.0	74.0	60.0
1962	49.0	58.0	70.0	85.0	90.0	94.0	89.0	95.0	89.0	87.0	61.0	59.0
1963	48.0	51.0	80.0	82.0	86.0	95.0	95.0	92.0	87.0	88.0	68.0	59.0
1964	58.0	60.0	65.0	79.0	86.0	90.0	94.0	96.0	93.0	74.0	87.0	53.0
1965	62.0	58.0	60.0	83.0	86.0	80.0	86.0	82.0	89.0	82.0	90.0	83.0
1966	58.0	63.0	80.0	75.0	90.0	91.0	101.0	91.0	90.0	79.0	71.0	67.0
1967	66.0	62.0	79.0	84.0	96.0	94.0	91.0	93.0	84.0	88.0	61.0	64.0
1968	53.0	57.0	77.0	78.0	87.0	93.0	91.0	92.0	88.0	83.0	72.0	56.0
1969	58.0	44.0	70.0	78.0	87.0	93.0	97.0	93.0	90.0	86.0	66.0	51.0

TABLE A28

DAILY AVERAGE MINIMUM HUMIDITY (PER CENT)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1955	27.0	35.0	23.0	13.0	19.0	45.0	44.0	35.0	29.0	29.0	28.0	46.0
1956	20.0	17.0	11.0	10.0	14.0	25.0	31.0	30.0	14.0	13.0	19.0	27.0
1957	30.0	26.0	15.0	22.0	14.0	20.0	21.0	24.0	16.0	18.0	18.0	30.0
1958	27.0	31.0	22.0	15.0	16.0	18.0	29.0	23.0	20.0	14.0	18.0	14.0
1959	31.0	25.0	15.0	15.0	16.0	17.0	15.0	23.0	16.0	23.0	19.0	25.0
1960	37.0	25.0	37.0	33.0	32.0	28.0	25.0	29.0	22.0	16.0	25.0	36.0
1961	36.0	26.0	19.0	13.0	15.0	21.0	16.0	26.0	15.0	15.0	20.0	23.0
1962	16.0	32.0	22.0	19.0	19.0	25.0	22.0	33.0	17.0	12.0	18.0	14.0
1963	41.0	29.0	12.0	10.0	16.0	17.0	31.0	25.0	13.0	6.0	13.0	26.0
1964	17.0	19.0	9.0	8.0	12.0	6.0	20.0	19.0	14.0	9.0	10.0	32.0
1965	28.0	26.0	21.0	14.0	31.0	8.0	18.0	8.0	50.0	48.0	50.0	34.0
1966	40.0	36.0	30.0	26.0	24.0	24.0	34.0	32.0	26.0	21.0	28.0	39.0
1967	28.0	36.0	32.0	30.0	28.0	32.0	36.0	41.0	33.0	29.0	33.0	24.0
1968	46.0	27.0	19.0	27.0	21.0	30.0	33.0	36.0	27.0	30.0	26.0	24.0
1969	45.0	24.0	24.0	28.0	30.0	28.0	28.0	9.0	23.0	9.0	22.0	38.0

TABLE A29

DAILY AVERAGE MAXIMUM HUMIDITY (PER CENT)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1955	99.0	99.0	99.0	99.0	99.0	99.0	99.0	98.0	98.0	99.0	99.0	99.0
1956	100.0	100.0	100.0	100.0	100.0	99.0	99.0	92.0	100.0	97.0	100.0	96.0
1957	96.0	94.0	98.0	96.0	94.0	92.0	95.0	90.0	100.0	96.0	92.0	100.0
1958	98.0	100.0	96.0	98.0	90.0	91.0	87.0	91.0	90.0	93.0	98.0	100.0
1959	98.0	100.0	92.0	90.0	90.0	90.0	92.0	97.0	100.0	96.0	100.0	100.0
1960	100.0	100.0	100.0	100.0	100.0	100.0	91.0	98.0	98.0	100.0	100.0	100.0
1961	99.0	100.0	91.0	92.0	88.0	100.0	100.0	96.0	97.0	98.0	98.0	89.0
1962	88.0	98.0	100.0	100.0	100.0	100.0	100.0	100.0	98.0	99.0	96.0	96.0
1963	99.0	100.0	95.0	96.0	96.0	94.0	95.0	98.0	98.0	91.0	94.0	98.0
1964	100.0	100.0	98.0	100.0	96.0	90.0	100.0	95.0	99.0	100.0	100.0	94.0
1965	95.0	100.0	92.0	94.0	100.0	100.0	100.0	100.0	96.0	94.0	89.0	100.0
1966	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1967	100.0	100.0	100.0	100.0	100.0	96.0	93.0	96.0	98.0	96.0	98.0	100.0
1968	98.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1969	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE A30

DAILY AVERAGE MAXIMUM WIND SPEED (MILES PER HOUR)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1955	15.20	22.42	20.66	12.55	12.40	11.38	8.63	8.08	8.29	10.31	14.26	12.98
1956	9.80	12.45	14.19	15.84	19.43	12.79	13.27	15.33	16.09	9.92	13.86	11.63
1957	11.94	17.86	15.41	15.94	15.33	7.74	18.24	24.28	21.00	17.79	20.92	20.26
1958	18.61	82.22	12.61	16.03	9.39	17.94	16.51	16.18	16.71	15.19	18.15	16.45
1959	18.90	16.24	29.38	20.07	21.30	15.05	13.90	13.06	17.58	21.46	19.72	16.56
1960	20.55	20.07	19.76	22.75	20.90	16.82	15.22	15.09	13.13	25.02	20.89	17.42
1961	15.04	20.02	21.92	22.85	17.03	17.10	12.95	18.52	19.34	14.24	19.75	23.27
1962	16.69	19.03	20.01	19.96	17.06	13.59	13.35	15.88	14.55	17.56	17.44	20.35
1963	19.66	21.77	24.37	21.04	17.03	14.58	12.21	15.67	18.35	17.23	26.93	21.49
1964	26.60	19.63	21.20	23.51	23.41	22.00	16.48	16.93	16.47	16.95	21.35	17.45
1967	19.61	20.92	17.96	18.34	17.56	13.09	13.38	13.33	14.28	15.77	14.83	20.90
1968	15.84	24.33	23.00	26.64	21.96	16.64	12.10	18.65	11.75	17.63	19.30	22.48
1969	21.10	17.29	21.94	21.06	12.22	17.99	15.41	14.89	13.97	15.25	16.61	15.76
1970	16.15	16.68	18.68	19.28	28.89	16.76	12.76	12.97	11.78	17.67	15.39	17.04
1971	17.26	23.23	22.58	16.00	16.48	12.40	12.71	11.35	13.85	18.59	16.85	20.23
1972	19.62	20.97	17.69	16.79	17.01	13.27	13.59	11.59	13.71	13.94	21.15	15.99
1973	20.99	16.57	22.70	19.75	18.15	14.41	13.40	13.40	13.32	15.74	18.14	18.63
1974	14.10	10.22	16.70	26.08	13.97	15.49	13.32	13.30	16.49	17.27	15.85	20.12
1975	20.51	18.47	18.57	18.49	13.47	24.27	12.28	14.03	18.21	15.57	19.81	19.25
1976	19.82	14.68	22.53	19.53	20.60	14.85	13.22	13.85	12.03	15.02	14.40	16.96

TABLE A31

DAILY AVERAGE MINIMUM WIND SPEED (MILES PER HOUR)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1955	15.20	22.42	20.66	12.55	12.40	11.38	8.63	8.08	8.29	10.31	14.26	12.98
1955	2.90	3.56	2.87	3.08	1.86	0.88	0.99	0.84	0.79	1.15	2.64	1.77
1956	1.87	3.06	3.49	3.39	3.78	1.08	2.62	0.69	1.45	0.84	2.67	1.71
1957	1.22	1.49	2.19	1.78	1.94	0.86	1.65	0.83	0.72	3.31	4.24	2.68
1958	2.96	2.57	2.80	2.60	1.94	1.99	1.86	3.16	1.53	2.73	5.95	2.70
1959	4.50	3.20	3.72	5.00	4.41	4.12	3.48	4.05	4.21	4.67	4.33	4.67
1960	4.64	6.12	4.65	7.66	4.81	5.61	5.40	4.61	5.25	3.37	6.08	6.66
1961	5.15	4.19	5.36	6.67	2.16	2.49	1.22	3.15	1.41	0.98	1.80	3.05
1962	6.02	3.96	1.94	5.41	2.90	1.26	1.45	0.51	1.25	1.58	2.86	2.21
1963	3.58	4.92	4.73	5.36	4.07	3.56	2.71	2.59	2.72	4.55	5.39	3.70
1964	4.50	4.07	4.86	4.65	4.31	2.56	2.08	3.80	2.75	1.76	2.50	3.69
1967	5.82	2.97	2.82	6.04	3.44	2.29	2.54	2.10	2.97	5.24	4.79	3.89
1968	3.60	0.63	4.96	3.21	3.95	3.73	2.98	2.65	2.86	4.06	2.34	4.53
1969	1.54	4.32	4.13	3.86	2.21	2.74	2.78	1.67	3.13	3.38	3.22	3.62
1970	5.00	3.11	2.69	3.46	6.88	4.33	3.39	1.85	2.63	2.78	2.62	1.36
1971	3.46	4.31	4.15	2.71	3.77	3.70	3.11	2.97	3.12	2.78	3.48	3.18
1972	4.55	2.98	4.89	4.45	2.81	2.10	3.54	3.20	3.33	2.48	3.91	3.28
1973	3.80	5.16	3.69	3.79	4.07	4.40	4.56	2.50	3.28	2.56	3.57	2.93
1974	1.59	7.14	6.82	4.25	3.99	4.64	2.19	2.05	2.90	1.52	1.94	3.65
1975	3.32	6.19	3.99	4.62	3.82	3.08	2.83	2.51	1.51	4.14	2.44	2.53
1976	4.56	2.38	3.13	1.90	3.62	2.21	2.54	3.08	2.70	2.79	1.44	5.17

APPENDIX B

FREQUENCY DISTRIBUTION COMPUTATIONS

APPENDIX B1

Procedure for Fitting the Log-Normal Frequency Distribution

The procedure used by McGuinness and Brakensiek (1964) is used in the study. The procedure is based on the general formula for hydrologic frequency analysis developed by Chow (1957). The general formula is:

$$\log_{10}x \;/\; \overline{\log_{10}x} = 1 + C_v K_y \quad \ldots\ldots \quad [14]$$

and since C_v is defined as $s/\overline{\log_{10}x}$, the above formula becomes:

$$\log_{10}x = \overline{\log_{10}x} + sK_y \quad \ldots\ldots \quad [15]$$

where C_v is the coefficient of variation, and s is the standard deviation which is estimated from:

$$s = \Sigma\,(\log_{10}x - \overline{\log_{10}x})^2 \;/\; \Sigma\,(\log_{10}x)\;K_y \quad \ldots\ldots \quad [16]$$

where K_y is the frequency factor from Appendix B, Table B1.

The step by step procedure for fitting the log-normal frequency distribution is as follows:

1. Rank the logarithms of the observed data in decreasing order.
2. Refer to Table B1 for K_y for the corresponding sample size or number of years of data (N).
3. Calculate the standard deviation s using the formula [16].
4. Calculate the mean of the logarithms of the observed data, $\overline{\log_{10}x} = \Sigma\,(\log_{10}x) \;/\; N$.
5. Substitute the calculated s, $\overline{\log_{10}x}$, and K_y into formula [15].

Note: Steps 1, 3, and 4 can be done using the computer program which is listed in Appendix B2.

APPENDIX B2

COMPUTER PROGRAM LIST

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 LOG-NORMAL DISTRIBUTION FREQUENCY ANALYSIS FOR MONTHLY AND
                     ANNUAL TOTAL RAINFALL
 REAL AMEAN(14),PROB,RI,SUMB(14),SUMC(14),SD(14)
 REAL X(100,14),JAN,MAR,MAY,JUN,JUL,NOV
 INTEGER YEAR(100),NUM(14),N
 PRINT,'MONTHLY AND ANNUAL TOTAL RAINFALL'
 THE PRINT STATEMENT NEEDS TO BE CHANGED FOR OTHER DATA
 PRINT 112
 FORMAT(12X,'JAN',4X,'FEB',4X,'MAR',5X,'APR',4X,'MAY',5X,
$ 'JUN',5X,'JUL',4X,'SEPT',4X,'OCT',6X,'NOV',5X,'DEC',
$ 4X,'ANN')
 FORMAT STATEMENT NEEDS TO BE CHANGED FOR GROWING SEASON
 DATA
 N=0
 N IS THE NUMBER OF YEARS, AS A COUNTER
 READ 10,YEAR(N+1),JAN,FEB,MAR,APR,MAY,JUN,JUL,AUG,SEP,OCT,
$ NOV,DEC,ANN,AKY
 FORMAT(I4,14F5.2)
 IF (YEAR(N+1).EQ.0) GOTO 8
 N=N+1
 X(N,1 )=JAN
 X(N,2 )=FEB
 X(N,3 )=MAR
 X(N,4 )=APR
 X(N,5 )=MAY
 X(N,6 )=JUN
 X(N,7 )=JUL
 X(N,8 )=AUG
 X(N,9 )=SEP
 X(N,10)=OCT
 X(N,11)=NOV
 X(N,12)=DEC
 X(N,13)=ANN
 X(N,14)=AKY
 GOTO 30
 ALL NUMBERS OF 13 IN THE DO STATEMENT ARE THE NUMBER OF THE
 VARIABLES OR NUMBER OF COLUMNS OF DATA IN THE DATA CARDS
 DO 9 I=1,13
 NUM(I)=N
 NUM IS THE NUMBER
 DO 40 I=1,13
 N=NUM(I)
 CONTINUE
 PRINTING OUT THE BASIC DATA
 DO 47 I=1,N
 PRINT 48,YEAR(I),X(I,1),X(I,2),X(I,3),X(I,4),X(I,5),X(I,6),
```

```
 $ X(I,7),X(I,8),X(I,9),X(I,10),X(I,11),X(I,12),X(I,13),
 $ X(I,14)
8  FORMAT(I5,14F6.2)
   RANKING THE DATA IN THE DECREASING ORDER
   DO 55 L=1,13
   N=NUM(L)
   NM1=N -1
   DO 80 I=1,NM1
   J=I+1
   DO 90 IO=J,N
   IF(X(I,L).GT.X(IO,L)) GOTO 90
   TEMP=X(I,L)
   X(I,L)=X(IO,L)
   X(IO,L)=TEMP
0  CONTINUE
0  CONTINUE
5  CONTINUE
   PRINT,'RANKED MONTHLY AND ANNUAL TOTAL RAINFALL'
   THE PRINT STATEMENT NEEDS TO BE CHANGED FOR OTHER DATA
   PRINT 114
4  FORMAT (2X,'RANK',5X,'JAN',6X,'FEB',6X,'MAR',6X,'APR',6X,
 $ 'MAY',6X,'JUN',6X,'JUL',6X,'AUG',6X,'SEP',6X,'OCT',6X,
 $ 'NOV',6X,'DEC',5X,'ANNUAL',5X,'KY')
   PRINTING OUT THE RANKED DATA AND THE CORRESPONDING
   FREQUENCY FACTOR KY
   THE LAST COLUMN IN THE DATA CARDS ARE THE FREQUENCY FACTOR
   KY FOR THE CORRESPONDING NUMBER OF SAMPLE SIZE
   DO 101 I=1,N
1  PRINT 102,I,X(I,1),X(I,2),X(I,3),X(I,4),X(I,5),X(I,6),
 $ X(I,7),X(I,8),X(I,9),X(I,10),X(I,11),X(I,12),X(I,13),
 $ X(I,14)
2  FORMAT(I5,14F6.2)
   DO 49 I=1,13
   N=NUM(I)
   TAKING THE LOGARITHMS TO THE BASE OF 10 OF THE DATA
   DO 74 J=1,N
   X(J,I)=ALOG10(X(J,I))
4  CONTINUE
   SUM=0
   CALCULATING THE LOGARITHM-MEAN
   DO 59 J=1,N
9  SUM=SUM+X(J,I)
   AMEAN(I)=SUM/N
9  CONTINUE
   PRINT,'LOG.DEPTH-FREQUENCY RELATIONSHIP'
   PRINT 29
9  FORMAT (2X,'RANK',1X,'PROB',4X,'RI',3X,'JAN',3X,'FEB',3X,
 $ 'MAR',3X,'APR',3X,'MAY',3X,'JUN',3X,'JUL',3X,'AUG',3X,
 $ 'SEP',3X,'OCT',3X,'NOV',3X,'DEC',3X,'ANN',3X,'KY')
   THE FORMAT NEEDS ADJUSTMENT FOR OTHER DATA
   XN=N
```

```
   CALCULATING THE PROBABILITY AND RECCURENCE INTERVALS
   DO 45 L=1,N
   XL=L
   PROB=XL/(XN +1)
   RI=1./PROB
5  PRINT 46,L,PROB,RI,X(L,1),X(L,2),X(L,3),X(L,4),X(L,5),
  $ X(L,6),X(L,7),X(L89),X(L,9 ),X(L,10),X(L,11),X(L,12),
  $ X(L,13),X(L,14)
6  FORMAT (I5,16F6.2)
   PRINTING OUT THE LOGARITHMS OF THE DATA
   DO 33 I=1,13
   CALCULATING THE STANDARD DEVIATION S
   SUMC(I)=0
   SUMB(I)=0
   DO 41 J=1,N
   SUMB(I)=SUMB(I)+X(J,I)*X(J,14)
   THE X(J,14) IS THE FREQUENCY FACTORS KY,NEEDS ADJUSTMENT
   ACCORDING TO THE LOCATION OR THE COLUMN OF THE KY IN
   THE CARDS
   SUMC(I)=SUMC(I)+(X(J,I)-AMEAN(I))**2
1  CONTINUE
3  CONTINUE
   DO 44 I=1,13
   SD(I)=SUMC(I)/SUMB(I)
   SD IS STANDARD DEVIATION
   CONTINUE
   PRIN3ING OUT THE LOGARITHMNS-MEAN AND THE STANDARD
   DEVIATIONS
   PRINT 78,AMEAN(1),AMEAN(2),AMEAN(3),AMEAN(4),AMEAN(5),
  $ AMEAN(6),AMEAN(7),AMEAN(8),AMEAN(9),AMEAN(10),AMEAN(11),
  $ AMEAN(12),AMEAN(13),SD(1),SD(2),SD(3),SD(4),SD(5),SD(6),
  $ SD(7),SD(8),SD(9),SD(10),SD(11),SD(12),SD(13),N2
3  FORMAT(12X,'MEAN=',13F6.3/12X,'SD  =',13F6.3/
  $ 12X,'N    =',I4)
   STOP
   END
RY
   THE DATA CARDS AS INPUTS ARE PLACED HERE
OP
```

Table B1

Standardized Normal Deviates or Frequency Factors

(K_y) for Various Sample Sizes (N) Used in the Study[a]

Rank	Frequency Factor K_y for:						
	N=15	N=20	N=23	N=24	N=25	N=26	N=27
1	1.53	1.67	1.73	1.75	1.77	1.79	1.80
2	1.15	1.31	1.38	1.40	1.43	1.45	1.47
3	0.89	1.07	1.15	1.18	1.20	1.23	1.24
4	0.67	0.87	0.97	0.99	1.02	1.04	1.07
5	0.49	0.71	0.81	0.84	0.87	0.90	0.92
6	0.32	0.57	0.67	0.71	0.74	0.77	0.79
7	0.16	0.43	0.55	0.58	0.61	0.65	0.67
8	0	0.30	0.43	0.47	0.50	0.54	0.56
9	-0.16	0.18	0.32	0.36	0.40	0.43	0.46
10	-0.32	0.06	0.21	0.25	0.29	0.33	0.37
11	-0.49	-0.06	0.10	0.15	0.19	0.24	0.27
12	-0.67	-0.18	0	0.05	0.10	0.14	0.18
13	-0.89	-0.30	-0.10	-0.05	0	0.05	0.09
14	-1.15	-0.43	-0.21	-0.15	-0.10	-0.05	0
15	-1.53	-0.57	-0.32	-0.25	-0.19	-0.14	-0.09
16		-0.71	-0.43	-0.36	-0.29	-0.24	-0.18
17		-0.87	-0.55	-0.47	-0.40	-0.33	-0.27
18		-1.07	-0.67	-0.58	-0.50	-0.43	-0.37
19		-1.31	-0.81	-0.71	-0.61	-0.54	-0.46
20		-1.67	-0.97	-0.84	-0.74	-0.65	-0.56
21			-1.15	-0.99	-0.87	-0.77	-0.67
22			-1.38	-1.18	-1.02	-0.90	-0.79
23			-1.73	-1.40	-1.20	-1.04	-0.92
24				-1.75	-1.43	-1.23	-1.07
25					-1.77	-1.45	-1.24
26						-1.79	-1.47
27							-1.80

[a]From McGuinness, J. L. and D. L. Brakensiek, 1964.

Table B2

Descriptive Statistics for Monthly and Annual Total Rainfall

Data	Descriptive Statistics	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
RG-1	log-mean	-0.044	0.116	0.285	0.532	0.459	0.525	0.507	0.381	0.378	0.166	0.314	0.127	1.525
	std. dev.	0.966	0.329	0.340	0.271	0.333	0.349	0.251	0.319	0.454	1.058	0.314	0.700	0.086
RG-5	log-mean	-0.152	0.136	0.320	0.535	0.469	0.514	0.419	0.361	0.376	0.199	0.308	0.099	1.524
	std. dev.	1.302	0.312	0.331	0.277	0.323	0.345	0.469	0.323	0.463	0.569	0.296	1.004	0.092
RG-3[a]	log-mean				0.523	0.469	0.517	0.485	0.385	0.352	0.215			
	std. dev.				0.283	0.314	0.323	0.235	0.329	0.450	0.460			
RG-4[a]	log-mean				0.523	0.468	0.541	0.482	0.356	0.294	0.227			
	std. dev.				0.268	0.336	0.310	0.251	0.344	0.510	0.463			
RG-6[a]	log-mean				0.519	0.456	0.527	0.500	0.367	0.364	0.206			
	std. dev.				0.237	0.313	0.329	0.247	0.308	0.470	0.461			
Combined raingages[b]	log-mean	-0.098	0.126	0.302	0.526	0.464	0.525	0.429	0.370	0.353	0.203	0.311	0.113	1.525
	std. dev.	1.134	0.320	0.335	0.267	0.324	0.561	0.291	0.325	0.469	0.602	0.305	0.852	0.089
Watershed A-1	log-mean	-0.128	0.142	0.330	0.556	0.431	0.522	0.498	0.387	0.384	0.187	0.305	0.118	1.520
	std. dev.	1.315	0.313	0.303	0.320	0.319	0.344	0.249	0.324	0.423	0.568	0.929	1.011	0.085
Watershed B-1	log-mean	-0.119	0.133	0.330	0.524	0.441	0.522	0.494	0.387	0.379	0.213	0.305	0.122	1.523
	std. dev.	1.324	0.325	0.304	0.275	0.325	0.341	0.262	0.330	0.431	0.559	0.298	1.014	0.085
Watershed W-1	log-mean	-0.140	0.136	0.331	0.531	0.447	0.524	0.494	0.381	0.380	0.196	0.308	0.113	1.521
	std. dev.	1.311	0.317	0.306	0.265	0.325	0.344	0.251	0.328	0.431	0.551	0.291	1.008	0.086
Watershed W-2	log-mean	-0.147	0.138	0.330	0.520	0.444	0.530	0.499	0.375	0.373	0.177	0.307	0.109	1.519
	std. dev.	1.311	0.314	0.311	0.266	0.335	0.324	0.257	0.314	0.474	0.557	0.296	1.006	0.087

[a]Growing season data.

[b]Average of RG1 and RG5 for non-growing season, and average of all the raingages for growing season.

Table B3

Descriptive Statistics for Annual Maximum Rainfall Intensities

Data	Descriptive Statistics	Duration (minutes)										
		2	5	10	15	20	30	60	120	240	360	720
RG-1	log-mean	0.69	0.62	0.55	0.47	0.42	0.32	0.11	-0.11	-0.33	-0.45	-0.70
	std. dev.	0.23	0.19	0.15	0.15	0.14	0.14	0.15	0.13	0.15	0.15	0.16
RG-5	log-mean	0.76	0.69	0.59	0.49	0.41	0.31	0.10	-0.11	-0.34	-0.49	-0.70
	std. dev.	0.26	0.19	0.16	0.15	0.16	0.16	0.19	0.16	0.16	0.16	0.15
Combined RG-1 and RG-5	log-mean	0.73	0.66	0.57	0.48	0.42	0.32	0.11	-0.11	-0.34	-0.47	-0.70
	std. dev.	0.25	0.19	0.16	0.15	0.15	0.15	0.17	0.15	0.16	0.16	0.16
Watershed A-1	log-mean	0.74	0.66	0.58	0.49	0.43	0.32	0.11	-0.11	-0.34	-0.47	-0.72
	std. dev.	0.15	0.15	0.14	0.15	0.14	0.15	0.15	0.14	0.16	0.15	0.15
Watershed B-1	log-mean	0.71	0.63	0.55	0.46	0.41	0.30	0.10	-0.12	-0.34	-0.47	-0.72
	std. dev.	0.15	0.16	0.17	0.16	0.15	0.15	0.15	0.15	0.16	0.15	0.16
Watershed W-1	log-mean	0.64	0.56	0.48	0.40	0.33	0.23	0.06	-0.14	-0.35	-0.49	-0.73
	std. dev.	0.21	0.15	0.12	0.13	0.14	0.15	0.16	0.15	0.16	0.16	0.16
Watershed W-2	log-mean	0.78	0.72	0.61	0.52	0.44	0.32	0.10	-0.11	-0.34	-0.47	-0.72
	std. dev.	0.13	0.10	0.11	0.14	0.15	0.18	0.18	0.17	0.16	0.15	0.16

Table B4

Descriptive Statistics for Annual Exceedance Runoff Depth

Water-shed	Descriptive Statistics	Duration (hours) 1	2	6	12	24	48	72	120	192
A-1	log-mean	-0.633	-0.439	-0.217	-0.123	-0.089	-0.072	-0.064	-0.064	-0.064
	std. dev.	0.286	0.247	0.214	0.223	0.221	0.247	0.242	0.243	0.243
B-1	log-mean	-0.656	-0.444	-0.217	-0.118	-0.059	-0.022	-0.007	-0.002	-0.002
	std. dev.	0.226	0.232	0.238	0.241	0.215	0.224	0.230	0.237	0.237
W-1	log-mean	-0.815	-0.666	-0.451	-0.328	-0.203	-0.098	-0.028	0.035	0.120
	std. dev.	0.287	0.294	0.291	0.276	0.256	0.260	0.251	0.263	0.262
W-2	log-mean	-0.685	-0.506	-0.284	-0.174	-0.097	-0.043	0.001	0.049	0.076
	std. dev.	0.252	0.216	0.184	0.196	0.173	0.189	0.183	0.182	0.188

Table B5

Descriptive Statistics for Temperature, Humidity, and Wind Speed

Data	Descriptive Statistics	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Min.[a] Temp.	log-mean	1.165	1.306	1.490	1.664	1.694	1.801	1.853	1.832	1.756	1.636	1.515	1.325
	std. dev.	-0.033	-0.039	-0.030	-0.019	-0.043	-0.027	-0.015	-0.014	-0.023	-0.030	-0.023	-0.037
Max. Temp.	log-mean	1.760	1.762	1.852	1.906	1.942	1.964	1.968	1.967	1.959	1.915	1.852	1.779
	std. dev.	0.082	0.069	0.055	0.022	0.022	0.027	0.020	0.023	0.020	0.026	0.058	0.064
Min. Hum.	log-mean	1.474	1.432	1.286	1.236	1.289	1.315	1.409	1.382	1.317	1.229	1.334	1.437
	std. dev.	-0.200	-0.145	-0.226	-0.251	-0.192	-0.306	-0.187	-0.294	-0.223	-0.299	-0.224	-0.207
Max. Hum.	log-mean	1.991	1.997	1.988	1.989	1.986	1.985	1.985	1.985	1.992	1.988	1.989	1.992
	std. dev.	0.021	0.013	0.020	0.020	0.026	0.024	0.025	0.019	0.017	0.016	0.021	0.021
Min. Wind Speed	log-mean	0.433	0.430	0.466	0.492	0.420	0.299	0.292	0.219	0.247	0.297	0.398	0.391
	std. dev.	-0.240	-0.288	-0.158	-0.190	-0.178	-0.281	-0.209	-0.325	-0.274	-0.266	-0.195	-0.192
Max. Wind Speed	log-mean	1.139	1.189	1.191	1.182	1.130	1.072	1.026	1.057	1.064	1.102	1.152	1.151
	std. dev.	0.114	0.233	0.098	0.093	0.128	0.124	0.081	0.114	0.108	0.108	0.108	0.089

[a]Coded to actual temperature = (t coded - 20)°F.

APPENDIX C

COMPARISON TEST DATA

APPENDIX C1

Procedure of t-Test for Testing the Differences Between Two Sets of Data

First, we have to list the two sets of data as follows:

Pair #	Data from Station: 1	2	Difference $X_i = Y_{i1} - Y_{i2}$
1	Y_{11}	Y_{12}	X_1
2	Y_{21}	Y_{22}	X_2
3	Y_{31}	Y_{32}	X_3
.	.	.	.
.	.	.	.
n	Y_{n1}	Y_{n2}	X_n
	Total difference =		ΣX_i

In this table, a single observation is denoted by Y_{ij}, where the first subscript corresponds to the pair, the second to the station.

To estimate the mean difference and to test hypotheses about the difference between the station effects, we use the differences between the member of each pair,

$$X_i = Y_{i1} - Y_{i2} \quad \text{[17]}$$

and treat these as a random sample from the population differences. We then have,

$$\bar{X} = \frac{1}{n} \Sigma X_i \quad \text{[18]}$$

and

$$s_x^2 = \frac{1}{n-1} \Sigma (X_i - \bar{X})^2 \quad \text{[19]}$$

as unbiased estimates for U_X, the mean differences, and for σ_X^2, the variance of the differences, respectively.

The variance of the mean difference $\overline{X}$ is estimated unbiasedly by,

$$s_{\overline{X}}^2 = \frac{s_X^2}{n} \qquad [20]$$

The test of the hypotheses H_o: $U_X = U_o$ is the single-sample t-test with (n-1) degrees of freedom based on the statistic,

$$t = \frac{\overline{X} - U_o}{s_{\overline{X}}} \qquad [21]$$

The test of the hypotheses of no difference in the data of the two stations is the special case H_o: $U_X = 0$. If the calculated t is less than the t-table at the selected level of significance, then we can conclude that there is no difference between the two sets of data.

APPENDIX C2

COMPUTER PROGRAM LIST FOR TESTING THE DIFFERENCES BETWEEN TWO SETS OF DATA (T-TEST)

```
      REAL JAN,MAR,MAY,JUN,JUL,OCT,NOV
      REAL SUMD(15),AVDIF(15),SUMDSQ(15),SD(15)
      REAL AVA(15),AVB(15),SDB(15),TCALC(15),X(60,15),SUMA,SUMB
      INTEGER YEAR(60),N,NUM(15)
      N=0
30    READ 10,YEAR(N+1),JAN,FEB,MAR,APR,MAY,JUN,JUL,AUG,SEP,OCT,
     $ NOV,DEC,ANN
      THE READ AND FORMAT STATEMENTS HAVE TO BE CHANGED FOR
      OTHER DATA
10    FORMAT (I4,12F5.2,F6.2)
      IF (YEAR(N+1).EQ.0) GOTO 8
      N=N+1
      THROUGH THE ENTIRE PROGRAM, ALL NUMBERS OF 13 HAVE TO BE
      CHANGED FOR OTHER DATA
      X(N,1)=JAN
      X(N,2)=FEB
      X(N,3)=MAR
      X(N,4)=APR
      X(N,5)=MAY
      X(N,6)=JUN
      X(N,7)=JUL
      X(N,8)=AUG
      X(N,9)=SEP
      X(N,10)=OCT
      X(N,11)=NOV
      X(N,12)=DEC
      X(N,13)=ANN
      THE VARIABLES AFTER = HAVE TO BE CHANGED FOR OTHER DATA
      GO TO 30
 8    DO 9 I=1,13
 9    NUM(I)=N
      DO 40 I=1,13
      N=NUM(I)
      AVA IS THE AVERAGE OF THE FIRST SET OF DATA
      AVB IS THE AVERAGE OF THE SECOND SET OF DATA
      SUMD IS THE SUM OF THE DIFFERENCES
      SUMDSQ IS THE TOTAL OF THE SQUARE OF THE DIFFERENCES
      SD IS THE STANDARD DEVIATION OF THE DIFFERENCE
      TCALC IS THE CALCULATED T FOR THE TEST
      SUMA=0
      SUMB=0
      N2=N/2
      DO 50 J=1,N2
      SUMB=SUMB+X(J+  N2,I)
50    SUMA=SUMA+(X(J,I))
      AVA(I)=SUMA/N2
      AVB(I)=SUMB/N2
40    CONTINUE
```

```
      DO 77 I=1,13
      N2=N/2
      N=NUM(I)
      SUMD(I)=0
      SUMDSQ(I)=0
      DO 78 J=1,N2
   78 SUMD(I)=SUMD(I)+  (X(J,I)-X(J+N2,I))
      AVDIF(I)=SUMD(I)/N2
      N2=N/2
      DO 79  J=1,N2
   79 SUMDSQ(I)=SUMDSQ(I)+((X(J,I)-X(J+N2,I))-AVDIF(I))**2
   77 CONTINUE
      DO 11 I=1,13
   11 N=NUM(I)
      N2=N/2
      XN2=N2
      DO 98 I=1,13
      SD(I)  =SQRT(SUMDSQ(I)/(XN2   -1))
      SDB(I)=SD(I)/SQRT(XN2)
      TCALC(I)=AVDIF(I)/SDB(I)
   98 CONTINUE
      PRINT 112
  112 FORMAT(8X,'YEAR',3X,'JAN',3X,'FEB',3X,'MAR',3X,'APR',3X,
     $ 'MAY',3X,'JUN',3X,'JUL',3X,'AUG',3X,'SEP',3X,'OCT',3X,
     $ 'NOV',3X,'DEC',3X,'ANN')
      PRINT 66,AVA(1),AVA(2),AVA(3),AVA(4),AVA(5)└1e1(6),AVA(7),
     $ AVA(8),AVA(9 ),AVA(10),AVA(11),AVA(12),AVA(13),AVB(1),
     $ AVB(2),AVB(3),AVB(4),AVB(5),AVB(6),AVB(7),AVB(8),AVB(9),
     $ AVB(10),AVB(11),AVB(12),AVB(13),
     $ SUMD(1),SUMD(2),SUMD(3),SUMD(4),SUMD(5), SUMD(6),SUMD(7)
     $,SUMD(8),SUMD(9),SUMD(10),SUMD(11),SUMD(12),SUMD(13)
   66 FORMAT (2X,'MEAN A',13F8.2/2X,'MEAN B',13F8.2/
     $ 2X,'SUMDIF',13F8.2)
      PRINT 97,AVDIF(1),AVDIF(2),AVDIF(3),AVDIF(4),AVDIF(5),
     $ AVDIF(6),AVDIF(7),AVDIF(8),AVDIF(9 ),AVDIF(10),AVDIF(11),
      $ AVDIF(12),AVDIF(13),SUMDSQ(1),SUMDSQ(2),SUMDSQ(3),
     $ SUMDSQ(4),SUMDSQ(5),SUMDSQ(6),SUMDSQ(7),SUMDSQ(8),
     $ SUMDSQ(9),SUMDSQ(10),SUMDSQ(11),SUMDSQ(12),SUMDSQ(13)
   97 FORMAT (2X,'MEAN-D',13F8.2/1X,'SUM DSQ',13F8.2)
      PRINT 91,SDB(1),SDB(2),SDB(3),SDB(4),SDB(5),SDB(6),SDB(7),
     $ SDB(8),SDB(9),SDB(10),SDB(11),SDB(12),SDB(13),TCALC(1),
     $ TCALC(2),TCALC(3),TCALC(4),TCALC(5),TCALC(6),TCALC(7),
     $  TCALC(8 ),TCALC(9 )   ,TCALC(10),TCALC(11),TCALC(12),
     $ TCALC(13)
   91 FORMAT(2X,'SD-DIF',13F8.2/3X,'TCALC',13F8.2)
      PRINT 35,N2
   35 FORMAT(5X,'NUMBER OF YEARS=',I5)
      STOP
      END
$ENTRY
C     THE DATA CARDS AS INPUTS ARE PLACED HERE
$STOP
```

Table C1

Test of Differences in Monthly and Annual Total Rainfall

Differences Between:	Calculated t for:												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
RG-1 and RG-5	-1.24	1.03	1.96	0.32	0.90	-0.52	-1.48	-1.56	0.37	-1.96	-1.26	1.02	-0.12
Watersheds A-1 and B-1	-1.18	0.74	-1.18	0.97	-3.44[b]	0.11	-0.40	-0.48	0.21	-1.53	-1.22	-0.68	-2.12
Watersheds A-1 and W-1	1.61	0.60	-0.75	0.92	-2.39[a]	-0.66	0.88	0.96	0.38	-0.11	-0.71	1.77	-0.79
Watersheds A-1 and W-2	-1.50	-0.34	0.66	-0.99	2.21[a]	0.30	0.42	-1.79	-0.14	-1.72	0.19	-1.61	-0.12
Watersheds B-1 and W-1	2.18[a]	0.13	0.63	0.59	1.20	1.13	-0.85	-1.55	-0.22	-2.31[a]	0.16	-1.57	-0.85
Watersheds B-1 and W-2	-2.00	0.30	0.59	-0.19	1.12	0.41	0.24	-2.03	-0.01	-3.11[b]	-0.14	-1.62	-0.97
Watersheds W-1 and W-2	1.29	-0.47	-0.51	0.78	-0.18	0	-0.88	1.89	-0.18	2.34[a]	0.52	1.31	0.79
RG-1 and Urbana	-5.10[b]	-3.18[b]	-5.20[b]	-1.38	-0.57	-0.03	-2.51[a]	-1.07	0.69	-1.16	-2.15[a]	-3.34[b]	-4.40[b]
RG-5 and Urbana	-5.94[b]	-3.16[b]	-2.99[b]	1.36	-0.10	-0.23	-2.86[b]	-1.77	-0.83	-1.98	-2.50[a]	-3.17[b]	-4.43[b]

t-table are 2.060 (5% level of significance), and 2.787 (1% level of significance)

[a]Significantly different

[b]Highly significantly different

Table C2

Test of Differences in Growing Season Monthly Total Rainfall

Differences Between:	Calculated t for:							t-table	
	Apr.	May	June	July	Aug.	Sept.	Oct.	5%	1%
RG1 and RG3	0.43	-0.16	-0.05	1.31	0.45	2.94[b]	1.64	2.064	2.797
RG1 and RG4	0.52	-0.14	0.93	3.08[b]	1.62	2.45[a]	1.60	2.064	2.797
RG1 and RG5	0.32	0.90	-0.52	-1.48	-1.56	0.37	-1.96	2.056	2.779
RG1 and RG6	1.05	0.87	0.55	1.35	2.07	1.60	1.11	2.060	2.787
RG3 and RG4	0.60	0.71	0.16	1.37	1.20	0.58	0.44	2.069	2.807
RG3 and RG5	0.10	-0.28	0.61	-0.14	1.08	-2.46	-0.05	2.064	2.797
RG3 and RG6	-1.06	-0.49	-0.36	0.40	-1.38	0.83	0.03	2.064	2.797
RG4 and RG5	-0.56	-1.61	0.60	-1.79	-0.04	-2.05	-0.74	2.064	2.797
RG4 and RG6	1.64	0.55	-0.70	-2.05	0.25	-1.67	-0.13	2.064	2.797
RG5 and RG6	0.77	0.64	-1.23	-0.44	1.05	1.17	-0.13	2.060	2.787

[a] Significantly different

[b] Highly significantly different

Table C3

Test of Differences in Monthly and Annual Total Rainfall

Differences Between:	Calculated t for:												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
RG1 and Watershed A1	0.15	-1.47	-2.23[a]	-0.81	2.34[a]	0.69	2.07	1.12	0.35	2.18[a]	1.14	-3.01[b]	1.59
RG1 and Watershed B1	-1.56	-1.27	-2.30[a]	1.08	1.72	0.99	1.48	-1.19	0.68	1.98	1.12	-2.98[b]	0.78
RG1 and Watershed W1	1.60	-1.28	-2.42[a]	0.67	1.33	0.37	2.68[a]	-0.44	0.59	3.11[b]	1.12	-2.49[a]	1.18
RG1 and Watershed W2	1.68	-1.32	-2.30[a]	1.23	0.94	0.25	0.53	0.98	0.34	3.45[b]	1.14	-1.93	1.54
RG5 and Watershed A1	-1.18	-0.65	0.42	-0.72	2.98[b]	-0.12	-0.23	-1.50	0.48	1.14	0.11	-2.57[a]	1.07
RG5 and Watershed B1	-1.53	-0.24	0.38	0.86	2.35[a]	-0.11	-0.35	-1.53	0.78	0.31	0.02	-2.54[a]	0.43
RG5 and Watershed W1	-0.79	-0.39	0.25	0.90	1.87	-0.41	0.14	-1.31	0.71	1.37	-0.01	-2.41	0.87
RG5 and Watershed W2	-0.18	-0.69	0.08	1.69	1.93	-0.42	-0.52	-0.62	0.46	2.26[a]	0.07	-1.86	1.91

Note: the t-table for 5% level of significance is 2.060 and for 1% level of significance is 2.787

[a]Significantly different

[b]Highly significantly different

Table C4

Test of Differences in Rainfall Intensities

Differences Between:	Calculated t for Duration (minutes):											t-table	
	2	5	10	15	20	30	60	120	240	360	720	5%	1%
RG1 and RG5	-1.23	-1.57	-1.37	0.53	0.38	0.26	-0.15	-0.13	0.41	0.85	0.19	2.056	2.779
Watersheds A1 and B1	-1.43	-1.35	-1.83	-2.10[a]	-2.07[a]	-2.13[a]	-2.39[a]	0.16[a]	0.56	0.87	0.19	2.056	2.779
Watersheds A1 and W1	-1.56	-4.75[b]	-5.94[b]	-5.40[b]	-6.65[b]	-6.20[b]	-4.94[b]	-4.29[b]	-2.58[a]	-2.20[a]	-1.09	2.056	2.779
Watersheds A1 and W2	-1.47	-2.04	-1.41	-1.34	-0.73	-0.57	-0.20	-0.37	0.37	0.24	-0.32	2.056	2.779
Watersheds B1 and W1	-1.16	-3.01[b]	-3.66[b]	-3.70[b]	-4.92[b]	-4.20[b]	-3.23[b]	-2.63[a]	-3.49[b]	-2.96[b]	-1.73	2.056	2.779
Watersheds B1 and W2	-2.07[a]	-2.52[a]	-1.97	-2.28[a]	-1.42	-1.07	-0.83	-0.88	0.59	0.54	-0.27	2.056	2.779
Watersheds W1 and W2	-2.44[a]	-5.72[b]	-7.14[b]	-6.02[b]	-5.08[b]	-3.60[b]	-2.72[a]	-2.17[a]	-0.75	-0.81	-0.79	2.056	2.779

[a]Significantly different

[b]Highly significantly different

Table C4 (continued)

Differences Between:	Calculated t for Duration (minutes):											t-table	
	2	5	10	15	20	30	60	120	240	360	720	5%	1%
RG1 and Watershed A1	-0.65	-0.89	-1.37	-1.06	-0.34	0.04	-0.54	0.50	1.13	1.95	2.09[a]	2.056	2.779
RG1 and Watershed B1	0.15	-0.04	-0.21	0.52	0.75	1.25	1.13	1.60	1.00	2.16[a]	2.46[a]	2.056	2.779
RG1 and Watershed W1	0.92	2.26[a]	3.35[b]	3.96[b]	4.72[b]	4.89[b]	5.34[b]	4.56[b]	3.28[b]	3.01[b]	3.03[b]	2.056	2.779
RG1 and Watershed W2	-1.51	-2.18[a]	-2.49[a]	-2.40[a]	-1.02	-0.46	-0.40	-0.19	0.81	1.33	0.93	2.056	2.779
RG5 and Watershed A1	-0.97	-1.11	-0.68	0.15	0.64	0.26	0.05	-0.30	-0.44	-0.75	-1.44	2.056	2.779
RG5 and Watershed B1	1.30	1.64	1.29	0.77	0.05	0.37	0.56	0.81	0.17	0.39	1.46	2.056	2.779
RG5 and Watershed W1	1.70	3.04[b]	3.61[b]	2.95[b]	2.75[a]	2.99[b]	2.90[b]	.273[a]	2.24[a]	1.95	2.20[a]	2.056	2.779
RG5 and Watershed W2	0.35	-0.11	-0.25	-1.08	-1.16	-0.74	-0.24	-0.08	0.64	0.80	1.35	2.056	2.779

[a]Significantly different

[b]Highly significantly different

Table C5

Test of Differences in Annual Exceedances Runoff Depth

Differences Between:	Calculated t for Duration (hours):									t-table	
	1	2	6	12	24	48	72	120	192	5%	1%
Watersheds A1 and B1	3.00[b]	0.80	-0.89	-1.22	-2.60[a]	-1.87	-2.33[a]	-2.56[a]	-2.57[a]	2.069	2.807
Watersheds A1 and W1	-6.94[b]	-7.90[b]	-9.11[b]	-12.74[b]	-17.51[b]	-2.62[a]	0.03	2.79[a]	5.39[b]	2.074	2.819
Watersheds A1 and W2	5.24[b]	7.79[b]	7.03[b]	3.92[b]	2.73[a]	0.95	-0.55	-3.60[b]	-5.75[b]	2.069	2.807
Watersheds B1 and W1	-9.84[b]	-13.77[b]	-9.97[b]	-10.15[b]	-12.39[b]	-6.89[b]	-4.05[b]	0.94	6.11[b]	2.074	2.819
Watersheds B1 and W2	3.73[b]	5.44[b]	5.02[b]	5.29[b]	5.77[b]	4.40[b]	2.88[b]	-0.23	-2.56[a]	2.069	2.807
Watersheds W1 and W2	-5.36[b]	-4.81[b]	-5.33[b]	-5.20[b]	-4.37[b]	-1.91	-0.54	0.48	3.13[a]	2.074	2.819

[a]Significantly different

[b]Highly significantly different

APPENDIX D

LOG-PROBABILITY CURVES

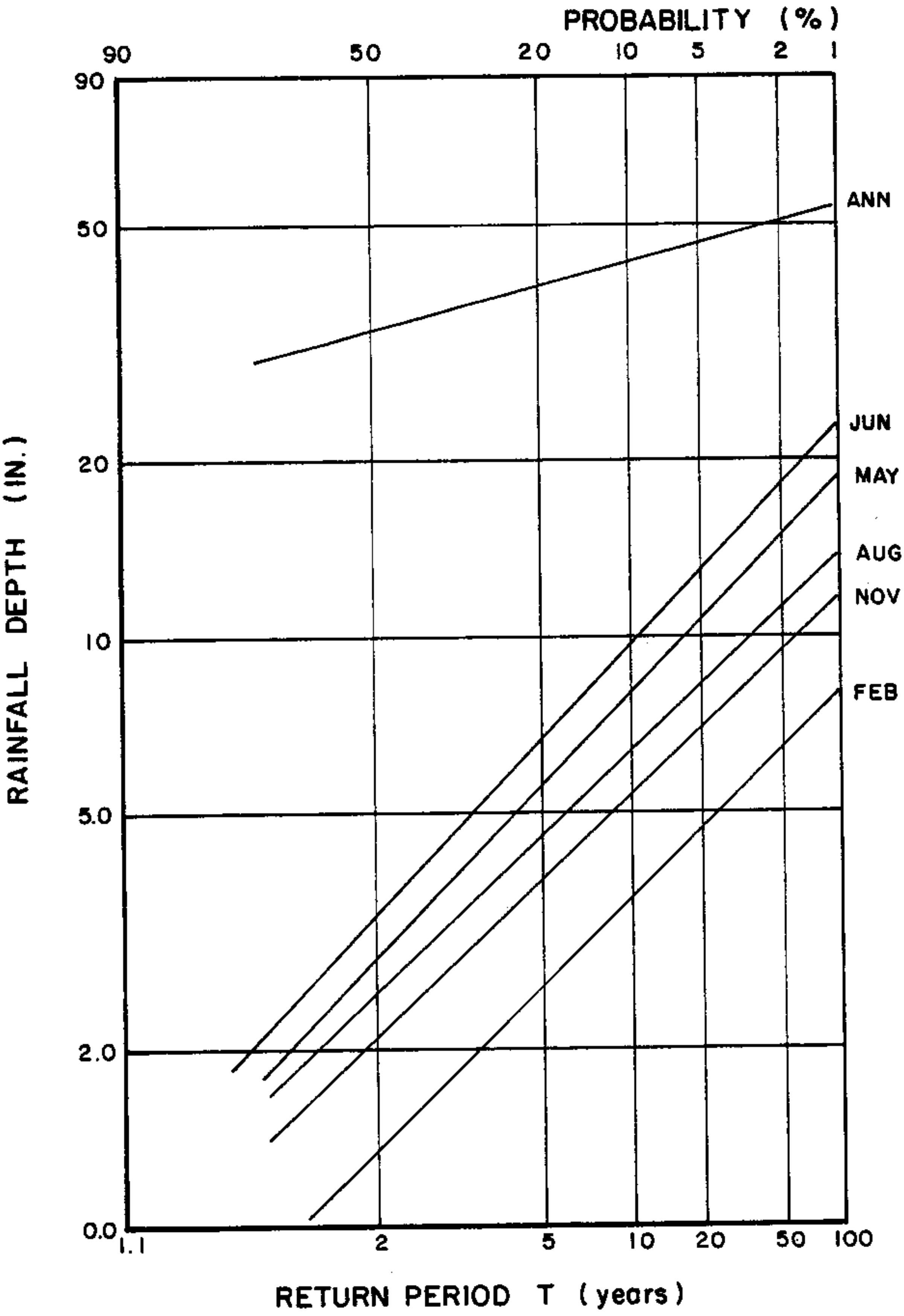

Figure D1. Log-Probability for Monthly and Annual Total Rainfall, RG-1

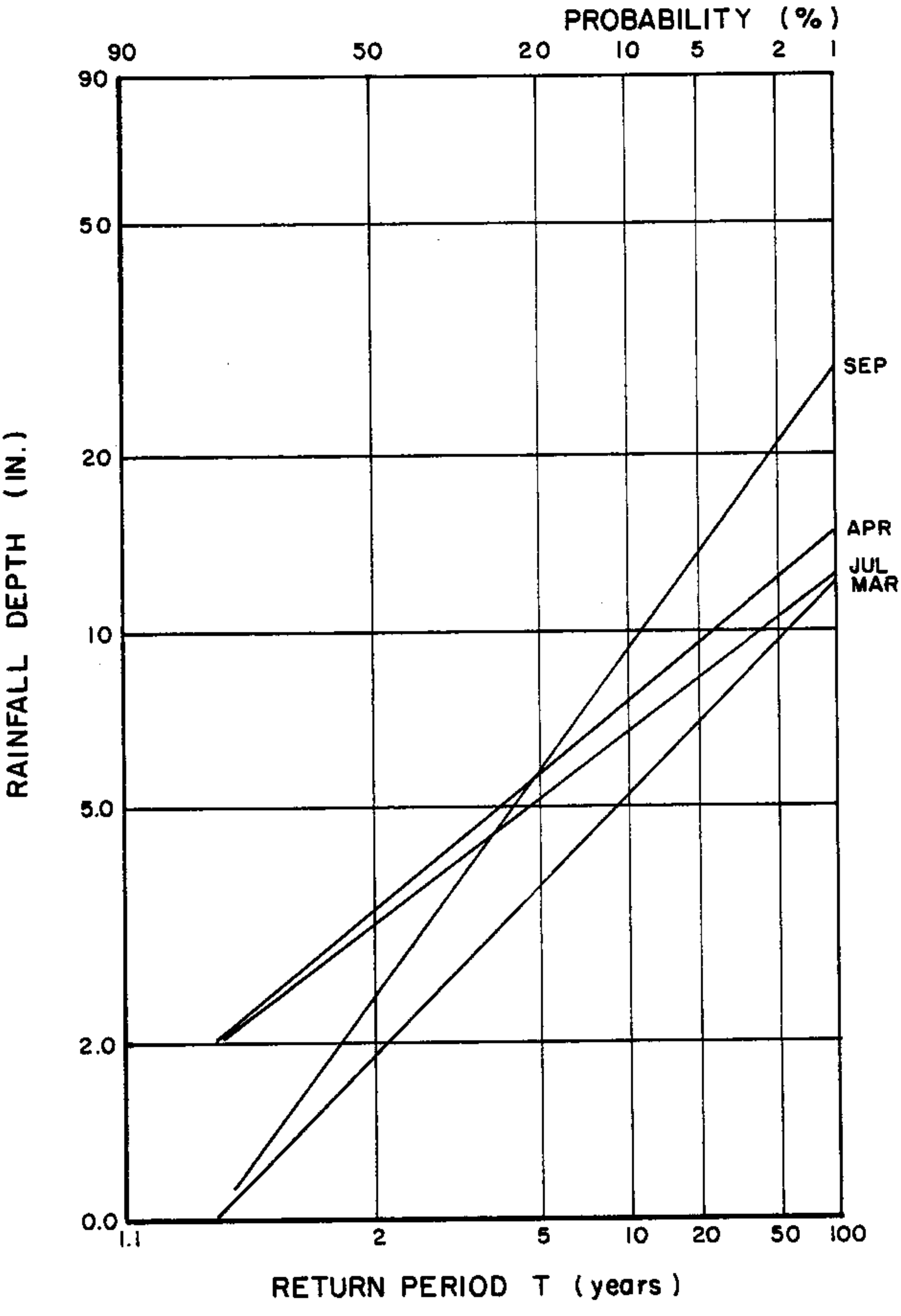

Figure D1. (continued)

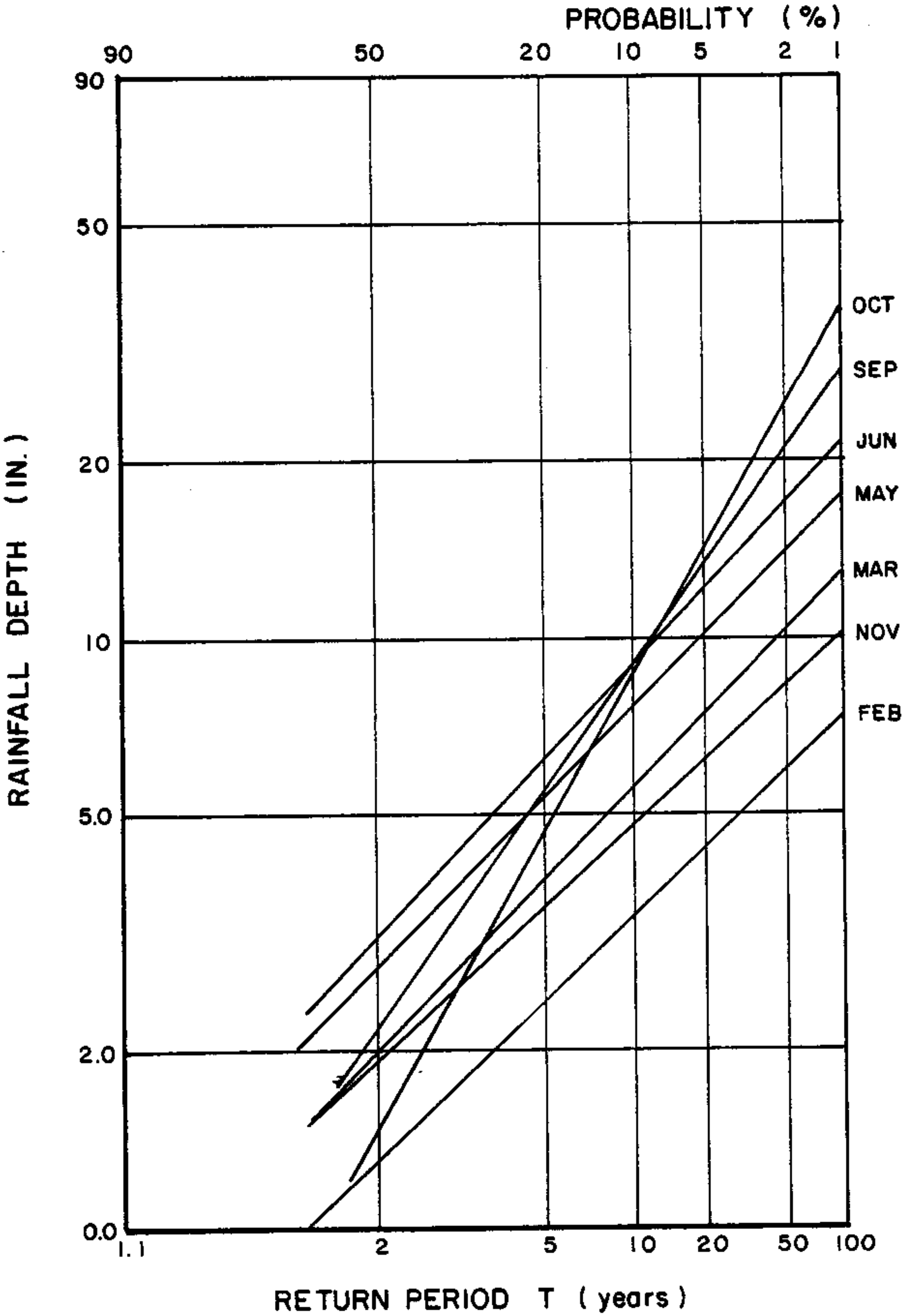

Figure D2. Log-Probability for Monthly and Annual Total Rainfall, RG-5

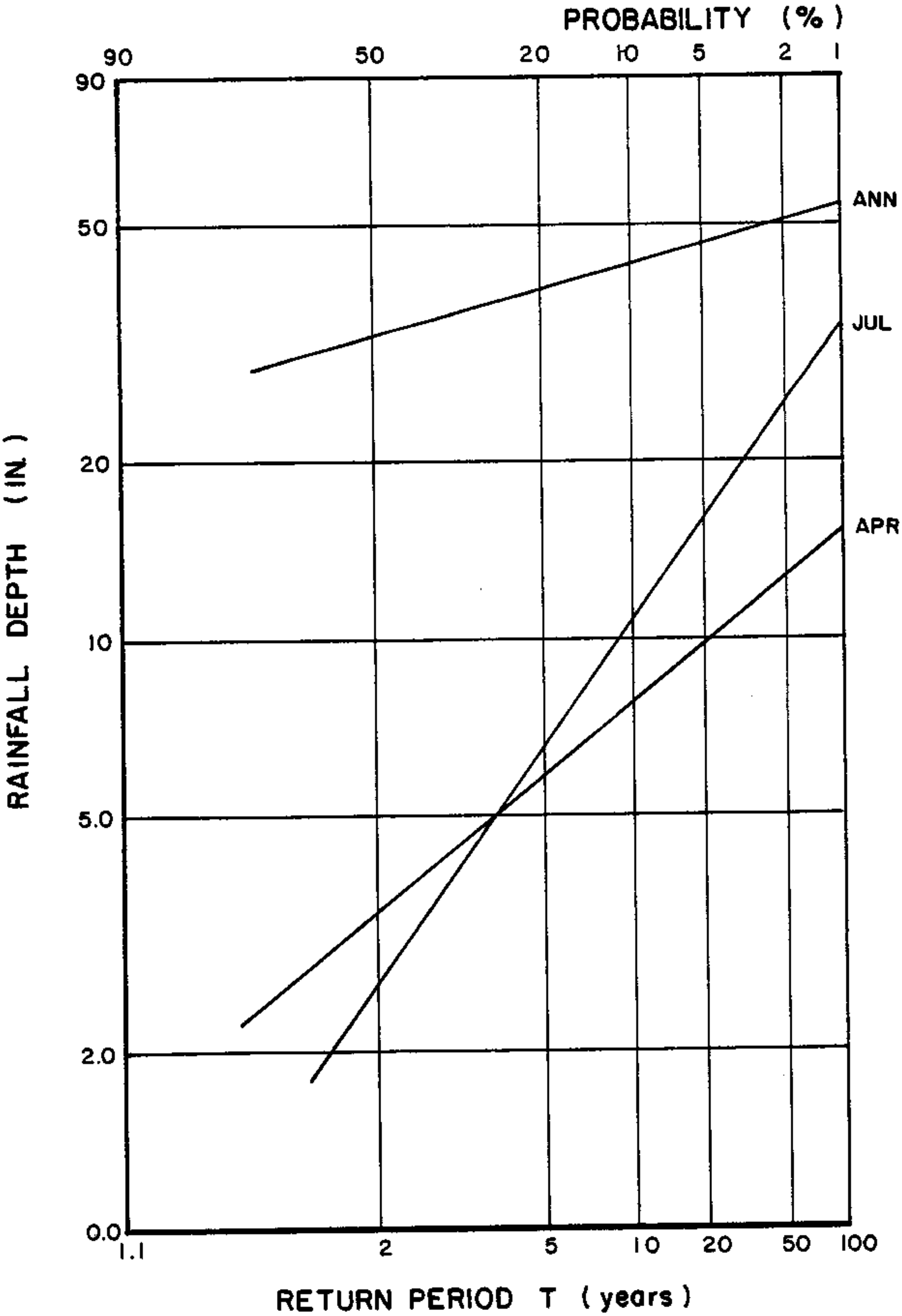

Figure D2. (continued)

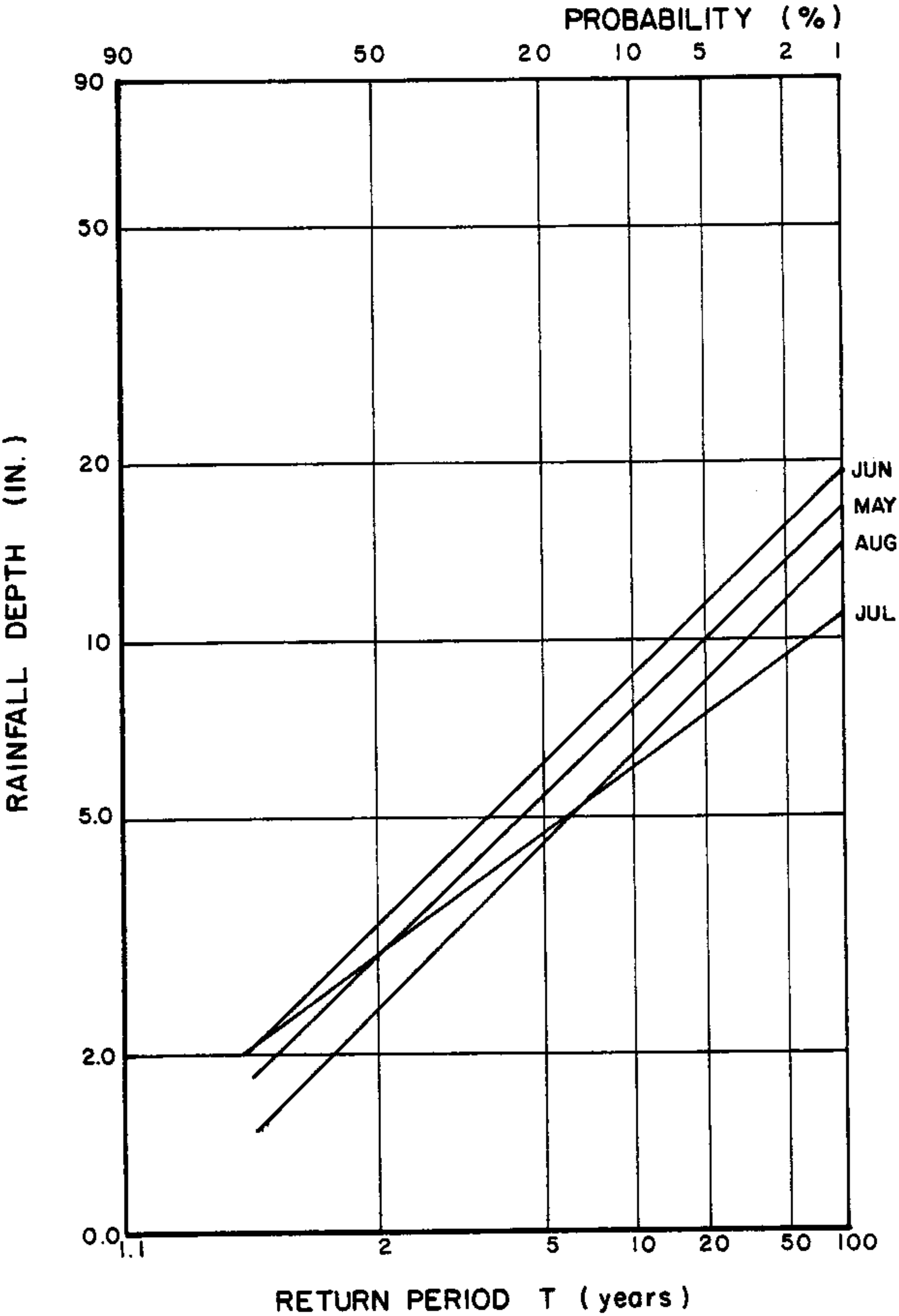

Figure D3. Log-Probability for Summer Monthly Total Rainfall, RG-3

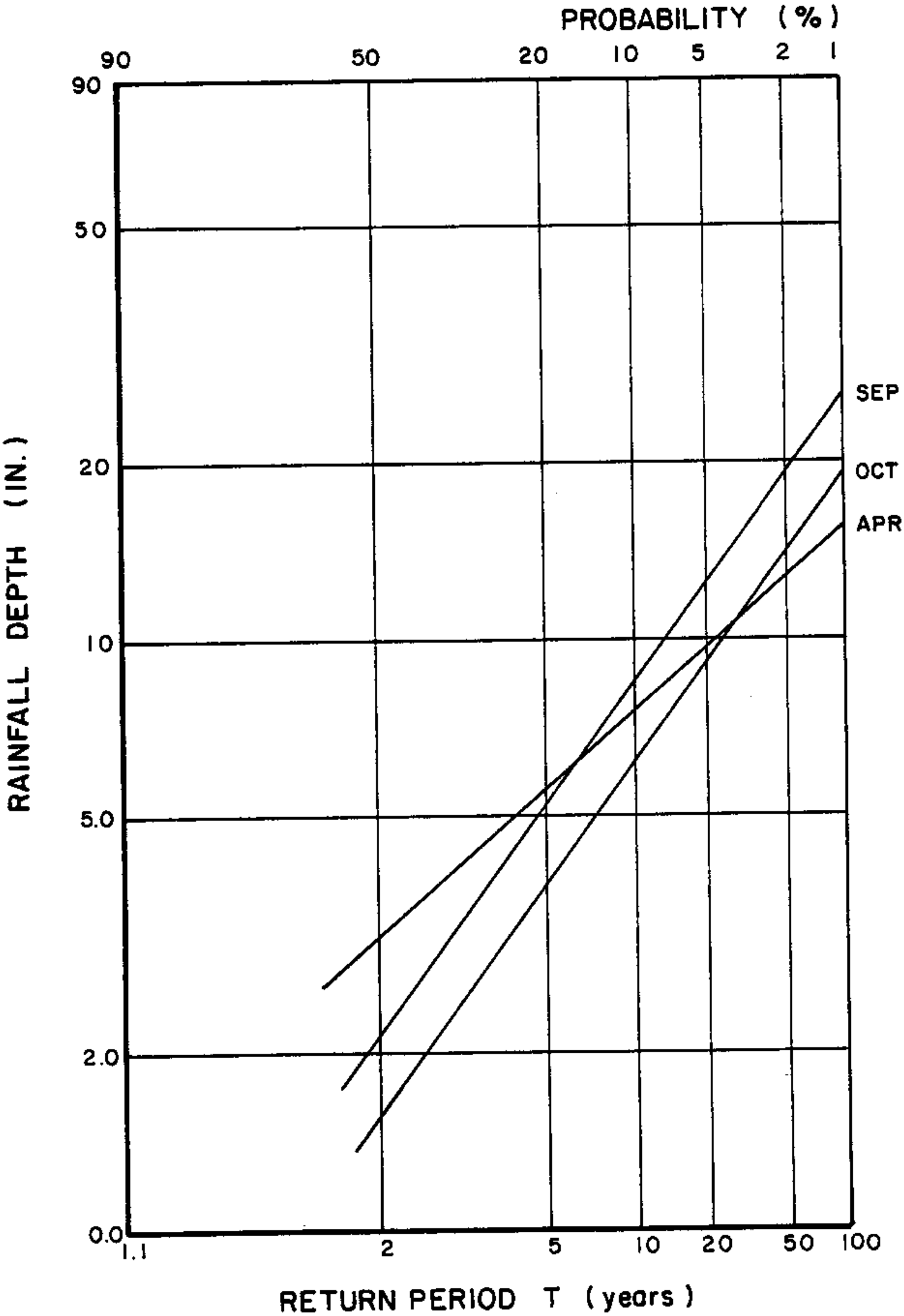

Figure D3. (continued)

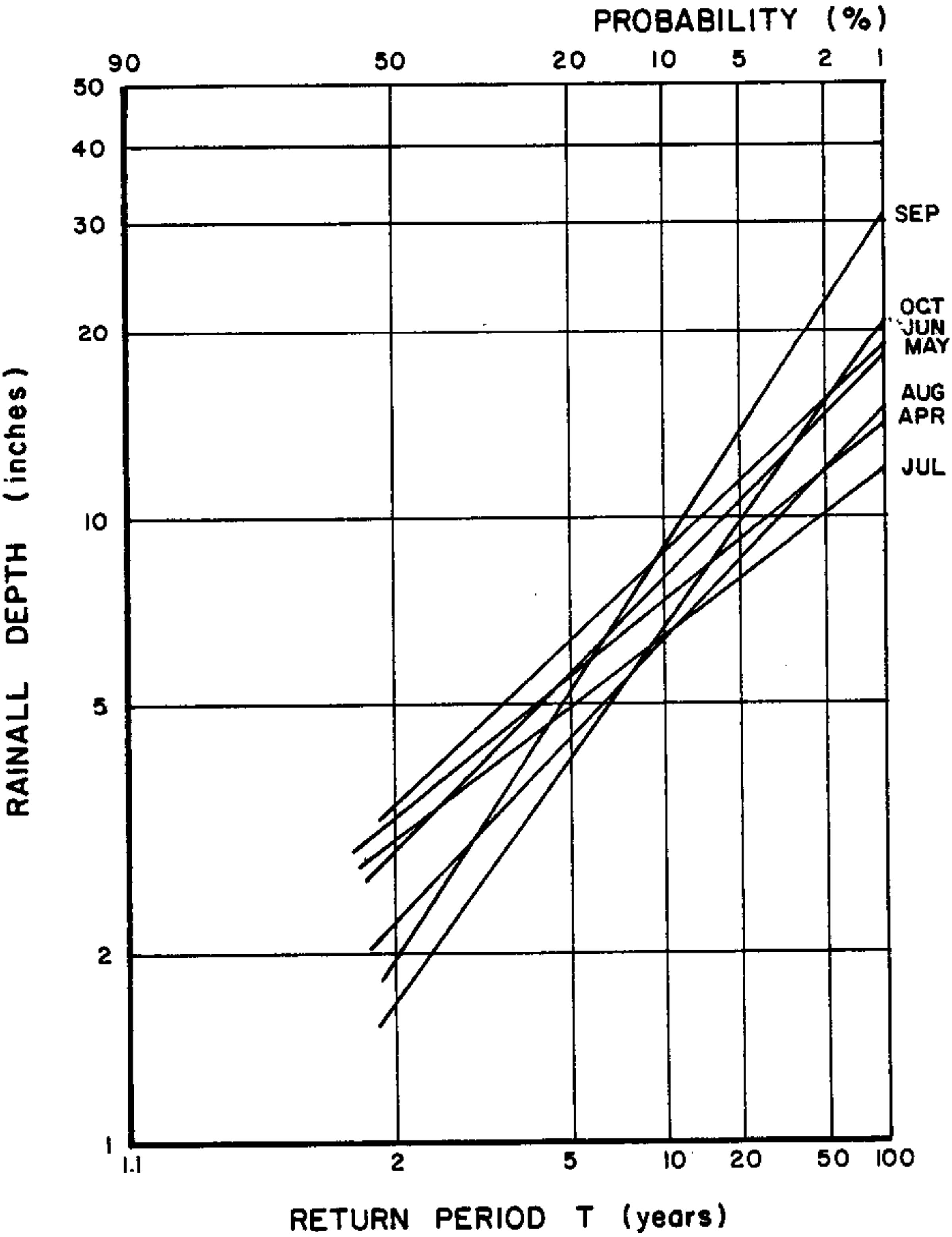

Figure D4. Log-Probability for Summer Monthly Total Rainfall, RG-4

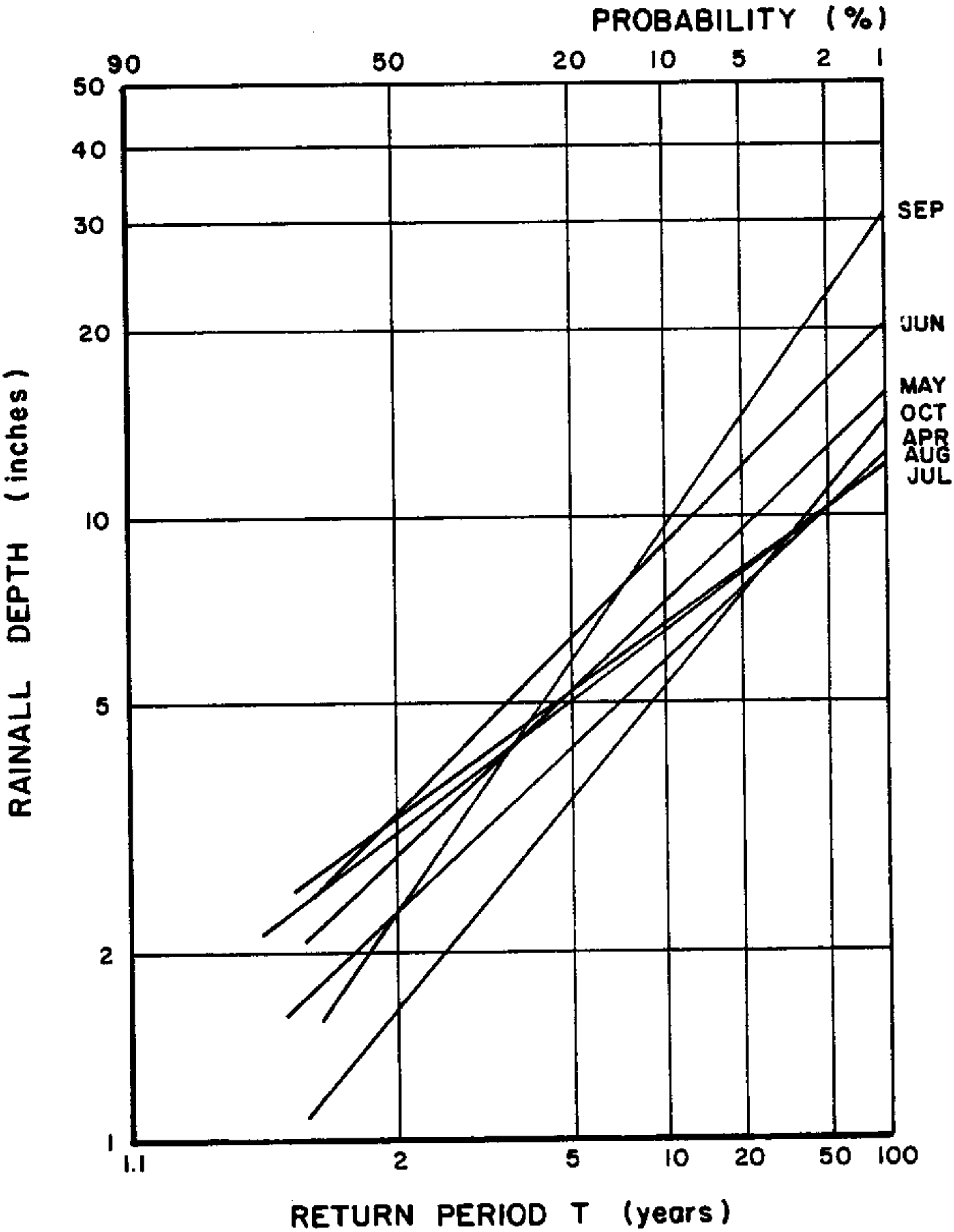

Figure D5. Log-Probability for Summer Monthly Total Rainfall, RG-6

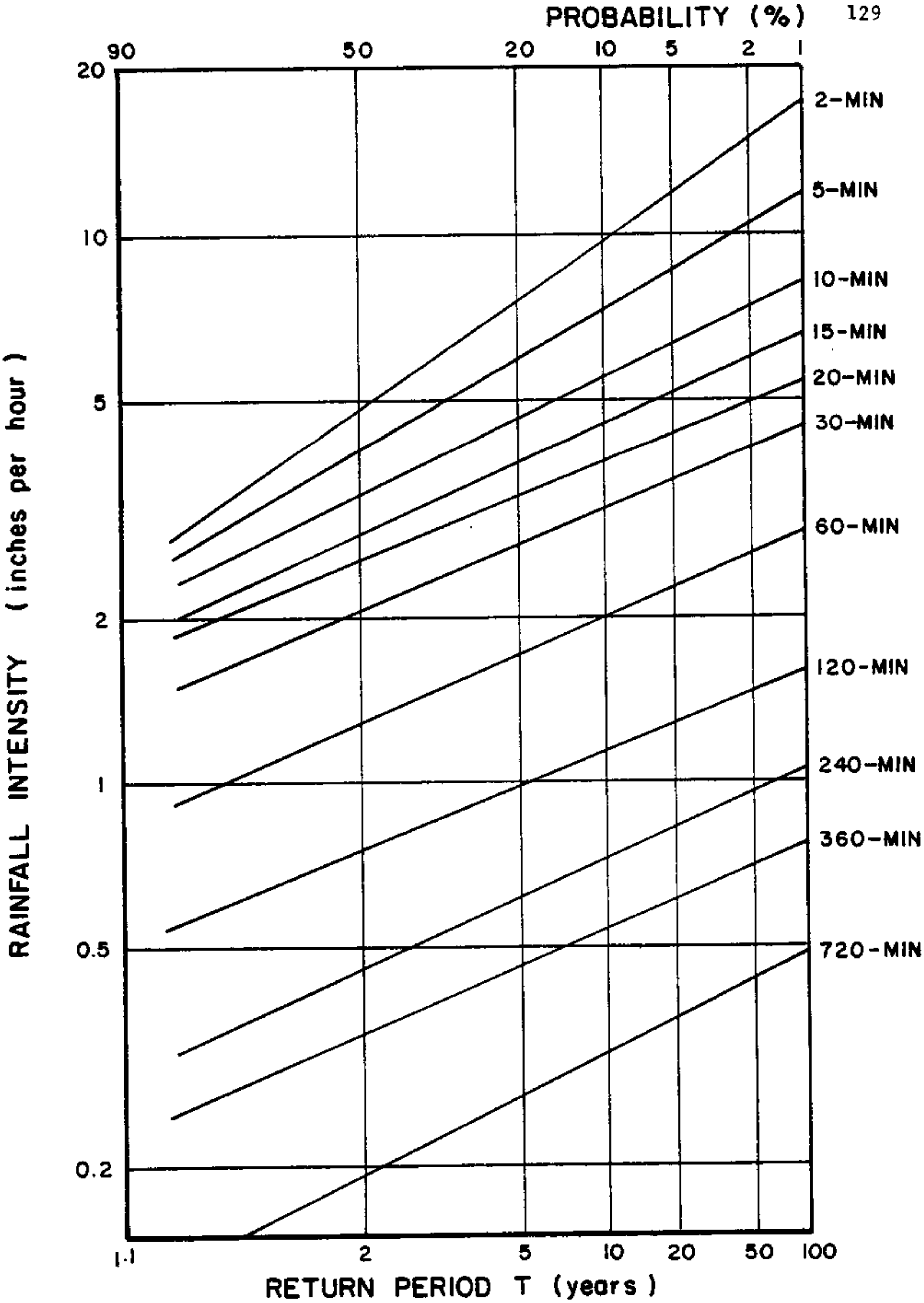

Figure D6. Log-Probability for Annual Maximum Rainfall Intensities, RG-1

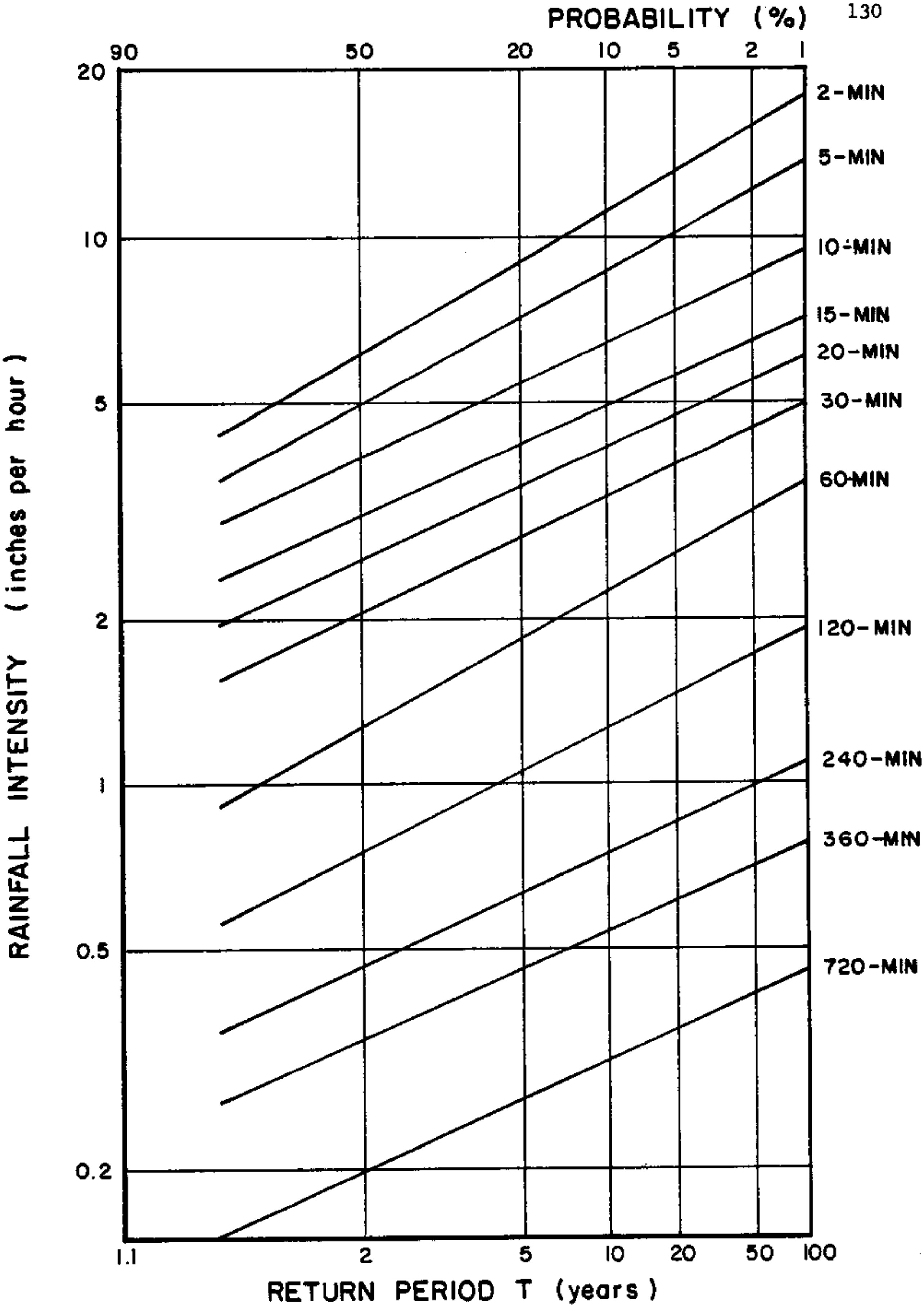

Figure D7. Log-Probability for Annual Maximum Rainfall Intensities, RG-5

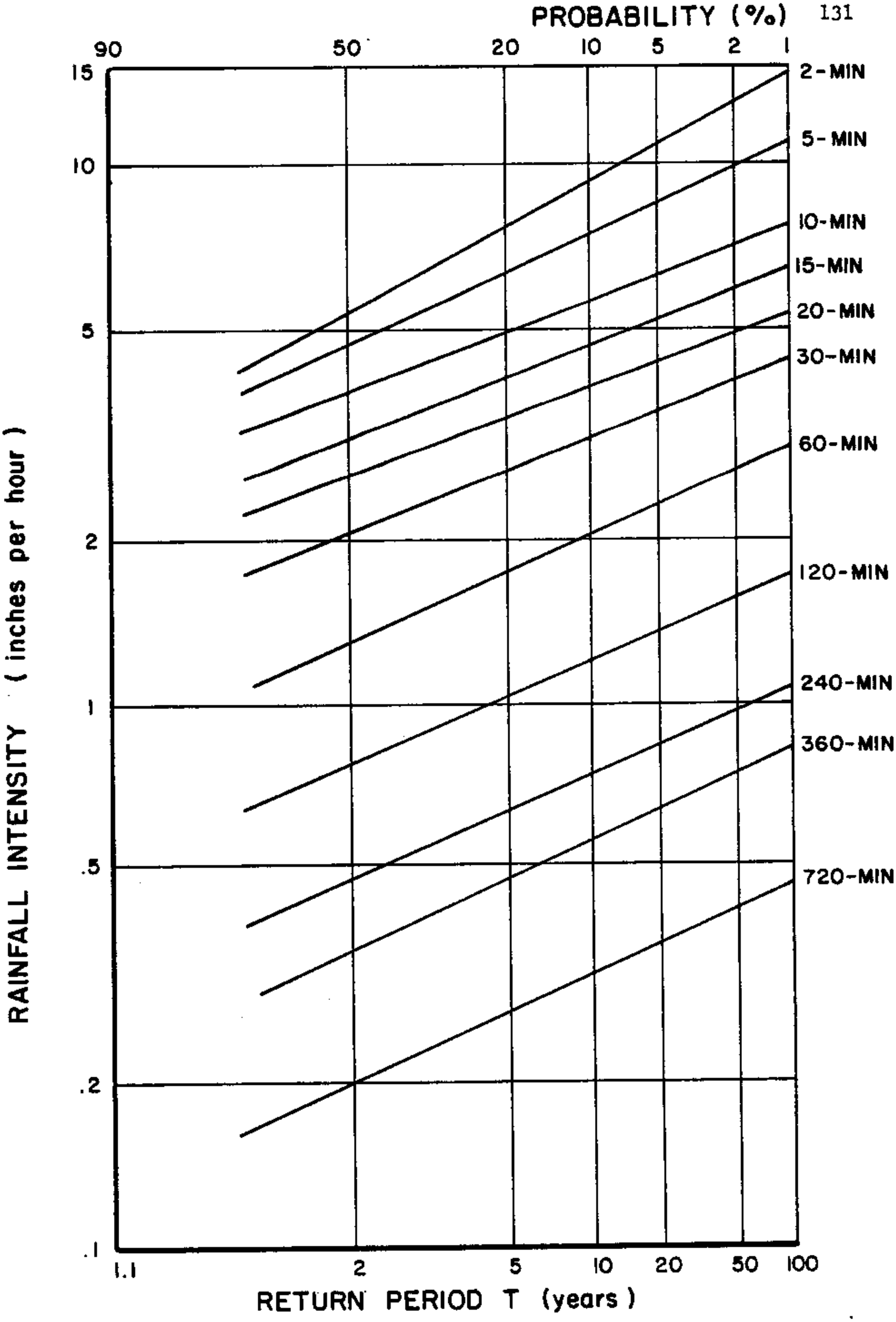

Figure D8. Log-Probability for Annual Maximum Rainfall Intensities, Average RG-1 and RG-5

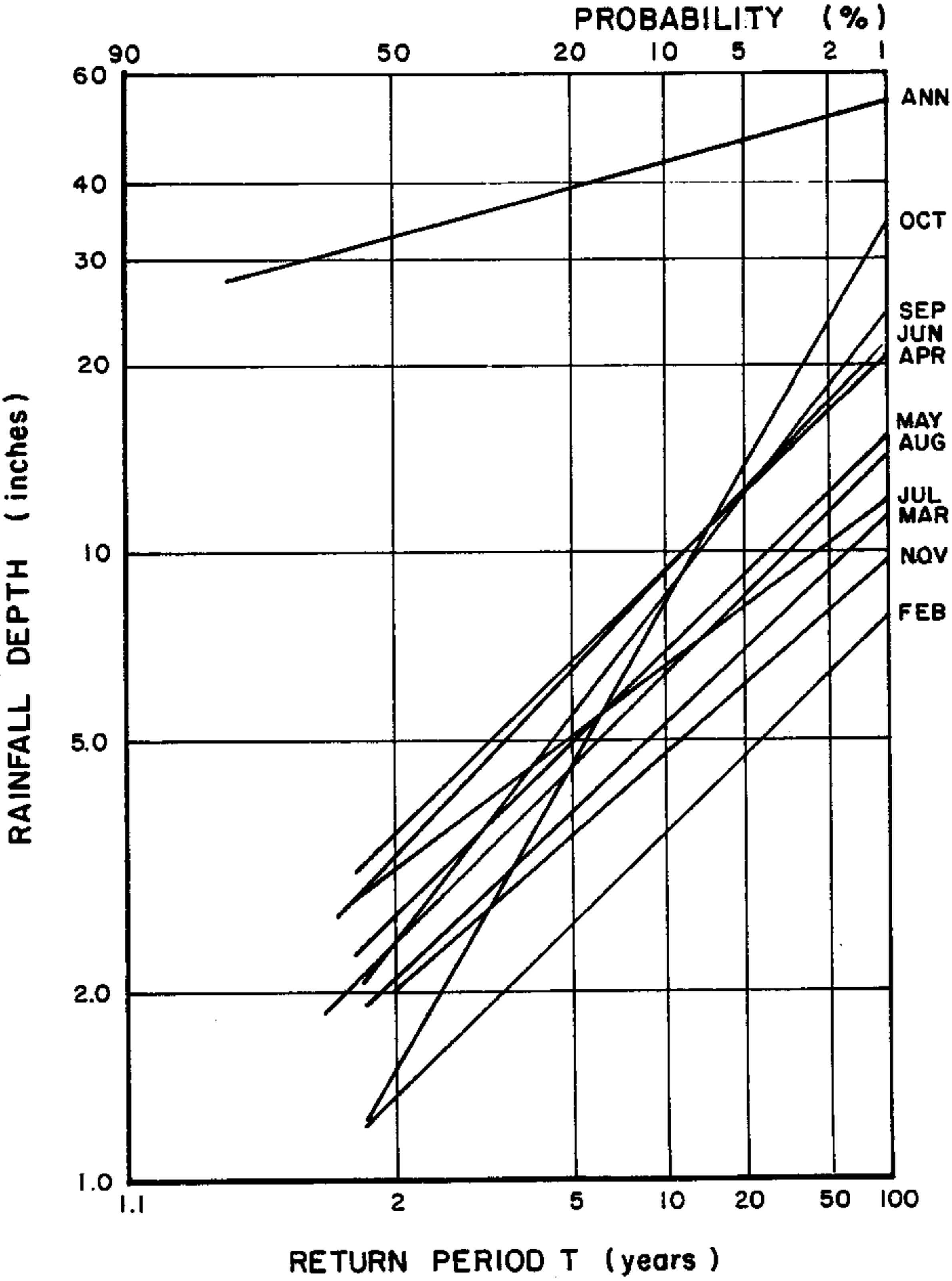

Figure D9. Log-Probability for Monthly and Annual Total Rainfall, Watershed A-1

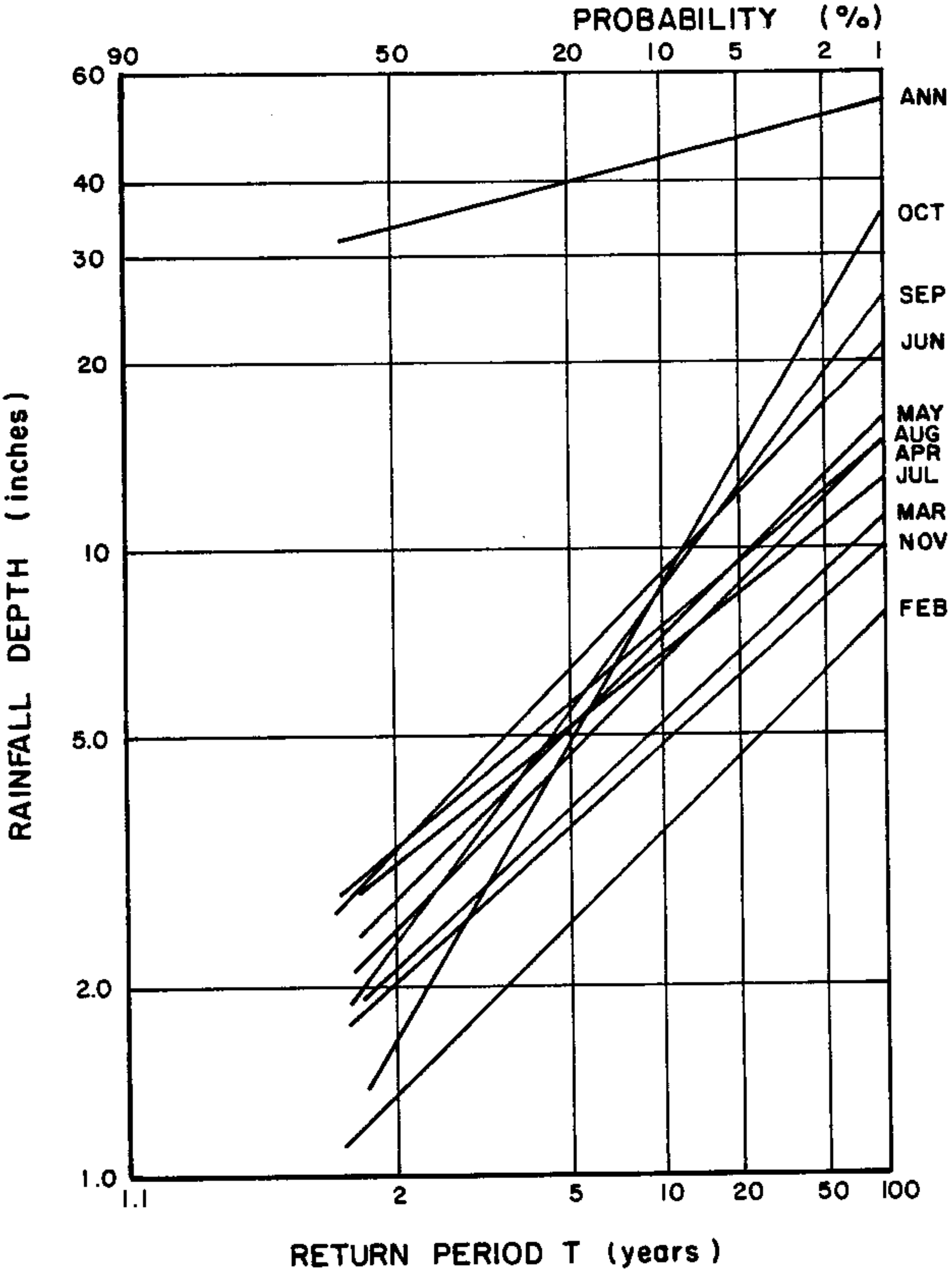

Figure D10. Log-Probability for Monthly and Annual Total Rainfall, Watershed B-1

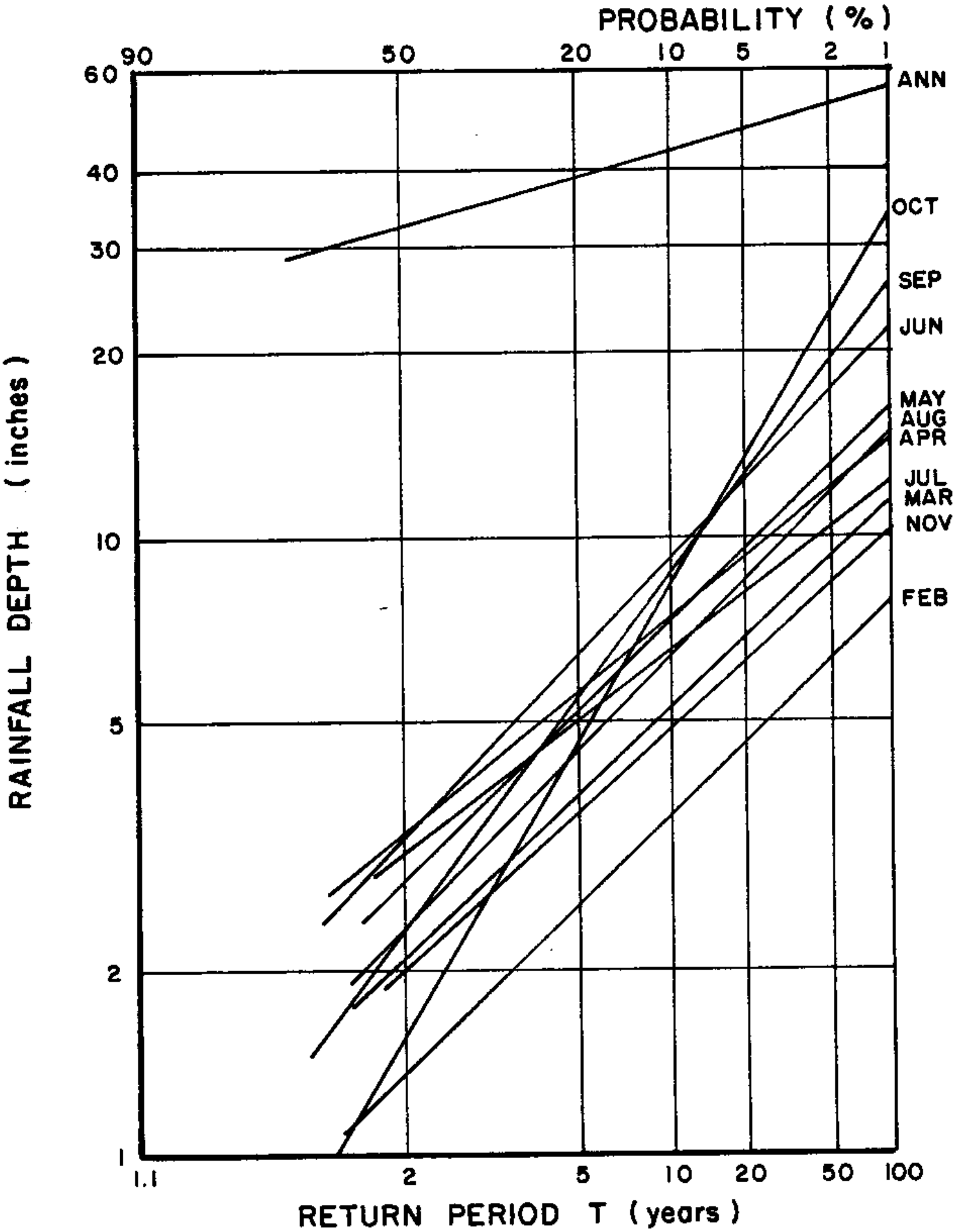

Figure D11. Log-Probability for Monthly and Annual Total Rainfall, Watershed W-1

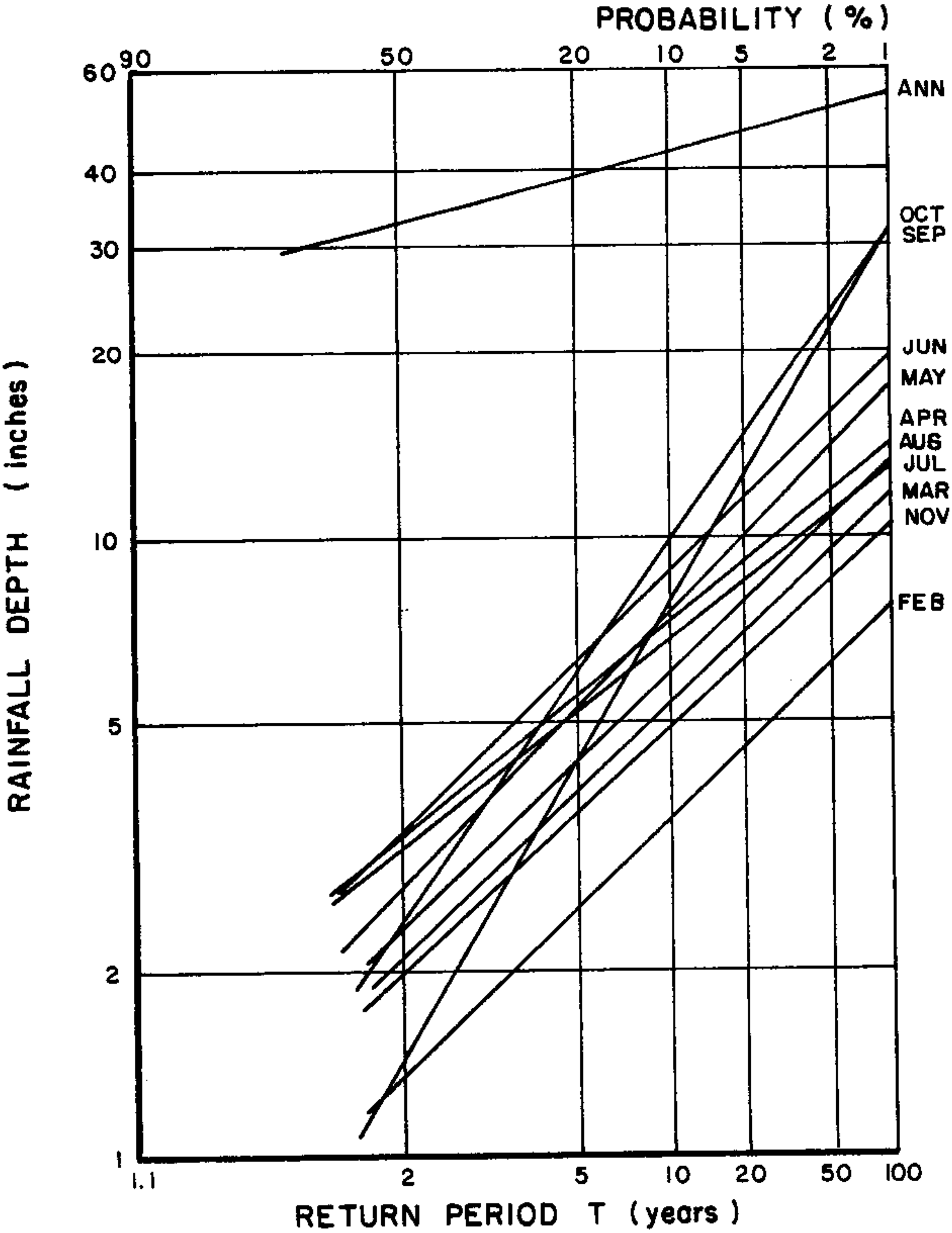

Figure D12. Log-Probability for Monthly and Annual Total Rainfall, Watershed W-2

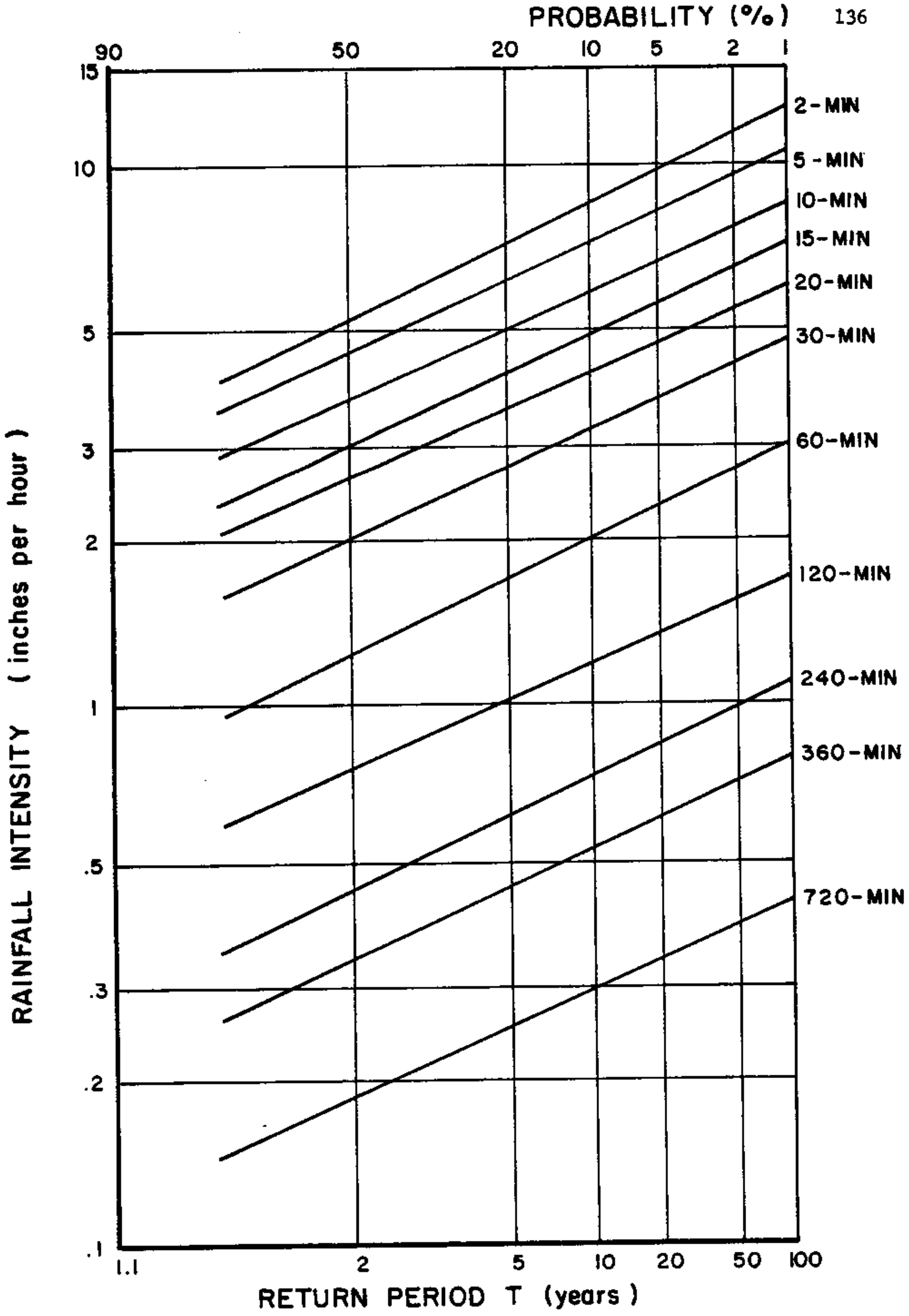

Figure D13. Log-Probability for Annual Maximum Rainfall Intensities, Watershed A-1

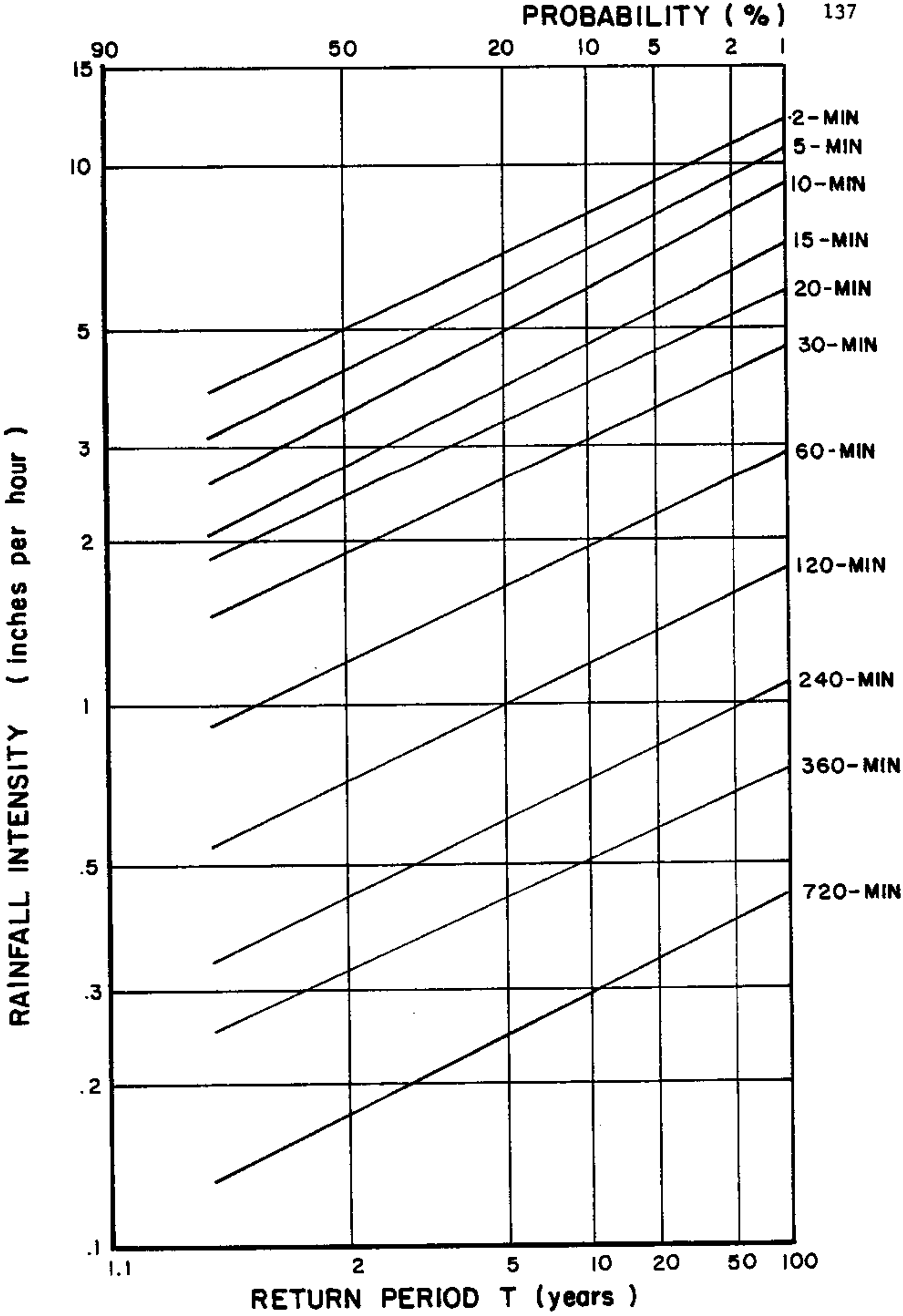

Figure D14. Log-Probability for Annual Maximum Rainfall Intensities, Watershed B-1

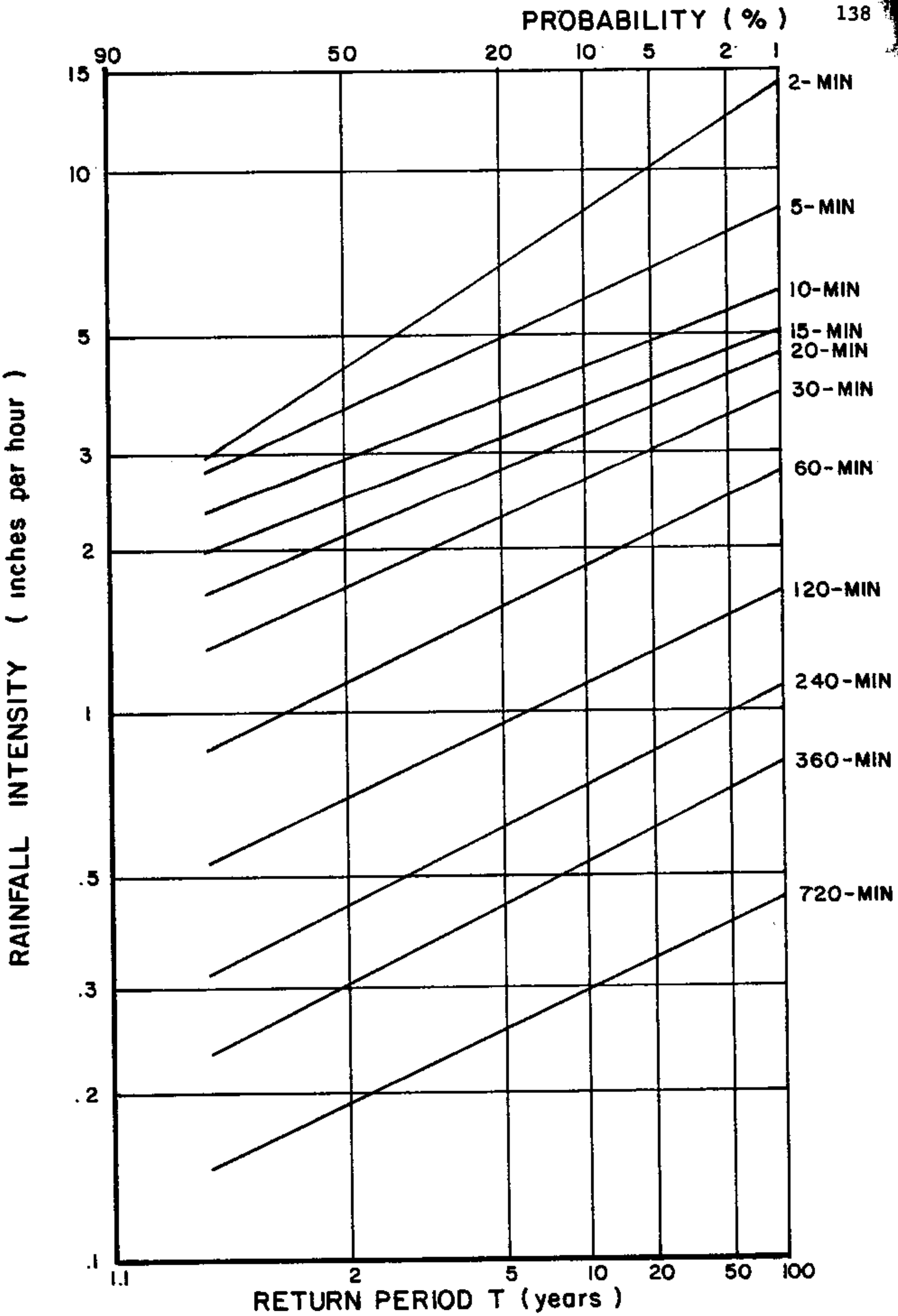

Figure D15. Log-Probability for Annual Maximum Rainfall Intensities, Watershed W-1

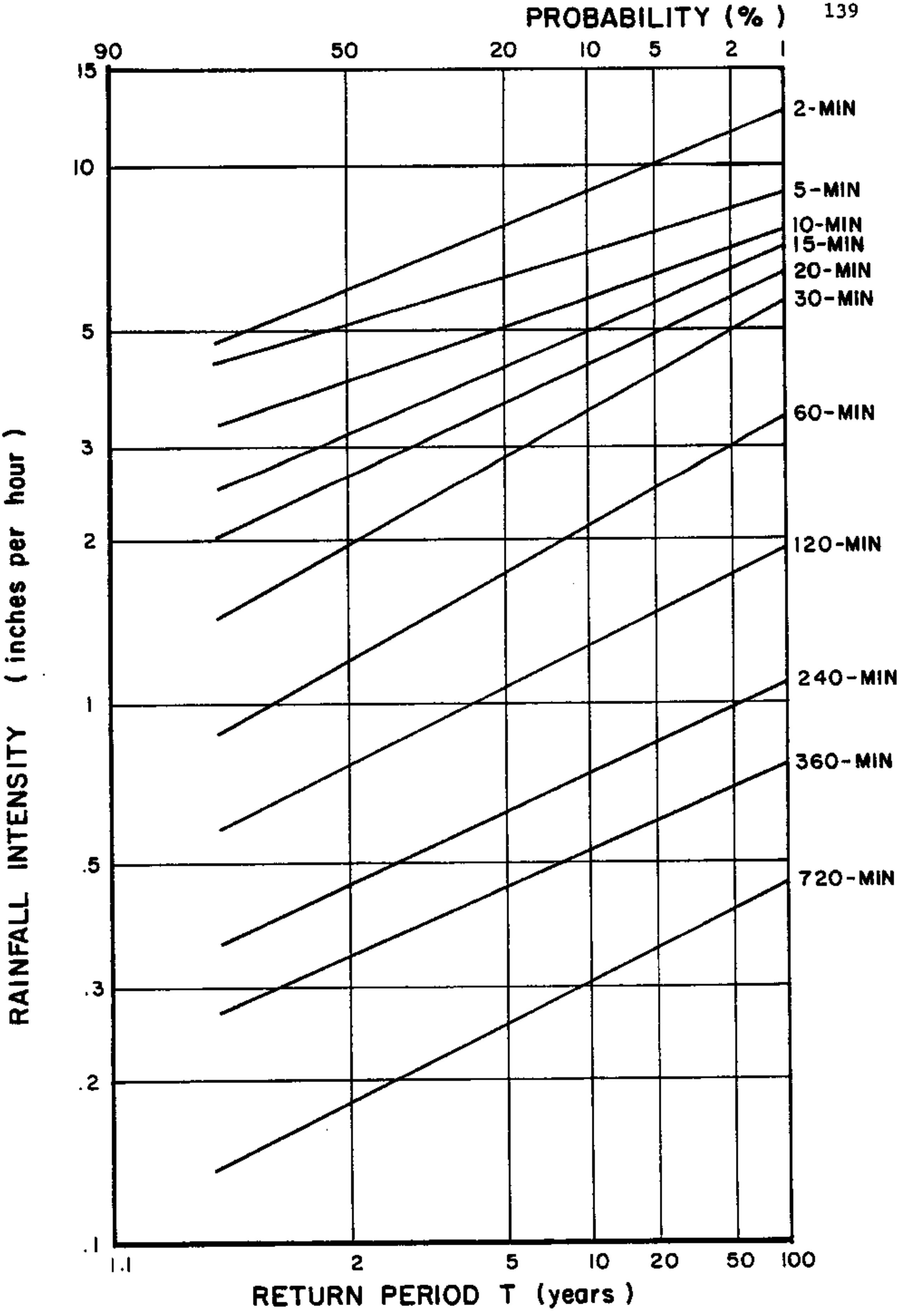

Figure D16. Log-Probability for Annual Maximum Rainfall Intensities, Watershed W-2

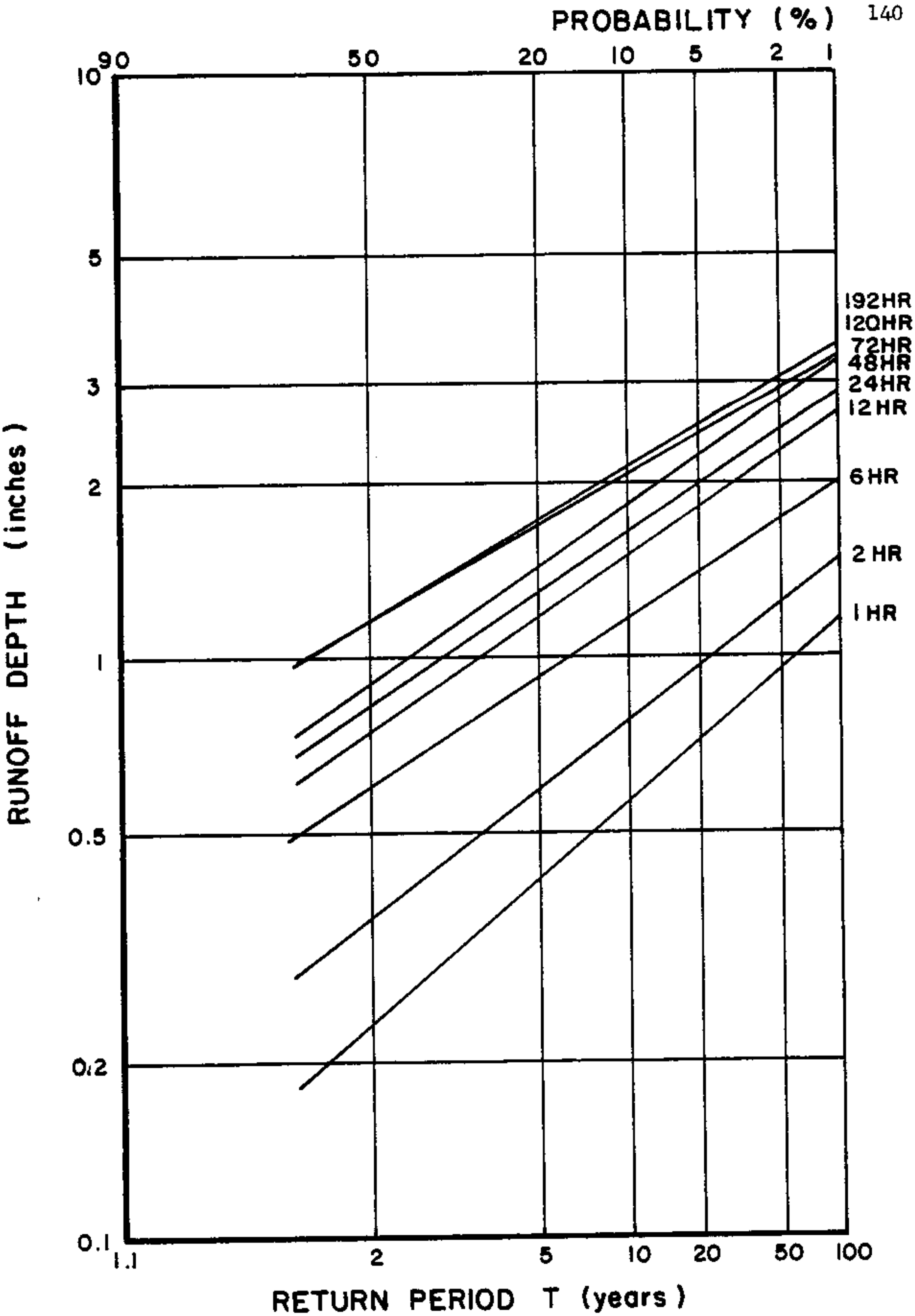

Figure D17. Log-Probability for Annual Exceedance Runoff Depth, Watershed A-1

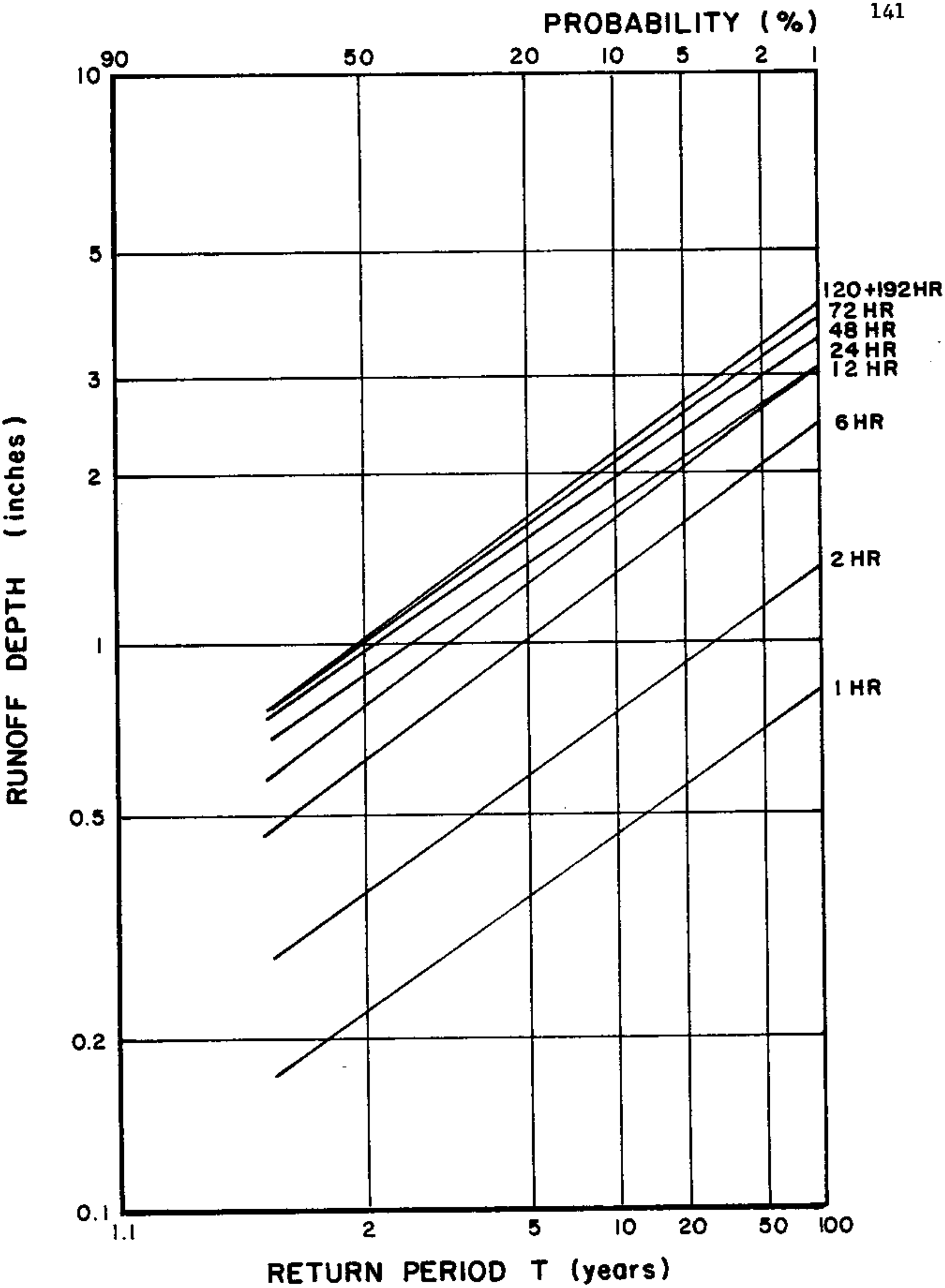

Figure D18. Log-Probability for Annual Exceedance Runoff Depth, Watershed B-1

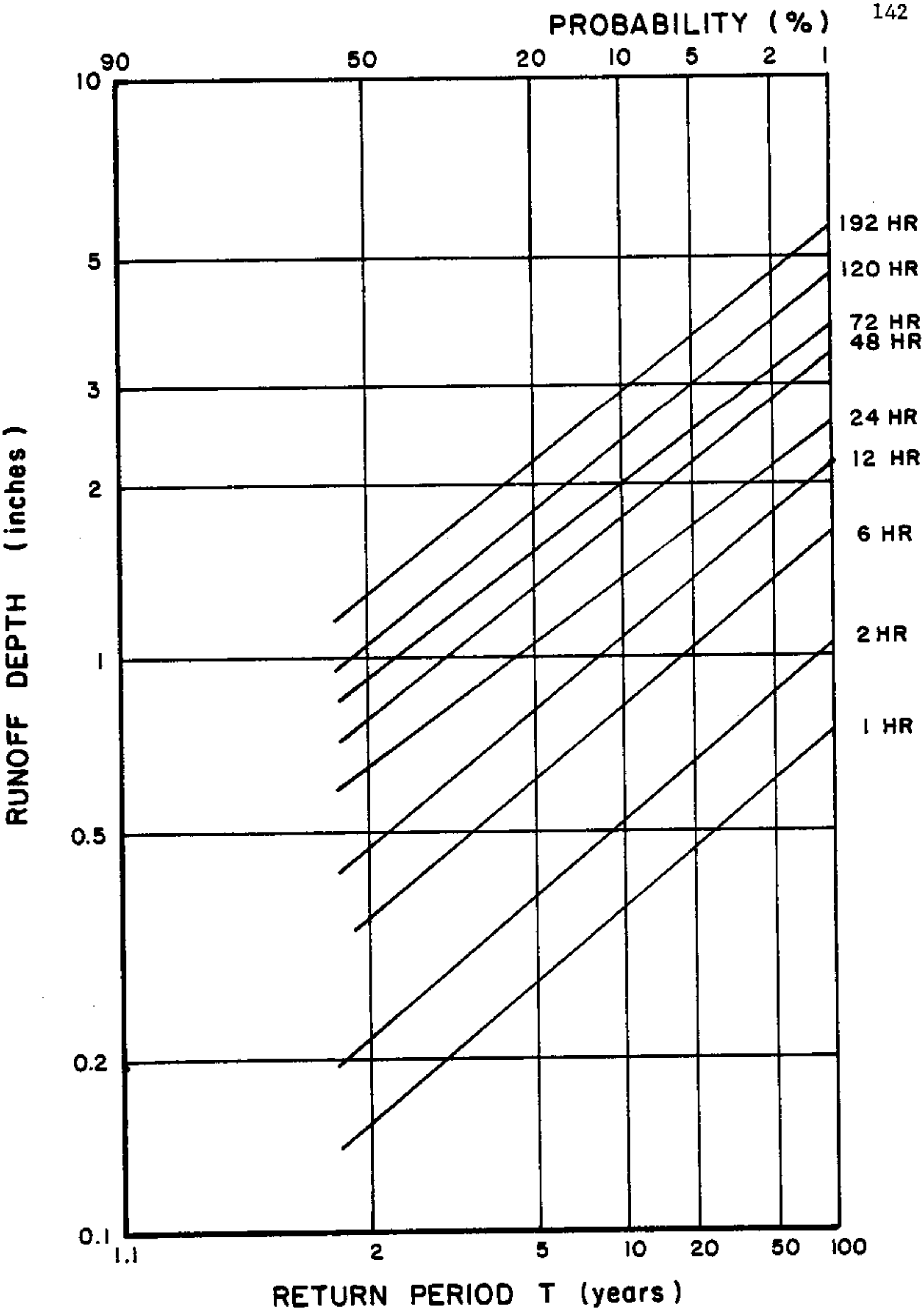

Figure D19. Log-Probability for Summer Months Exceedance Runoff Depth, Watershed W-1

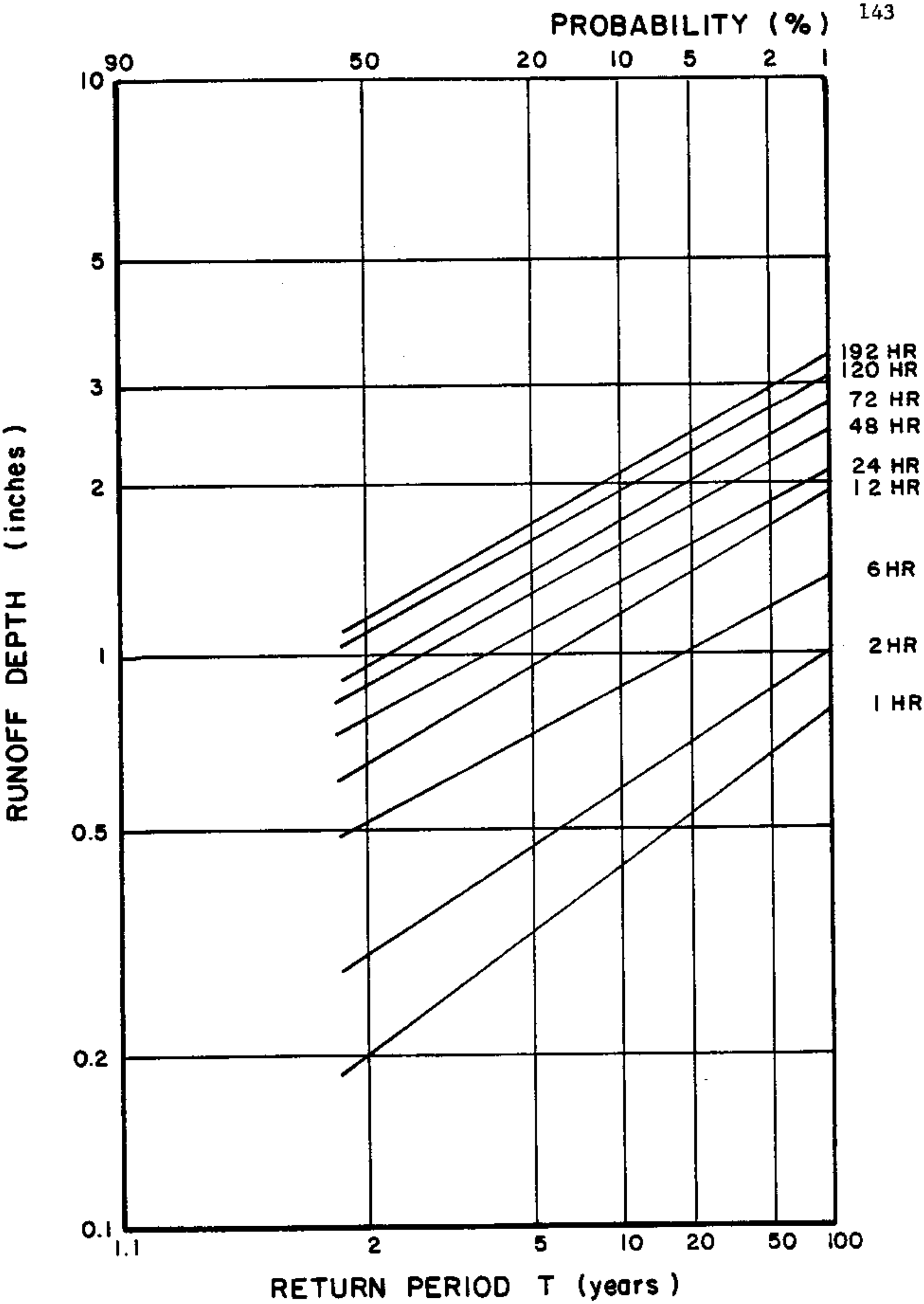

Figure D20. Log-Probability for Annual exceedance Runoff Depth, Watershed W-2

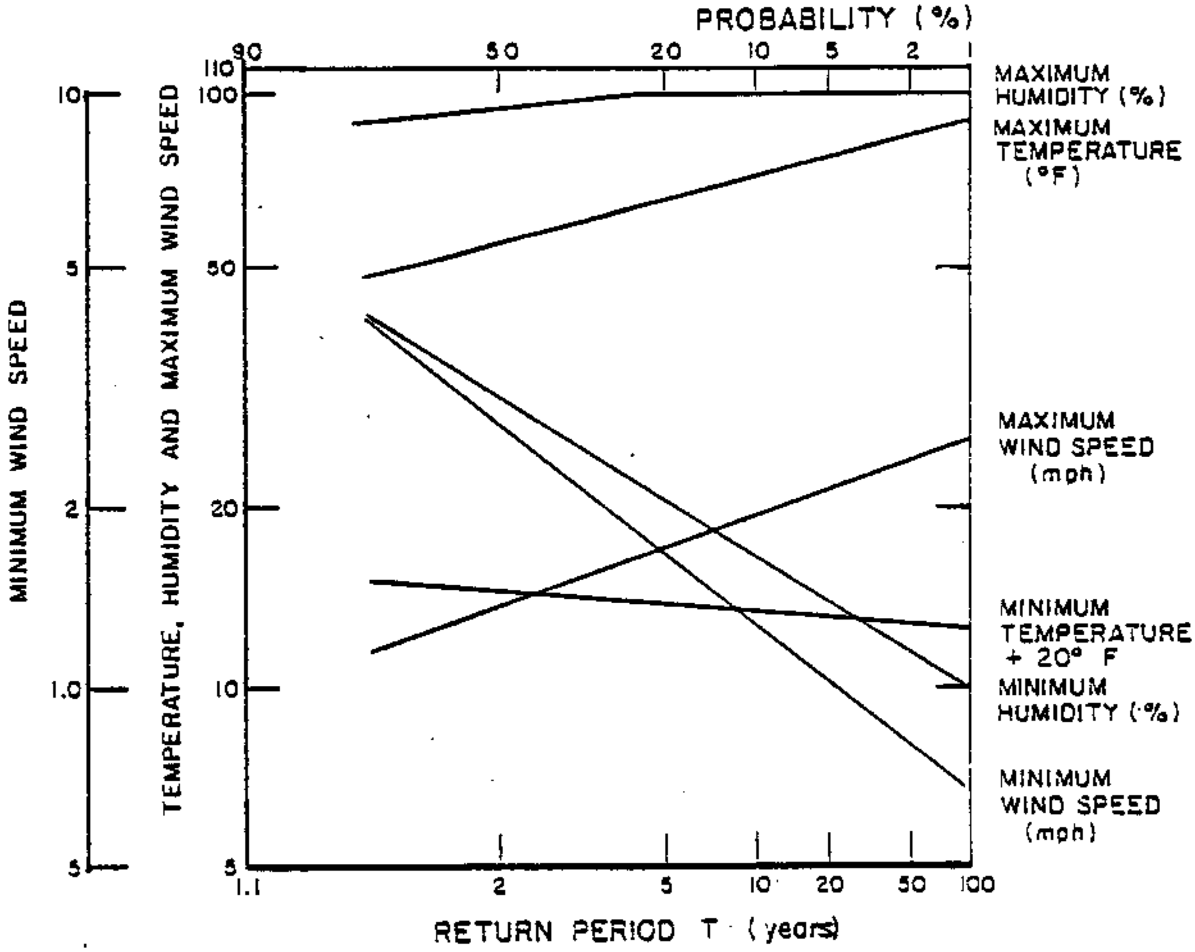

Figure D21. Log-Probability for Daily Average Minimum and Maximum Temperature, Humidity, and Wind Speed for January.

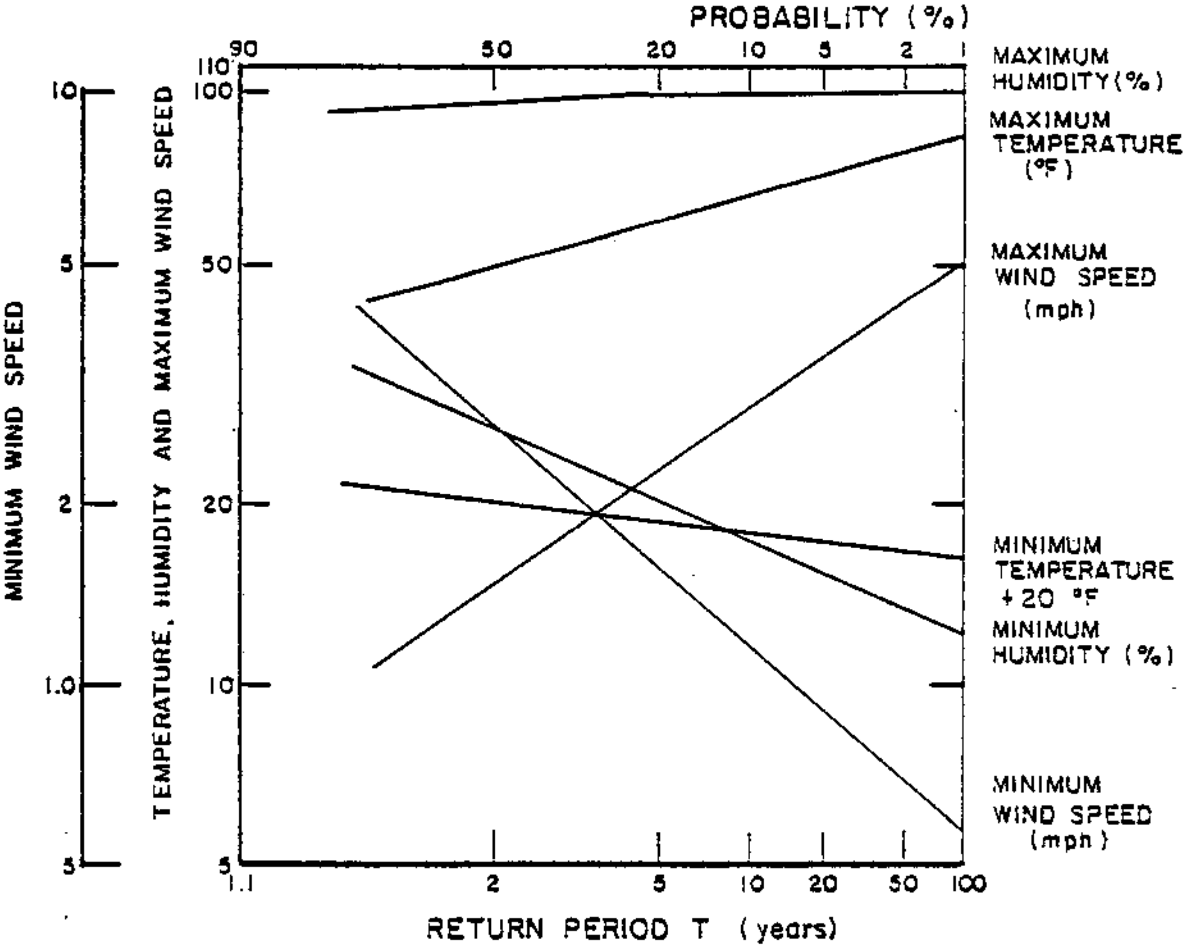

Figure D22. Log-Probability for Daily Average Minimum and Maximum Temperature, Humidity, and Wind Speed for February.

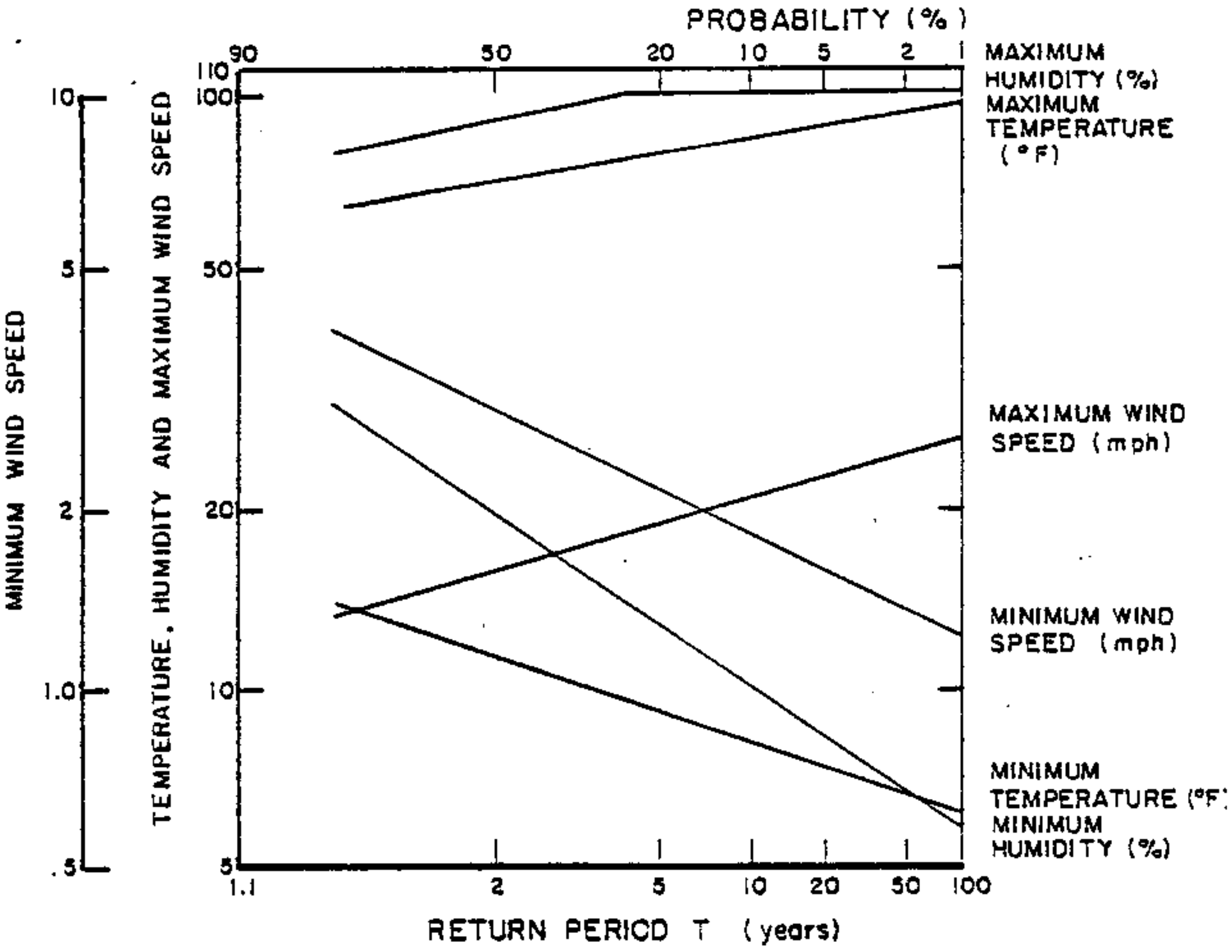

Figure D23. Log-Probability for Daily Average Minimum and Maximum Temperature, Humidity, and Wind Speed for March.

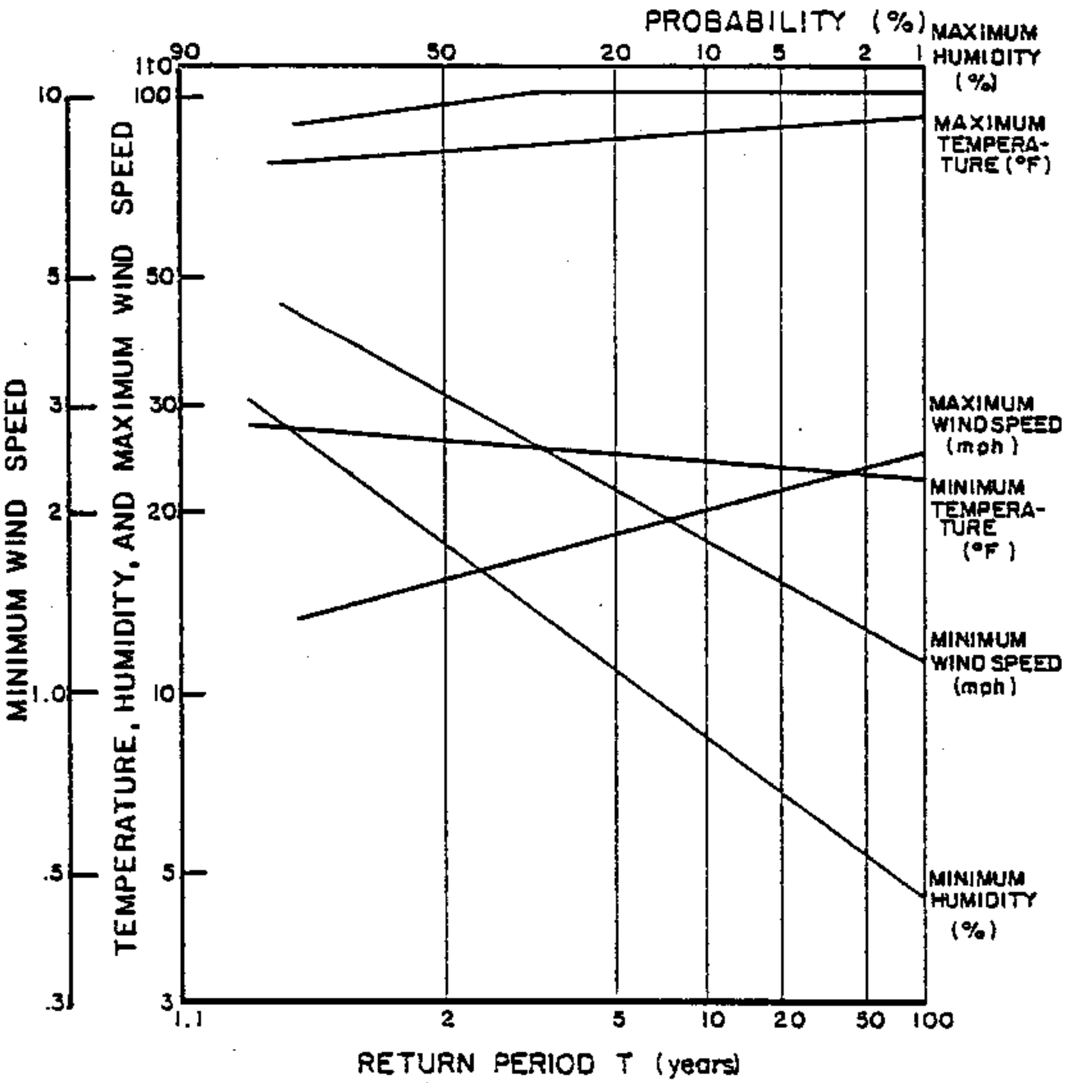

Figure D24. Log-Probability for Daily Average Minimum and Maximum Temperature, Humidity, and Wind Speed for April.

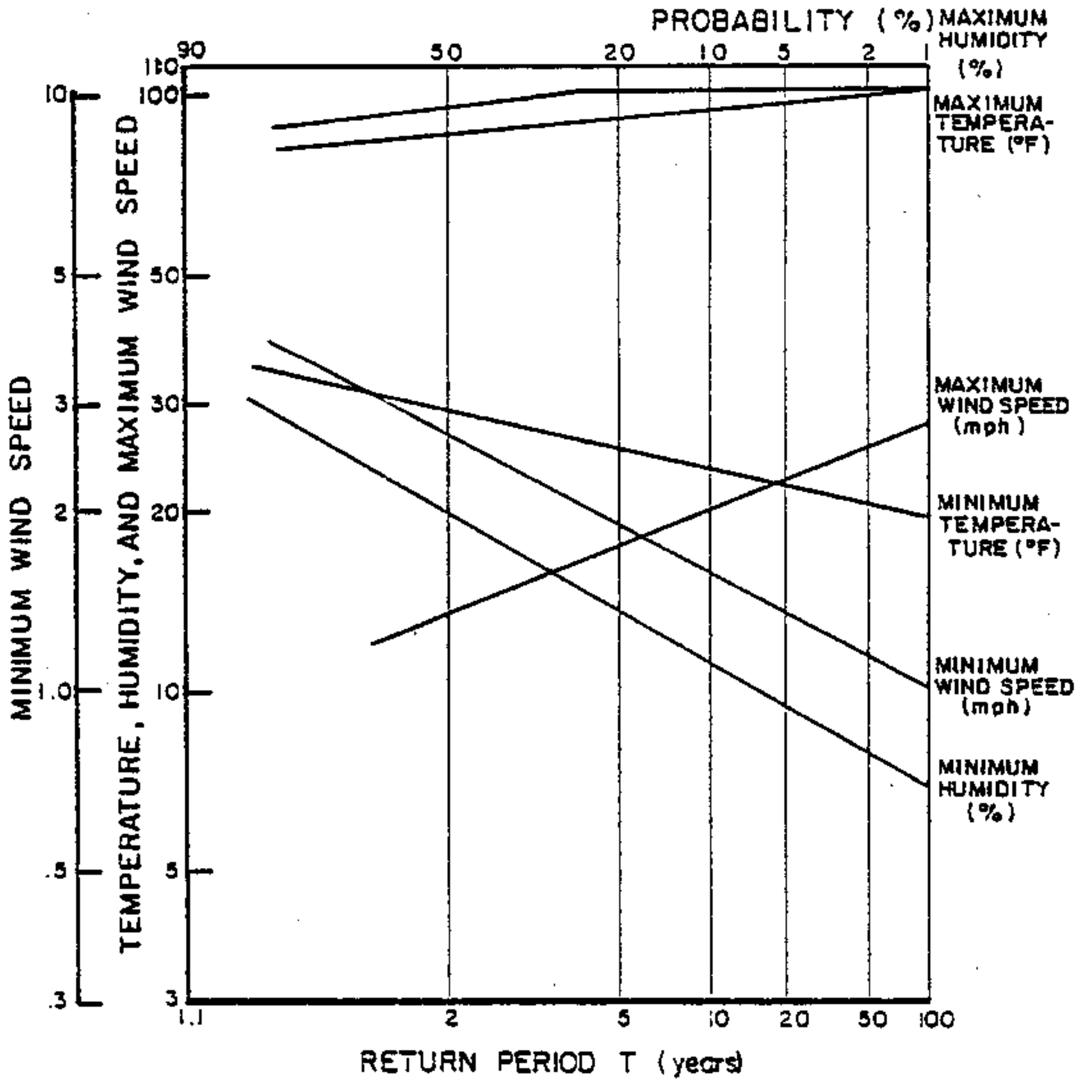

Figure D25. Log-Probability for Daily Average Minimum and Maximum Temperature, Humidity, and Wind Speed for May.

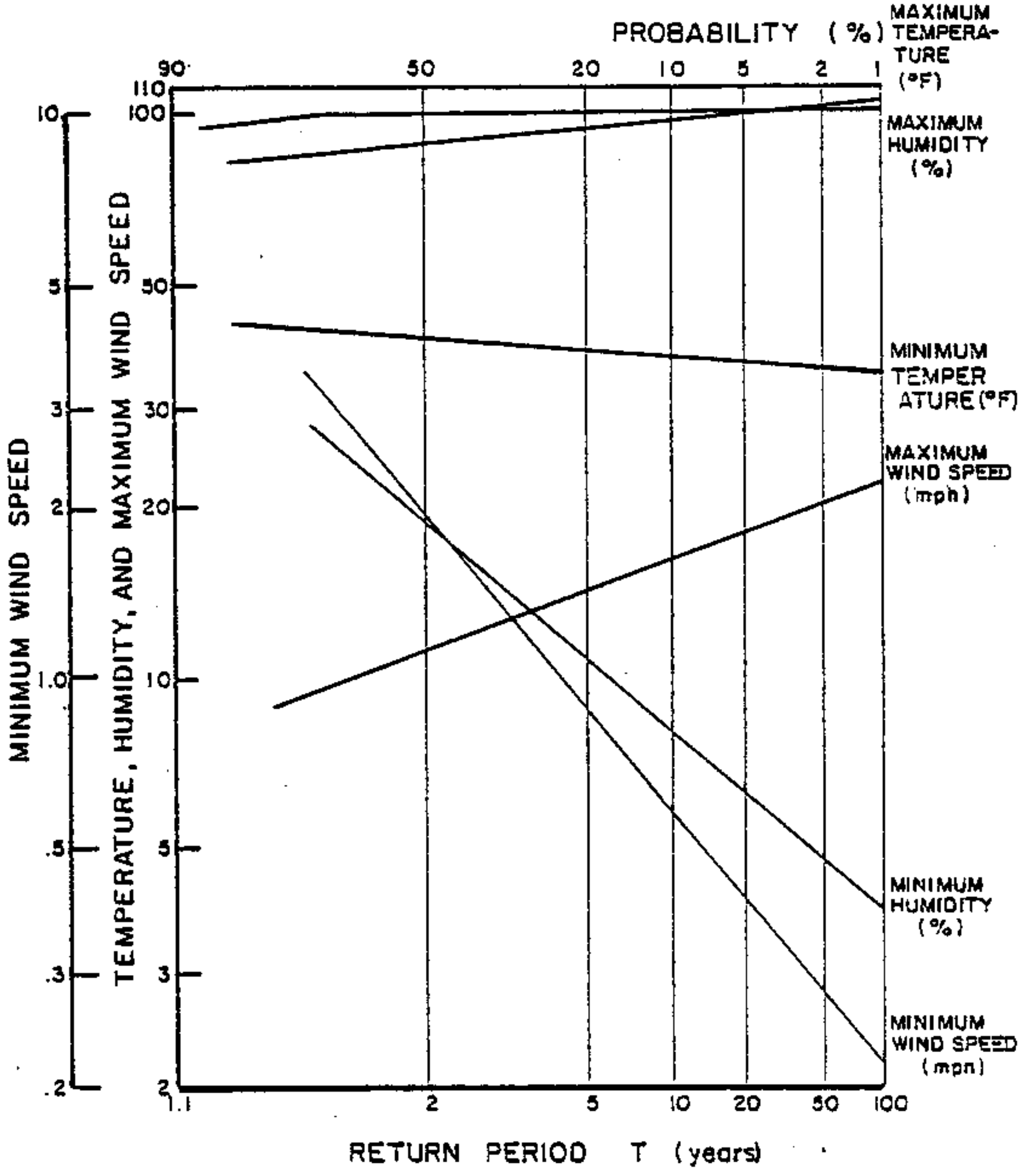

Figure D26. Log-Probability for Daily Average Minimum and Maximum Temperature, Humidity, and Wind Speed for June.

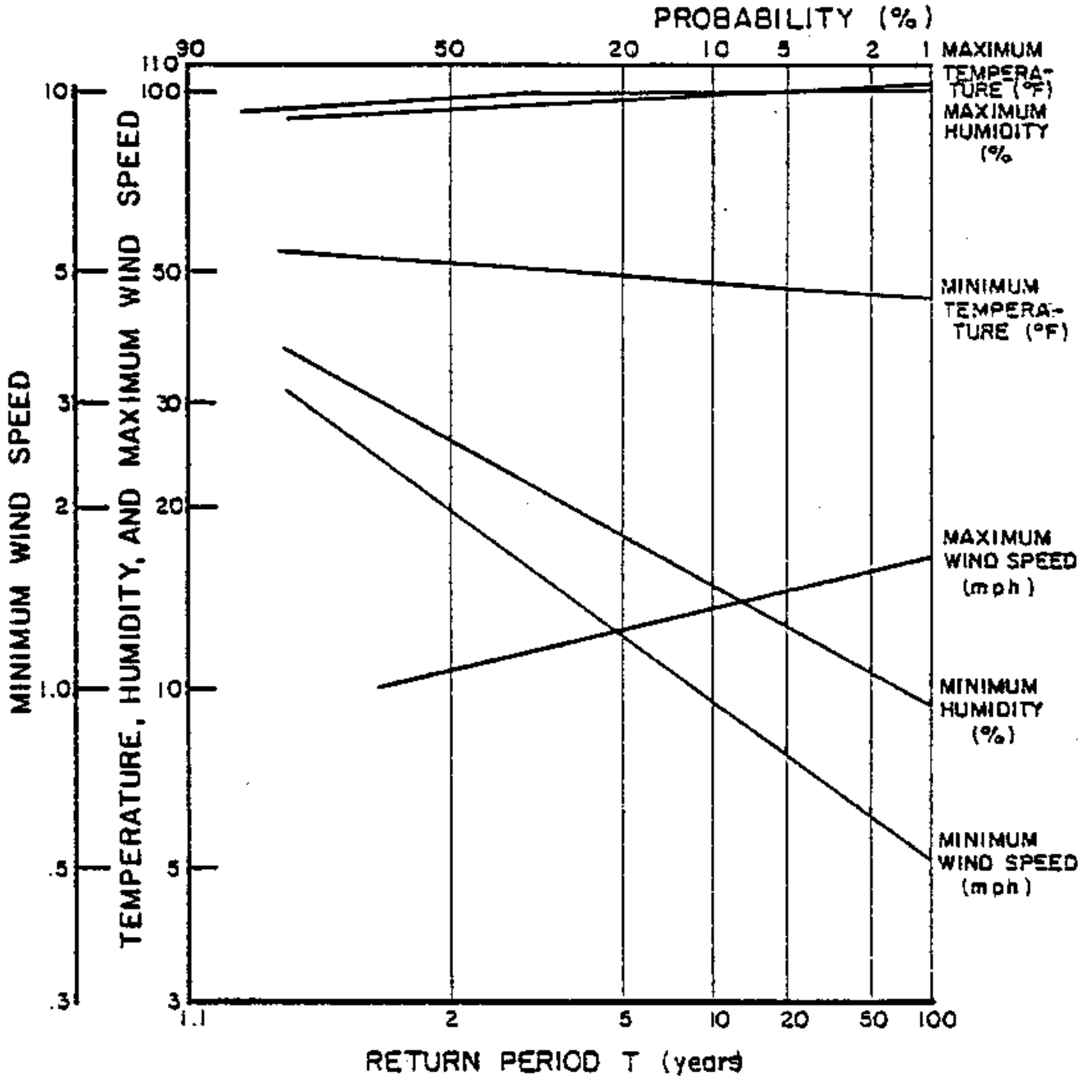

Figure D27. Log-Probability for Daily Average Minimum and Maximum Temperature, Humidity, and Wind Speed for July.

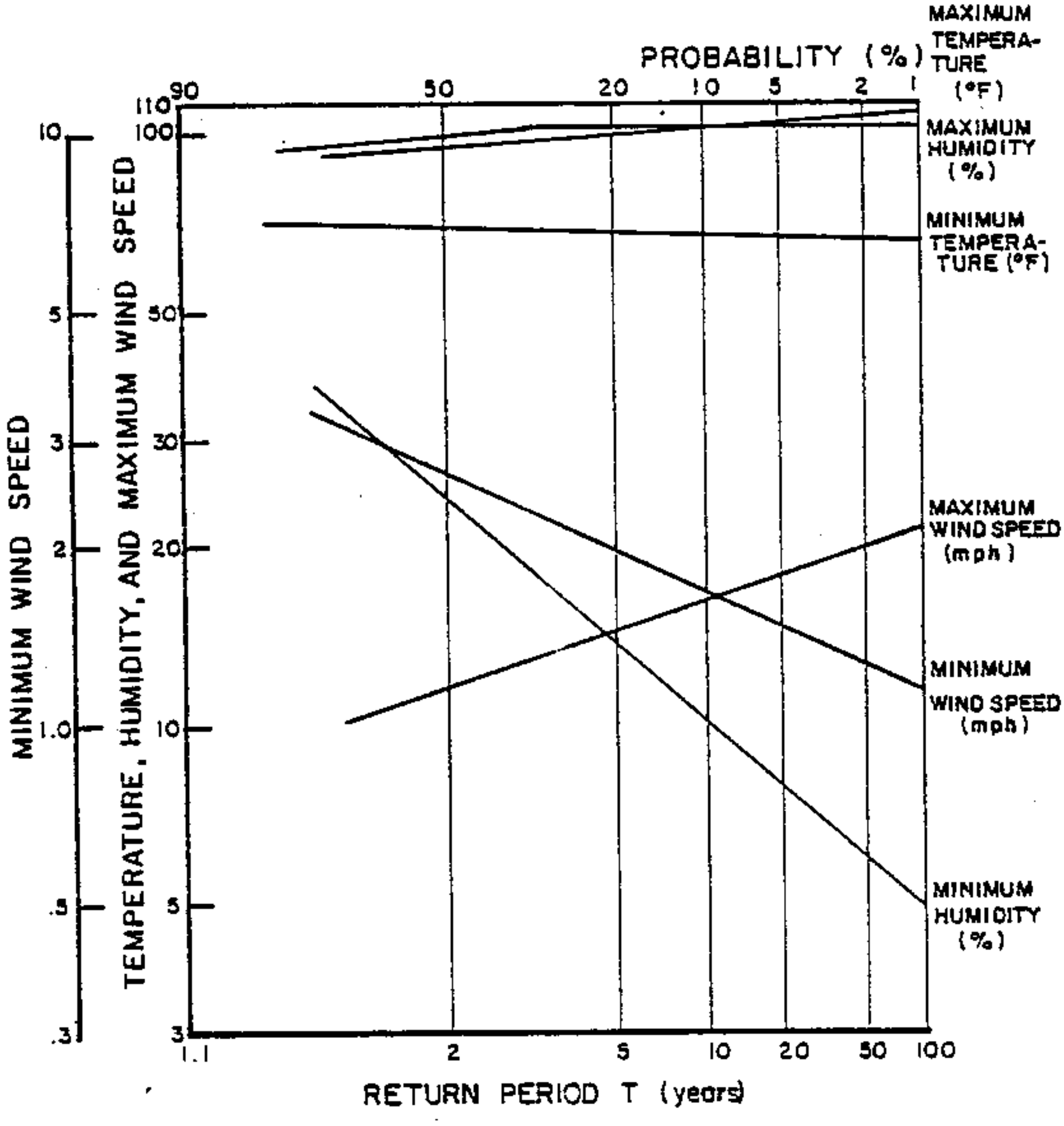

Figure D28. Log-Probability for Daily Average Minimum and Maximum Temperature, Humidity, and Wind Speed for August.

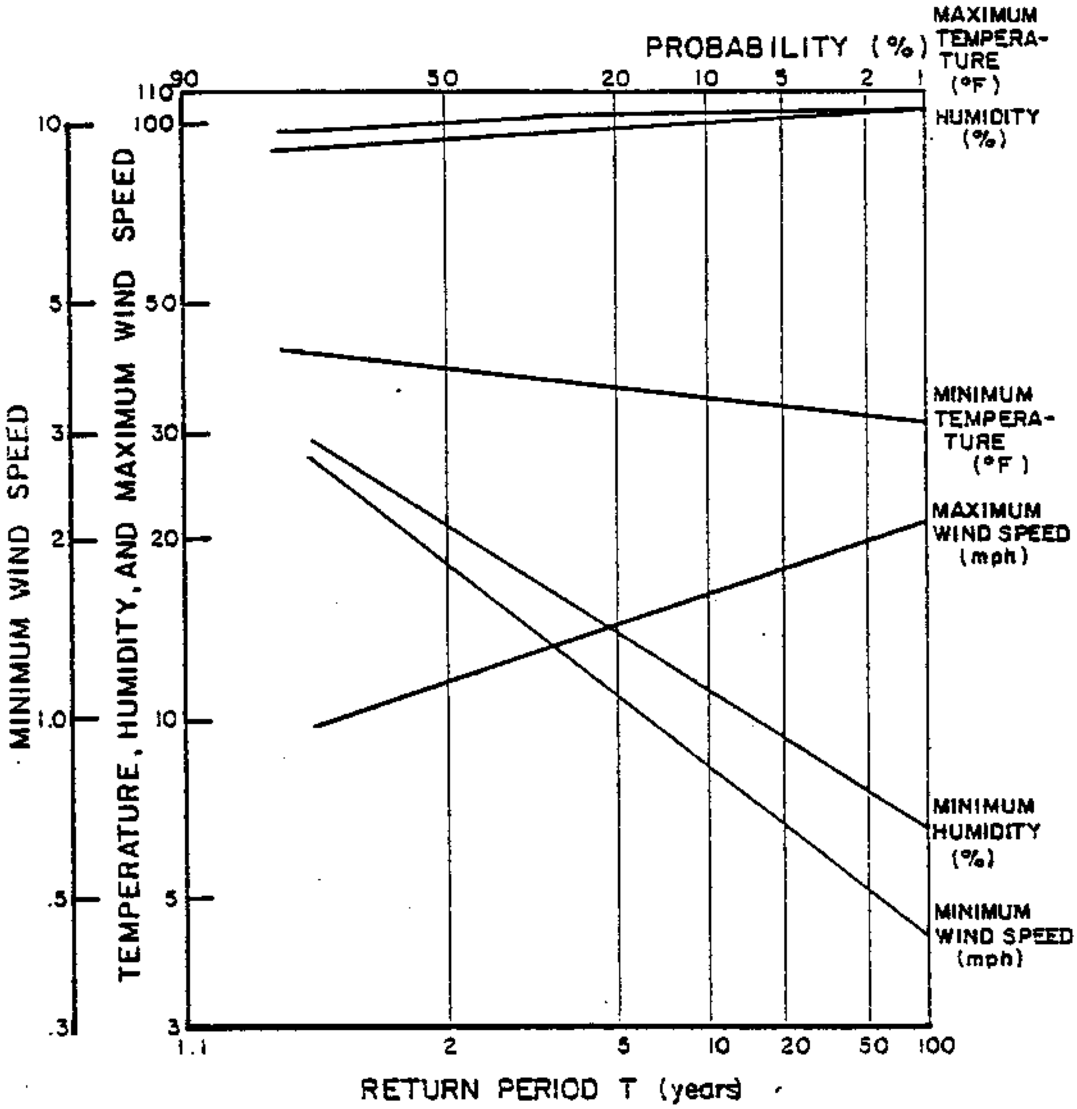

Figure D29. Log-Probability for Daily Average Minimum and Maximum Temperature, Humidity, and Wind Speed for September.

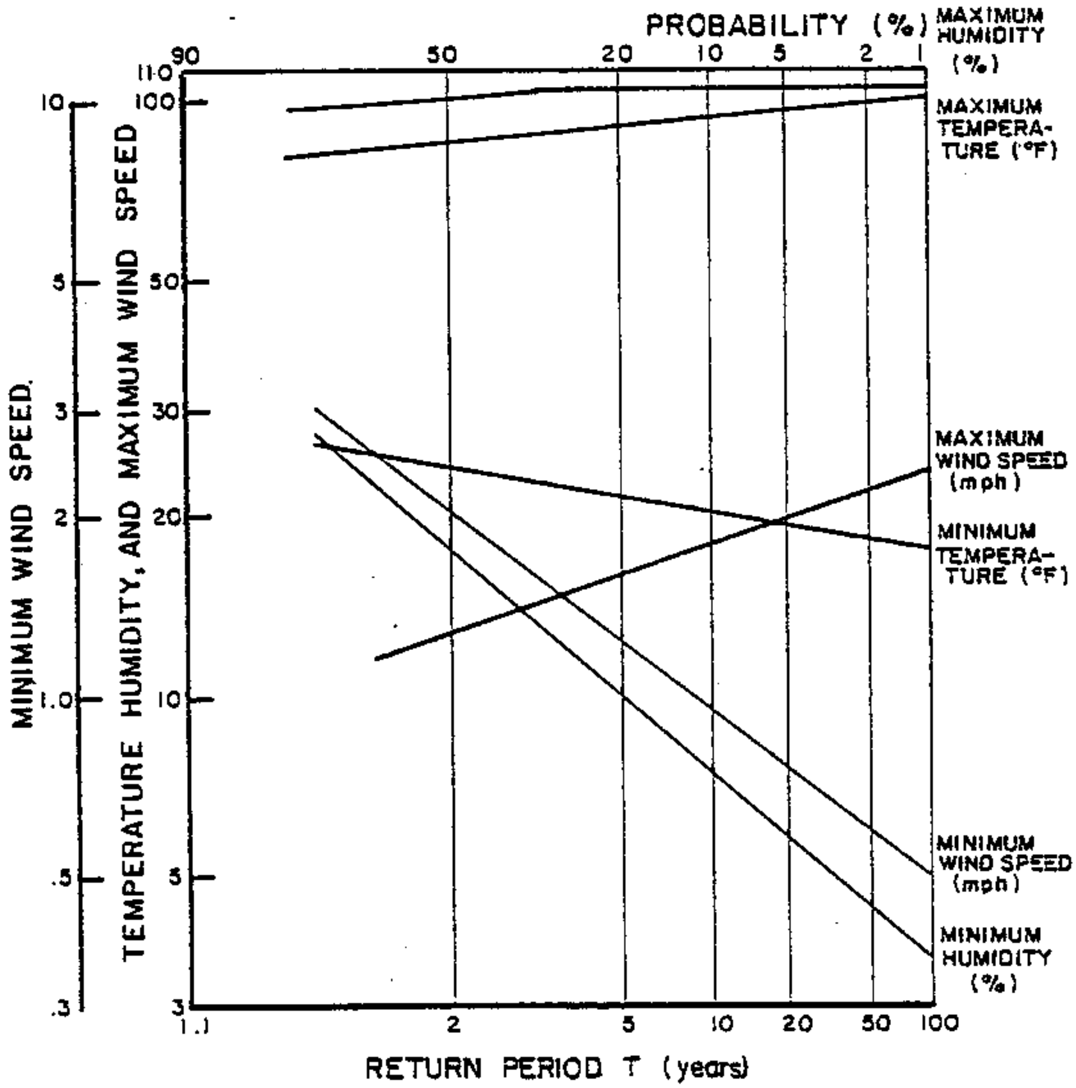

Figure D30. Log-Probability for Daily Average Minimum and Maximum Temperature, Humidity, and Wind Speed for October.

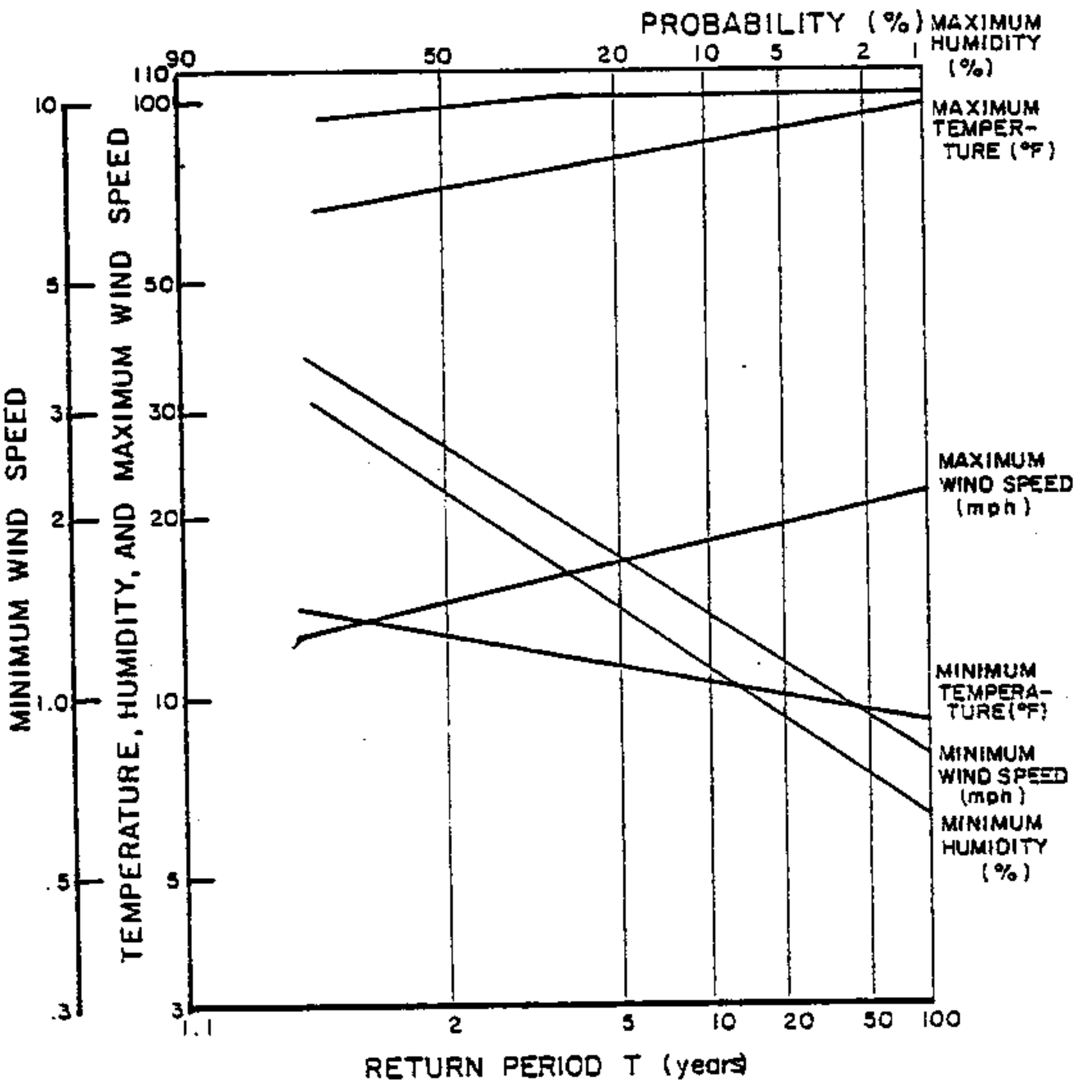

Figure D31. Log-Probability for Daily Average Minimum and Maximum Temperature, Humidity, and Wind Speed for November.

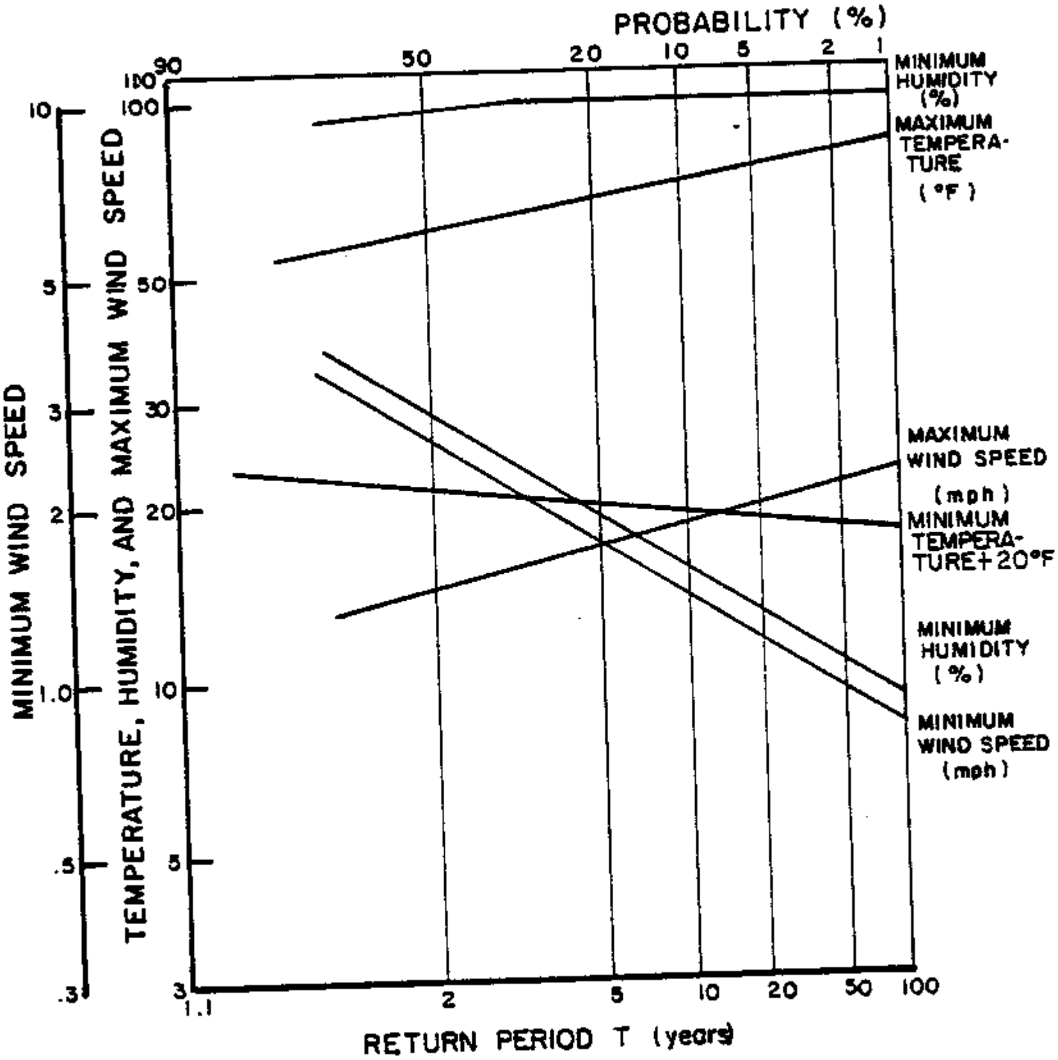

Figure D32. Log-Probability for Daily Average Minimum and Maximum Temperature, Humidity, and Wind Speed for December.

APPENDIX E

RAINFALL-RUNOFF CORRELATION

AND REGRESSION

APPENDIX E1

Calculation of Regression Equations

In a simple correlation (one in which there is only one independent variable), the linear regression equation is written

$$Y = A + BX \quad \ldots\ldots\ldots\ldots \quad [22]$$

in which Y is the dependent variable, X is the independent variable, A is the regression constant, and B is the regression coefficient. The coefficient B is evaluated from the tabulated data by use of equation

$$B = \Sigma\ (x_i y_i) / \Sigma\ x_i^2 \quad \ldots\ldots\ldots\ldots \quad [23]$$

in which x_i is the deviation of a single value X from the mean M_x of the series, and y_i is similarly defined from the mean M_y of its series. The regression constant A is obtained from the tabulated data by use of equation

$$A = M_y - BM_x \quad \ldots\ldots\ldots\ldots \quad [24]$$

in which M_x is the mean of the independent variable, M_y is the mean of the dependent variable, and B is the regression coefficient.

The correlation coefficient R is the square root of the coefficient of determination R^2 which is determined from the equation

$$R^2 = (\Sigma x_i y_i)^2 / \Sigma x_i^2\ \Sigma y_i^2 \quad \ldots\ldots\ldots\ldots \quad [25]$$

The number of degrees of freedom (df) is obtained by subtracting the number of variables (dependent and independent) from the number of events tabulated for each variable.

APPENDIX E2

COMPUTER PROGRAM LIST FOR RAINFALL-RUNOFF

CORRELATION ANALYSIS

```
   REAL PCPTN,RUNOFF
   REAL X(100,2),SUMA,SUMB,SUMC,AMEAN(2)
   INTEGER YEAR,NUM(2)
   PRINT 8
3  FORMAT (6X,'LEGEND'/6X,' RSQ =COEFFICIENT OF DETERMINATION'/
  $ 6X,' R  =COEFFICIENT OF CORRELATION'/6X,' B  =REGRESSION
  $ COEFFICIENT OR SLOPE'/6X,' A  =REGRESSION CONSTANT OR POINT
  $ OF INTERCEPT'/6X,' N  =NUMBER OF YEARS')
   PRINT 3
3  FORMAT(5X,'YEAR',5X,'PCPTN',5X,'RUNOFF')
   N=0
)  READ 12,YEAR,PCPTN,RUNOFF
2  FORMAT (I4,1X,F7.4,F7.4)
   PRINT 6,YEAR,PCPTN,RUNOFF
5  FORMAT (5X,I4,2F10.4)
   IF(YEAR.EQ.0) GOTO 22
   N=N+1
   X(N,1)= RUNOFF
   X(N,2)= PCPTN
   GO TO 10
2  DO 11 I=1,2
   SUM=0
   DO 44 J=1,N
4  SUM=SUM+X(J,I)
   AMEAN(I)= SUM/N
1  CONTINUE
   SUM A=0
   SUM B=0
   SUM C=0
   DO 55 J=1,N
   SUM A=SUM A+(X(J,1)-AMEAN(1))*(X(J,2)-AMEAN(2))
   SUM B=SUM B+(X(J,1)-AMEAN(1))**2
   SUM C=SUM C+(X(J,2)-AMEAN(2))**2
5  CONTINUE
   RSQ= SUM A**2/(SUM B*SUM C)
   R=SQRT(RSQ)
   B=SUM A/SUM C
   A=AMEAN(1)-B*AMEAN(2)
   PRINT 7,N,RSQ,R,B,A
 7 FORMAT(6X,' N    =',I5/6X,' RSQ =',F10.4/6X,' R    =',F10.4/
  $ 6X,' B    =',F10.4/6X,' A    =',F10.4)
   STOP
   END
NTRY
   THE INPUT DATA CARDS ARE PLACED HERE
TOP
```

Table E1

Confidence Intervals and Confidence Limits for

the Correlation Coefficient R

Watershed	Correlation Coefficient R			Std. Dev. of Correlation Coefficient S_R	Confidence Limits		Remark
	Calculated	Table[a]			$R-3\ S_R$	$R+3\ S_R$	
		5%	1%				
1. Annual rainfall-runoff							
A-1	0.6454	0.388	0.496	0.114	0.302	0.989	$R \neq 0$
B-1	0.7005	0.388	0.496	0.100	0.400	1.000	$R \neq 0$
W-2	0.6574	0.396	0.505	0.114	0.317	0.998	$R \neq 0$
2. Summer months rainfall-runoff							
W-1	0.5297	0.423	0.537	0.153	0.069	0.990	$R \neq 0$

[a]From Snedecor (1957)

Table E2

t-Test for Differences in Regression Lines

(B = slope; A = point of intercept)

Difference Between Watersheds	D.F.	S_p^2	t-Calculated		t-Table	
			For B	For A	5%	1%
A1 and B1	48	1.379	-0.847	21.769[b]	2.010	2.682
A1 and W1	46	5.056	-0.237	30.260[b]	2.013	2.688
A1 and W2	47	7.004	-1.990	-40.838[b]	2.012	2.684
B1 and W1	46	5.224	0.199	-40.856[b]	2.013	2.688
B1 and W2	47	7.168	-1.727	33.547[b]	2.012	2.684
W1 and W2	45	11.184	1.508	54.182[b]	2.074	2.690

[a]Significantly different

[b]Highly significantly different

APPENDIX F

LENGTH OF RECORDS

Table F1

Minimum Acceptable Years of Record (Y) for Monthly and

Annual Total Rainfall

Data	Minimum Acceptable Years of Record (Y)[a]:												
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Ann.
RG1	b	40	40	29	42	43	25	36	68	b	36	b	9
RG5	b	36	40	29	40	52	74	37	70	b	34	b	9
Watershed A1	b	38	35	37	37	42	25	39	60	100	32	b	9
Watershed B1	b	39	35	39	39	42	27	40	65	100	33	b	9
Watershed W1	b	39	35	28	38	43	26	41	65	b	33	b	9
Watershed W2	b	38	37	28	41	38	27	37	75	b	35	b	9

[a]Calculated from: $Y = (4.30\ t \log R)^2 + 6$
where t was obtained from t-table for (N-6) degrees of freedom
R is the ratio of 100-year event to 2-year event, each event was obtained from the corresponding log-probability curve

[b]The log-normal distribution method does not apply

Table F2

Minimum Acceptable Years of Record (Y) for Monthly

Total Growing Season Rainfall

Data	Minimum Acceptable Years of Record (Y)[a]:						
	Apr.	May	June	July	Aug.	Sept.	Oct.
RG3	32	37	38	23	39	70	70
RG4	28	40	36	26	43	84	69
RG6	24	36	39	25	35	76	55

[a]Calculated from $Y = (4.30\ t \log R)^2 + 6$
where t was obtained from t-table for (N-6) degrees of freedom
R is the ratio of 100-year event to the 2-year event, each
event was obtained from the corresponding log-probability curve

Table F3

Minimum Acceptable Years of Record (Y) for Maximum Rainfall Intensities

Data	Minimum Acceptable Years of Record (Y)[a] for Duration (minutes):										
	2	5	10	15	20	30	60	120	240	360	720
RG1	19	18	16	13	12	12	13	12	14	13	14
RG5	20	17	14	14	14	15	17	15	14	14	14
Watershed A1	14	13	13	13	12	12	14	13	14	14	14
Watershed B1	14	14	15	15	13	14	14	14	15	14	14
Watershed W1	24	13	10	11	12	13	14	13	12	13	12
Watershed W2	12	9	10	12	14	16	17	15	14	13	15

[a]Calculated from: $Y = (4.30\ t \log R)^2 + 6$
where t was obtained from t-table for (N-6) degrees of freedom
R is the ratio of 100-year event to 2-year event, each event was obtained from the corresponding log-probability curve

Table F4

Minimum Acceptable Years of Record (Y) for Annual Exceedances Runoff Depth

Data	Minimum Acceptable Years of Record (Y)[a] for Duration (hours):								
	1	2	6	12	24	48	72	120	192
Watershed A-1	27	25	24	22	22	20	17	21	21
Watershed B-1	23	27	25	24	21	22	23	24	24
Watershed W-1	31	32	30	30	26	27	26	28	28
Watershed W-2	24	21	16	18	16	17	17	17	17

[a]Calculated from: $Y = (4.30\ t \log R)^2 + 10$
where t was obtained from t-table for (N-6) degrees of freedom
R is the ratio of 100-year event to 2-year event, each event was obtained from the corresponding log-probability curve

Table F5

Minimum Acceptable Years of Record (Y) for Maximum Temperature, Humidity, and Wind Speed

Data	Minimum Acceptable Years of Record (Y)[a]:											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Daily Average Maximum Temperature	11	23	9	9	12	11	9	10	10	10	8	9
Daily Average Maximum Humidity	6	6	6	6	6	6	6	6	6	6	6	6
Daily Average Maximum Wind Speed	9	9	7	7	7	7	7	7	7	7	8	8

[a]Calculated from: $Y = (4.30\ t\ \log R)^2 + 6$
where t was obtained from t-table for (N-6) degrees of freedom
R is the ratio of 100-year event to 2-year event, each event was obtained from the corresponding log-probability curve