US Army Corps of Engineers
Los Angeles District

LOS ANGELES, CALIFORNIA

DEBRIS METHOD

LOS ANGELES DISTRICT METHOD FOR PREDICTION OF DEBRIS YIELD

FEBRUARY 1992

UPDATED FEBRUARY 2000

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The Los Angeles District Debris Method Report was updated to include the data used in developing the debris yeild equations. These data are presented in Appendix E. This update also includes several editorial and formating corrections from the previous report.

***** There have been NO CHANGES to the methodology or resulting equations.*** **

PREFACE

The Los Angeles District Method for Prediction of Debris Yield was developed to provide a systematic approach for determining the debris yield from a single flood event to be used in design of debris basins.

The Method was developed using data from coastal-draining, mountainous, Southern California watersheds, varying in area from 0.1 to 200 mi². It is intended to estimate debris yield for flood events greater than those with a 5-year recurrence.

Outside the area from which the equations are based, application of the Adjustment-Transposition Factor and the Fire Factor must be carefully applied.

Los Angeles District

U.S. ARMY CORPS OF ENGINEERS

Prepared by Elden Gatwood, John Pedersen, and Kerry Casey
Hydrology and Hydraulics Branch

CESPL-ED-HH
911 Wilshire Blvd., Suite 1260
Los Angeles, CA 90017-3401

(213)-452-3547

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1. INTRODUCTION, OBJECTIVE, BACKGROUND, AND LIMITATIONS.

1.1. Introduction. In Southern California, increasing population pressure has resulted in development on alluvial fans and floodplains, historically areas of considerable erosion and aggradation. The estimation of debris yield from an erosive upland watershed, resulting from the occurrence of a single large storm event, is of great importance in the design and maintenance of debris basins and reservoirs protecting these areas.

"*Total debris yield*" is the total debris outflow (silt, sand, clay, gravel, boulders, and organic materials) from a watershed (or drainage basin) measurable at a specified concentration point for a specified flood event. "*Debris yield*", as determined by the procedure discussed in this report, is the quantity of debris actually caught by a debris-catching structure. Thus, it is the quantity used to size a debris-catching structure. "*Debris production*" is the gross erosion within a watershed. The entire debris production may not necessarily reach the concentration point due to the occurrence of intermediate storage within the watershed, resulting from a lack of transporting capacity of the conveyance system.

The ratio between debris yield and debris production, called the "*delivery ratio*", is usually expressed as a percentage and can be estimated if one is knowledgeable about the soils, climate, topography, and geomorphic characteristics of the watershed. For very small watersheds, debris yield and production may be equivalent (i.e., the delivery ratio may be unity). Delivery ratio decreases with increasing drainage area size. Since measured debris volume ("yield") records have been used in developing the predictive equations presented herein, debris quantities predicted by these equations will be referred to as debris "yields" and represent the amount of debris for which a debris-catching structure should be sized.

The extent, recency, and frequency of forest and brush fires (wildfire) directly affects the amount of runoff and debris yield from a watershed. Since the occurrence of flood and wildfire events are independent processes, coincident-frequency analysis depicting the relationship between fire frequency and the frequency of flood events is a viable approach to determine the probabilities of occurrence of debris yield events of various magnitudes.

1.2. Objective. The primary objective of this study is to develop a method to estimate unit debris yield values for "n-year" flood events for the design and analysis of debris-catching structures in coastal Southern California watersheds, considering the coincident frequency of wildfire and flood magnitude. The principle area of application is shown on Figure 1. Such structures are normally sized to intercept debris from a single large flood event. Flood history in Southern California clearly demonstrates the debris yield hazard as one associated with singular storm events. Normal maintenance practice is to excavate immediately following a major flood event to regain storage

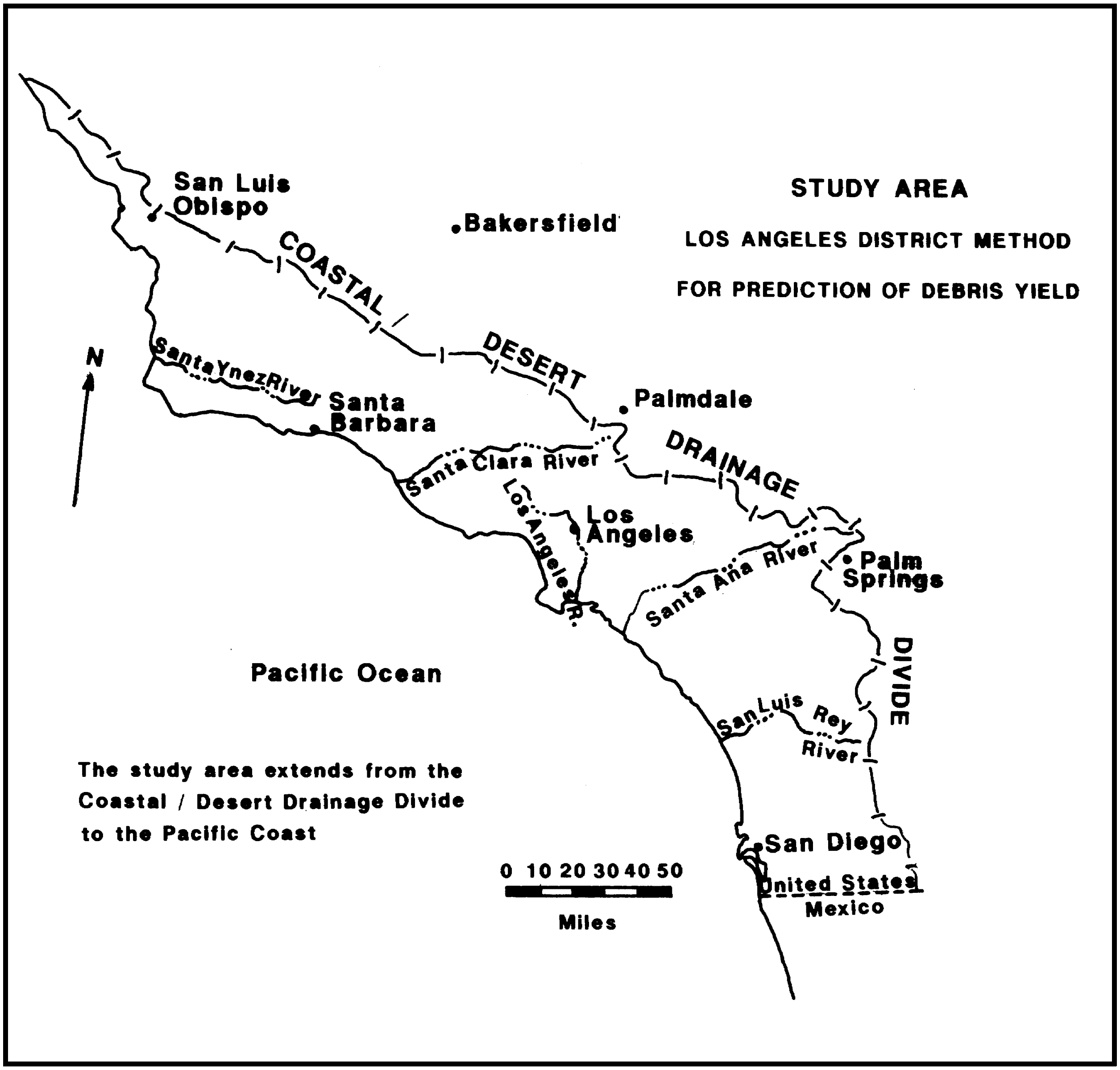


Figure 1: Principle Area of Application

capacity before subsequent storms occur. Such maintenance practice is essential toward keeping construction cost down to affordable levels and toward minimizing environmental effects associated with structure size. The project owner's ability to implement such timely maintenance should always be considered when determining storage requirements in the design process.

1.3. Background. The necessity for a single-event approach to debris yield versus a long-term approach is explained in part by examination of daily suspended sediment discharge measurements taken by the U.S. Geological Survey (USGS) in selected coastal Southern California watersheds (Ref. 8.25). It is apparent that the bulk of debris yielded by watersheds in Southern California results from a small number of discrete events. Records for San Diego Creek in Orange County, California indicate that, for the 1978-79 water year, over 99% of the volume of suspended sediment was yielded by the watershed during less than 8% of the time. Further examination indicated that over 50% of the suspended sediment yielded by the watershed during this water year resulted from a single two day event. Records from the Santa Clara River in Ventura County, California for the same water year indicate that over 60% of the suspended sediment yielded by the watershed during the year resulted from a single two day event.

During wetter years, watersheds in Southern California tend to yield an even greater proportion of their total debris load during short-term storm events. Records from San Diego Creek for the wet 1979-80 season indicate that over 99% of the annual volume of suspended sediment was yielded by the watershed during less than 4% of the time. In addition, over 80% of the annual volume of suspended sediment resulted from a single storm event. Analysis of debris yield records indicated that the debris yielded by smaller watersheds during short-duration events accounts for an even larger proportion of the total than was apparent in larger watersheds.

Suspended sediment records do not account for the bedload fraction of the total load, or the sediment and debris which moves along the streambed by traction and saltation. This portion of the total debris yield varies considerably with the magnitude of a given flood event, but commonly ranges from 5% to over 50% of the total debris volume, depending on the nature of debris movement. Since bedload requires larger amounts of flow to initiate movement, and it is clear that even the bulk of the more easily-entrained suspended load tends to result from a small number of larger events, the single-event approach is a necessity for the accurate prediction of debris yield from floods impacting coastal Southern California watersheds.

In 1963, Mr. Fred Tatum of the Los Angeles District of the Corps of Engineers introduced a new method for estimating debris storage requirements for debris basins. In the ensuing 23 years, numerous debris basins have been planned, designed, and constructed using the Tatum method. However, during that same period, several major floods have occurred, which provided a considerable expansion in the debris data base. This study seeks to utilize the new data to update traditional hydrologic procedures and design concepts. As more data accumulates in future years, updating of the current Method is envisioned. To this end, all agencies with a stake in the control of debris are encouraged to actively collect useful data for the enhancement of future designs.

This report presents a scientific, application-oriented Coincident-Frequency Analysis approach to assigning a frequency relationship to unit debris yield based on the total probability of wildfire and flood. Equations were developed to estimate unit debris yield from coastal Southern California watersheds on an single-event basis. The estimation method is based on multiple linear regression between measured unit debris yield and a set of physiographic, hydrologic, and/or meteorologic parameters found to influence the process of debris yield from these watersheds. Past experience has demonstrated that a single universal equation, regardless of complexity, does not adequately describe the complex nature of the process of debris yield from coastal Southern California watersheds.

In this study, multiple regression analyses indicated that unit debris yield is most highly correlated with the unit peak runoff rate from a watershed (or the maximum 1-hour precipitation depth), the relief of the drainage basin, the contributing area, the fire history, and geomorphologic characteristics of the watershed. The highest correlation was obtained with a log-transformation (base 10) of all quantifiable variables used in the final equations.

1.4. Limitations. Limitations on the use of the Method include the following:

1.4.1. <u>Geographic Location</u>. The Method is intended to be used for the estimation of debris yield mainly from coastal-draining, mountainous, Southern California watersheds (see Figure 1). Outside of the area from which the data were taken (San Gabriel Mountains), application of the Adjustment/ Transposition (A-T) Factor must be carefully applied. Use of the Method in areas outside those delineated in Figure 1 should be done with caution. Conditions different from those of the San Gabriel Mountains needs to be addressed. Because vegetation types and density are far different in desert-draining than coastal-draining watersheds, the effects of wildfire will not be the same. Therefore, the Fire Factor (FF) variable, which accounts for the impact of wildfire on debris yield from these watersheds, must also be carefully applied.

1.4.2. <u>Drainage Area Constraints</u>. The Method was developed for use in watersheds of 0.1 to 200 mi² in area. Use of the Method in watersheds smaller or larger than this must be done with caution. Because the data from which the regression equations were developed fall entirely within this range, and calibration was not performed on watersheds outside of this range, use of the Method should involve careful comparison with nearby watersheds for which debris data are available.

1.4.3. <u>Topographic Constraints</u>. The Method is intended for watersheds with a high proportion of their total area in steep, mountainous terrain. It is not intended for use in low-sloped valley areas, watersheds with a significant portion of their total area in residential or commercial development, or in areas with a large portion under agricultural usage. Use of the Method for watersheds with a high percentage of alluvial fan or valley fill areas (primarily depositional environments) may result in debris estimates higher than would actually be yielded by the watershed.

1.4.4. <u>Frequency Constraints</u>. The Method is intended to estimate debris yield from runoff or precipitation events of greater than 5-year recurrence. Estimates below this generally display large errors, and the Coincident-Frequency Analysis (CFA) program may even yield negative estimates for these events.

1.4.5. <u>Input Constraints</u>. The Method should not be used to estimate debris yield resulting from runoff events of less than 3 cubic feet per second per square mile ($ft^3/s/mi^2$), or for events during which the maximum 1-hour precipitation is less than 0.3 inches per hour (in/hr). Because the equations were derived using data from saturated watersheds, best results will be obtained for watersheds which have undergone significant antecedent rainfall. In most cases, this antecedent rainfall condition will be satisfied when the watershed has received at least 2 inches of prior rainfall in approximately 48 hours. When the Method is applied to watersheds which have not undergone sufficient antecedent rainfall, predicted debris yield may be considerably greater than that actually yielded by the watershed.

2. METHOD OF DATA ANALYSIS.

2.1. Multiple Linear Regression Analysis. Multiple linear regression analysis was selected as the method by which unit debris yield would be estimated in this study for several reasons. It has proven to be relatively rapid and accurate in prior studies (e.g., Refs. 8.1, 8.2, 8.7, 8.12 and 8.21). It also provides the investigator with a certain degree of flexibility and allows extrapolation of results to watersheds possessing similar geology, climate, and vegetation, within certain broad limitations.

Multiple linear regression yields a mathematical equation correlatively relating a dependent variable (in this case, unit debris yield in cubic yards per square mile - yd^3/mi^2) to a group of independent variables chosen for their value in explaining variation in the dependent variable (Ref. 8.27).

Twenty-four watershed variables used in prior studies were initially analyzed to determine their importance in the explanation of variation in debris yield by a simple graphical correlation between measured debris yield (calculated per unit area) and the independent variable chosen for the appropriate watershed. Correlation coefficients yielded by simple correlation of debris yield and the appropriate parameters are presented in Table 1. On the basis of this initial selection process, 19 of the 24 variables were selected for regression analysis. These variables are discussed in Section 3.

2.2. Logarithmic Transformation of Variables. In prior regression analyses (Refs. 8.12 and 8.21), logarithmic transformation (base 10) of all variables was carried out, for the following reasons:

1) a simple linear relationship is obtained among the transformed variables;

2) the distributions of the transformed variables resemble a normal distribution more closely than do those of untransformed variables; and

3) the variation of the points along the regression line is more homogeneous (i.e., variance is stabilized).

Therefore, in this study, all variables (with the exception of the non-dimensional Fire Factor) were log transformed. A log-transformation of variables in hydrologic studies may introduce a bias in itself if the record includes a predominance of small events and a relatively small number of large events, since the use of least squares of transformed variables in a multiple regression technique gives greater weight to more commonly occurring smaller values than to larger values (Ref. 8.27). In this analysis, however, debris yield measurements tended to encompass a broad range of values. When log transformed, the distribution had little skew, and in fact, very closely approached a normal distribution. In addition, debris yield records were chosen not only for their applicability to the study, but also on the basis of their representation of a broad range of hydrologic conditions and physical characteristics.

In this study, the group of variables which explained the greatest amount of variance in unit debris yield by examination of statistical indices (maximization of the coefficient of multiple determination adjusted for degrees of freedom - $\bar{R}^2$, and significance at the 95% confidence level) was selected for use in the final regression equations. Selection by statistical indices ensures that the sum of squared residuals of the dependent variable is minimized (Ref. 8.10) and consequently, the regression equations chosen are the best possible, considering the range and quality of the available data. A comparison of the study results with those of other methods developed for use in this area is presented in Table 2. In addition, a statistical summary for two of the equations presented in this study is shown in Table 3.

Intercorrelation was minimized by successive substitution of similar variables to determine that which produced the highest degree of quantifiable contribution ($\bar{R}^2$).

Some variables expected to contribute significantly to unit debris yield explanation (such as the Hypsometric-Analysis Index, Elongation Ratio, and Mean Channel Gradient) were found to possess less correlation with measured unit debris yield than more simple measures of watershed topography such as drainage area and relief ratio (see Table 1). This was determined to be either indicative of the homogeneity of certain characteristics in the studied watersheds, or that the variable was not an adequate indicator of the characteristic that it was intended to describe. This is not to imply that these variables would not appear highly significant in other studies on this topic.

2.3. Selection of Regression Package. A multiple linear regression analysis computer program, the "Statistical Package for the Social Sciences" (SPSS, Ref. 8.14), was chosen for this analysis. This program yields a large number of useful statistics and has the added benefit of being relatively simple to use. In the selected stepwise regression routine, independent variables are progressively added by the program in order of decreasing significance. Variables determined to be significant in earlier stages of the computations may be deleted upon introduction of more significant variables at a later stage. This process allows for determination of the effect of an independent variable on the dependent variable as well as the change in the relative value of this variable upon the inclusion of additional variables.

In addition to the regression equation(s) derived by the SPSS package, the following statistics were also calculated:

1) The coefficient of multiple determination (adjusted R^2 or $\bar{R}^2$), which represents the variation in the dependent variable accounted for by the regression equation, adjusted for degrees of freedom. An $\bar{R}^2$ value represents the overall test for "goodness of fit" of the regression equation, with a value of 1.0 representing perfect correlation between estimated and observed, and a value of zero representing no correlation. R^2 is the unadjusted value.

2) A simple correlation coefficient (B), which is the square root of the coefficient of determination for each independent variable, or the proportion of the variance of the dependent variable explained by the independent variable.

3) Multiple correlation coefficient (R), which is the square root of the unadjusted coefficient of determination (R^2).

4) The change in the coefficient of multiple determination ($\Delta\bar{R}^2$) that occurs upon inclusion of an additional independent variable.

5) The "F" ratios, which are used in tests of significance for the individual coefficients. The square of the "F" ratio, with an appropriate sign, is the "T" statistic, commonly used to evaluate the significance of each variable at a desired level of confidence. Simply stated, the higher the "F" ratio, the more likely that the variable chosen for analysis is appropriate.

6) A plot of residuals which indicate the difference between the estimate yielded by the regression equation and the observed value.

In addition, the SPSS package includes several options that may be chosen to enhance the usefulness of a regression equation. An important option chosen for use in this analysis enabled the regression equations to be forced through the origin. This simulates the process in which no debris yield will result (nor will be predicted) when no precipitation or runoff occurs within the basin (although considerable debris movement in the form of "dry ravel" or "gravity movement" may supply sediment to the channel system within a watershed). Furthermore, regression equations which were not forced through the origin had significantly lower $\bar{R}^2$ values and higher standard errors associated with the coefficients.

3. EVALUATION AND SELECTION OF VARIABLES FOR ANALYSIS.

3.1. Hydrologic Variables.

3.1.1. Precipitation. Recorded data indicate that there exists a great deal of variability in unit debris yield over a narrow range of rainfall conditions. Because comprehensive rain gage networks do not exist within most of the watersheds where historic debris yields were measured, a considerable amount of variation in rainfall behavior exists which was not accounted for in the recorded data. Factors not recognized include local variations in the volume and intensity of rainfall due to orographic and other effects, geographic aspect of the drainage basin, wind circulation effects, and other unmeasured parameters. A large number of precipitation variables were collected and evaluated to determine their influence on unit debris yield. Isohyetal maps were then prepared or obtained from local flood control agencies for each storm period for which debris yield measurements were available.

Precipitation variables pertaining to the storm event which caused debris inflow (as well as mean annual rainfall) included the following:

1) Maximum 15-minute rainfall
2) Maximum 30-minute rainfall
3) Maximum 1-hour rainfall
4) Maximum 3-hour rainfall
5) Maximum 6-hour rainfall
6) Maximum 24-hour rainfall
7) Maximum 72-hour rainfall

Since it was noted that antecedent soil conditions are highly important in the debris yield process, rainfall values were determined for the period following partial saturation of the soil mantle. Evaluation of the data indicated that antecedent rainfall of about two inches in a period of about two days was necessary in order for significant debris yield to occur. Thus, antecedent rainfall of approximately two inches within an approximately 48-hour period was used to designate the initiation of the rainfall period used in the regression analysis.

Precipitation values were determined by reduction of available data from several sources, such as county rain gage records, and isohyetal maps prepared by local agencies, NOAA, and the Los Angeles District (LAD) of the Corps of Engineers.

Debris yield measurements from watersheds in which wildfire had not occurred for at least ten years (to eliminate the possible effects of wildfire) were regressed against each of the precipitation variables calculated for the storm event in question. Correlation of unit debris yield with any precipitation variable was poor for watersheds greater than about 3 mi^2 in area, although short-term maximum rainfall proved to be significant in the analysis of smaller watersheds. This is probably due to the nature of prevailing storm systems that impact the Southern California area. Debris producing storms tend to be highly variable in intensity over large areas, making runoff a better indicator variable than short-term precipitation when dealing with the debris yield from large watersheds.

The choice of 3 mi^2 as the dividing line between Equations 1 and 2, and between the use of precipitation or runoff as the hydrologic variable, was based on several factors. Runoff data is generally unavailable for watersheds under 3 mi^2 in area, and the data that was available displayed poor correlation with measured unit debris yield. Watersheds larger than this were more likely to be controlled by reservoirs, which also commonly possessed inflow records for the debris yield event of interest. Peak unit inflow for these larger watersheds exhibited good correlation with measured unit debris yield. Precipitation over these larger watersheds exhibited greater variation areally than that falling on smaller watersheds, which resulted in poor correlation with unit debris yield when compared to unit peak runoff.

In a study by Ferrell et al (Ref. 8.7), the use of a short-term rainfall intensity variable had not proven to be as valuable an indicator of debris yield as 24-hour or longer precipitation variables. Long-term precipitation variables, however, do not account for the intensity of a given storm. Scott and Williams (Ref. 8.21) developed a factor that included both short-term intensity in conjunction with long-term precipitation. In the current study, the inclusion of short-term intensity in conjunction with long-term precipitation failed to improve $\bar{R}^2$ and only increased the error of the estimates.

Maximum 1-hour precipitation was adopted for use in the regression equation dealing with drainage areas of under 3 mi^2 because of its high correlation with measured debris yield (see Table 2).

3.1.2. <u>Runoff</u>. The inclusion of a runoff factor in the analysis (where this was available) proved to be a good predictor of debris yield from larger watersheds. Values of maximum 24-hour inflow, maximum 72-hour inflow, (both expressed in acre-feet per square mile - ac-ft/mi^2), and peak inflow (in $ft^3/s/mi^2$) were obtained from local flood control agencies and LAD for reservoirs and selected debris basins. Results indicated that unit peak runoff values from small watersheds were poor indicators of unit debris yield.

For watersheds over 3 mi^2 in area, however, unit peak inflow ($ft^3/s/mi^2$) proved to be highly significant in all phases of the analysis. The lack of correlation in small watersheds is attributed to errors in the estimation of runoff rates and the highly sporadic nature of debris movement in small watersheds, rather than an actual lack of correlation between debris yield and runoff. Unit peak inflow was adopted for use in the regression equations dealing with drainage areas of 3.0 to 200 mi^2 because of its high correlation with measured unit debris yield.

3.1.3. <u>Physiographic Variables</u>. Selection of physiographic variables to be used in the analysis depended on several factors. First, the variable must have demonstrated some physical significance in other studies. Second, it must also be easily calculated with relative accuracy using readily-obtainable maps or data. Third, the variable must be relatively inexpensive to obtain and evaluate. Fourth, the variable must have exhibited a high degree of correlation with measured debris yield.

Although several variables used in other research have proven to be of considerable value in the determination of debris yield (for example, Anderson's "Surface Aggregation Ratio", Ref. 8.1), collection of the data necessary for the quantification of such variables was determined to be beyond the scope of this analysis.

Variables selected by the aforementioned criteria for inclusion in the preliminary analysis are discussed below.

3.1.4. <u>Drainage Area</u>. This is defined as the contributing area of the watershed upstream of the chosen debris collection site (measured in both mi^2 and ac). Drainage area has been found to possess a high degree of correlation with debris yield in prior studies (Refs. 8.9 and 8.12), as well as in the current analysis. Drainage area was selected for use in the set of final regression equations.

3.1.5. <u>Total Stream Length</u>. (L1, L2). This is the total length of all streams in the watershed in miles. This variable was calculated for the extent of streams indicated by a blue line representing perennial or ephemeral flow on a standard USGS 1:24,000 scale topographic map (method 1 for L1). Method 2 (L2) used the blue lines as well as extension of the lines into areas on the map where a series of V-shaped contours indicate a stream or gully (as described by Morisawa, Ref. 8.13). Extension of streams by the latter technique was felt to better indicate the true extent of the stream network, although this refinement did not prove to be statistically significant. Neither L1 or L2 were used in the final regression equations.

3.1.6. Drainage Density. (DD1, DD2): The ratio of the sum of all stream lengths (in mi) to drainage area (in mi^2). This factor was also calculated by both of the methods indicated above (using L1 and L2) to establish DD1 and DD2, respectively. It has been stated that stream density appears to reach a maximum in areas of high debris yield (i.e., badlands topography, see Ref. 8.22), and as such it was felt that this factor should be included in the analysis. These variables, however, did not prove to be as statistically significant as other variables and were not used in the final regression equations.

3.1.7. Mean Bifurcation Ratio. (BR): The mean of the ratios of the number of streams of each order to the number of streams of the next order such that all first order streams are summed and divided by the number of second order streams, second order streams are summed and divided by the number of third order stream, etc. The mean bifurcation ratio is the average of all of these ratios. Stream order is defined as follows: the smallest stream channels in a drainage basin are "first order". When two first order streams join, they form a "second order" stream. When two second order streams join, they form a "third order" stream, and so on. For example, if a watershed has 24 first order streams, 12 second order streams, 4 third order streams, and 1 fourth order stream, the Mean Bifurcation Ratio is 3.0 to 1 ([24/12 + 12/4 + 4/1] /3 = 3). This factor was also calculated by both methods discussed in Section 3.2.2 above. However, it did not prove to be as statistically significant as other variables and was not included in the final regression equations.

3.1.8. Hypsometric-Analysis Index. (HI): This variable represents the relative height at which a watershed may be divided into two equal ground surface areas (Refs. 8.11 and 8.23). For example, a watershed with a maximum elevation of 3000 feet, and a minimum elevation of 1000 feet would have a Hypsometric-Analysis Index of 0.50 if the area of the watershed was equally divided at the 2000 foot contour line. The watershed would have a Hypsometric-Analysis Index of 0.75 if the area of the watershed was equally divided at the 2500 foot contour line. Although the HI has proven to be significant in other studies (Ref. 8.23), it did not prove to be as statistically significant in this study and was not included in the set of final regression equations.

3.1.9. Elongation Ratio. (ER): This ratio is produced by dividing the diameter of a circle of area equal to the area of the watershed by the maximum watershed length as measured along the longest stream from the concentration point to the watershed boundary. Scott and Williams found this variable to be highly significant in an analysis of erosion rates in the Western Transverse Ranges of Southern California (Ref. 8.21); however, it was not determined to be statistically significant in the current study and was not included in the final regression equations.

3.1.10. Relief Ratio. (RR): This factor (akin to the slope of a watershed) is determined by calculating the difference in elevation (feet) between the highest point in the watershed (measured at the end of the longest stream) and the lowest point (at the debris collection site) and dividing the difference between these two by the maximum stream length (in miles) as measured along the longest stream (Refs. 8.7 and 8.17). This variable proved to be highly significant in all phases of the analysis and was included in the final regression equations.

3.1.11. <u>Transport Efficiency Factor</u>. (T1): This variable is the product of the mean bifurcation ratio and total channel length (both calculated by method 1). Lustig (Ref. 8.12) found this factor to be highly significant in a regression equation calculated for use in Southern California. It did not prove to be as statistically significant in this analysis as other variables and was not included in the final regression equations.

3.1.12. <u>Mean Channel Gradient</u>. (S): The mean gradient of the main stream (measured at 5% intervals along the main channel) between highest and lowest points in the watershed (as defined in Sec. 3.2.7) in feet per mile. This variable did not prove to be as significant as other variables and was not included in the final regression equations.

4. DATA SELECTION.

4.1. Data Collection. Debris yield data selected for analysis included debris basin and reservoir survey data obtained from the Los Angeles County Department of Public Works (LACDPW, formerly known as the Los Angeles County Flood Control District), LAD, the Ventura County Flood Control District (VCFCD), the San Bernardino County Flood Control and Water Conservation District (SBCFCWCD), the Santa Barbara County Flood Control District (SBCFCD), and USGS. All known sources of applicable debris yield data in coastal Southern California were contacted in order to collect the largest possible number of observations for analysis. All agencies which were contacted responded, although in many cases, short-term debris and sediment yield measurements are not available.

Debris volume measurements are taken by agencies at intervals dependent on the noticeable reduction in reservoir or debris basin capacity, and as such, are taken more frequently following storm periods which yield large amounts of debris. In some cases, it is a matter of years between debris surveys, and in other cases, as little as a few weeks. There is a great need for short-term debris yield measurements, especially from less erosive areas, such as portions of Orange, San Diego, and Riverside Counties. These data are vitally needed to calibrate the Method accurately for use in these poorly-documented areas.

4.2. Data Evaluation And Selection. The primary goal of this study was to develop a method to estimate unit debris yield on a storm-event basis, rather than as an average annual volume. Therefore, each surveyed debris volume had to be related to only the storm period(s) that caused the debris inflow to the structure. For periods in which only a single large storm event occurred, apportionment of debris volume to a single peak flow or precipitation value was straightforward. For periods in which multiple storm events occurred, however, apportionment of debris volume to the storm events responsible was more complicated.

From a simple linear regression of single storm events, it was determined that debris yield per unit area is approximately proportional to the peak flow per unit area or precipitation depth for the watersheds examined in this study. For multiple event storm periods then, debris volumes were divided up on the basis of being proportional to the magnitude of precipitation or peak flow per unit area which occurred during the event in question (Table 4). This simple division of debris volume may not always be accurate, such as when a wildfire occurs in the period between surveys. However, the majority of survey periods were unaffected by the complicating influence of wildfire. For periods during which wildfire impacted the watershed of interest, apportionment of debris volume was performed on the basis of comparison with similarly-sized watersheds for which single storm event debris yields following wildfire were available.

Because the debris yield from a watershed is partly a function of the debris in storage within the floodplain (where present), streams, and hillslope storage sites, unit debris yield attributable to certain storm events (Feb. 1940, Feb. 1969, Mar. 1978) which closely followed major events (Mar. 1938, Jan. 1969, Feb. 1978) was deleted from the analysis due to generally low volumes. Cases in which debris volumes were uncharacteristically low resulted from the "flushing" of debris storage sites during earlier large events. This case is typical of situations in which a watershed has the vast majority of debris in storage "flushed out" during a large event, leaving little debris available for transport during later events, regardless of storm intensity or runoff magnitude. Debris yield estimates for these types of "follow-up" events consistently yielded the largest errors in prediction of any set of observations included in the analysis. Deletion of these observations was considered to be appropriate because of the intention to predict the debris yielded by watersheds during discrete single events of "n-year" recurrence for design purposes, not follow-up events which may yield considerably lower total debris volumes than is usual.

The highest recorded debris yields in Southern California have historically been the result of large storms impacting recently burned small watersheds (0.1 to 3.0 mi^2) which have not experienced similar large floods or wildfire for some time. Field investigations indicate that during certain storms, debris yielded by the flushing of canyon bottom and channel storage sites may have exceeded that yielded by all other sources of erosion. A small number of storage sites in extremely small watersheds may result in a moderate debris yield per unit area over a long period of time, or alternatively, a high yield immediately following a wildfire. However, the largest single unit debris yields have been recorded from watersheds which yielded little debris for an extended period of time as sediment moved into storage, followed by a large event (or events) which flushed tremendous amounts of debris from these storage sites. This may be illustrated by examining the records of Auburn and Bailey Debris Basins (LACDPW records). Both watersheds suffered 100% extent wildfires in late 1978. Beginning three months later, in January 1979, several small storms impacted these watersheds. Debris yields were slightly to considerably lower than might be expected from a flood event closely following a wildfire. This is especially true in the case of Bailey Canyon. It is probable that a lack of debris actually measured at the debris basin site was the result of debris going into storage in the channel system upstream. Hence, during the storm of February-March 1980, precipitation resulted in unit debris yields higher than that predicted by the regression equation. Because of the high degree of soil saturation, locally high rainfall intensities, and the availability of stored debris within the upstream storage sites, these watersheds flushed out much of the debris considered to have gone into storage during the period of February 1976 to January 1980. This type of behavior may be expected in some Southern California watersheds, which may typically exhibit highly sporadic debris movement. However, this type of behavior would not be predicted by the regression equations, which were developed for a typical (average) design debris-producing event.

Additional deletions occurred in cases of conflicting information from multiple sources, and in the case of missing precipitation or peak flow values.

An additional difficulty encountered in the data selection occurred in the case of debris retention structures located upstream of a site at which debris yields were measured (i.e., two debris basins in one watershed). In these cases, it was not possible to determine the volume of debris which "could have" reached the downstream structure and data from these was excluded from the analysis. An example of this is the case of Morris Reservoir, located a short distance downstream of San Gabriel Reservoir in the San Gabriel Mountains of Los Angeles County.

Although debris volume data exists for Morris Reservoir, it is unknown exactly how much of the total volume has resulted from flow carried through San Gabriel Reservoir during storm events and whether or not a significant proportion of this volume has resulted from sluicing. For these reasons, watersheds with a large part of their drainage area influenced by upstream controls were excluded from the analysis.

5. DATA ANALYSIS.

5.1. Preliminary Regression Analysis. Preliminary regression analysis provided the means by which to compare different variables, and was instrumental in the decision to break the data into different drainage area groupings. Because of data limitations (see Sec. 3.1.1.), one equation was designed to be used in watersheds under 3 mi^2 in area for which runoff data is unavailable. Data for areas larger than 3 mi^2 were initially used to calculate a single equation dealing with watersheds of 3 to 200 mi^2 in area. This single equation did not adequately predict unit debris yield from this broad a range of drainage area sizes, and hence, equations were developed for several ranges of drainage area sizes. Data from this preliminary analysis was also used to develop preliminary "Fire Factors" (a non-dimensional variable relating wildfire impact to debris yield).

In the initial analysis of small watersheds for which runoff data was generally unavailable (less than 3.0 mi^2 in area), it was noted that short-term precipitation (less than 1-hour) intensity did not correlate well with measured debris yield attributable to the storm event (see Table 1). This is probably because of the effects of variation in local intensities, wind, basin aspect, and other factors not accounted for by existing recording devices. Measures of 1-hour precipitation did, however, possess a strong correlation and proved to be significant in all phases of the analysis of small watersheds. This variable was defined as the maximum 1-hour precipitation during the storm event. In areas such as coastal Southern California, where some degree of soil saturation is necessary to initiate soil movement because of soil binding, precipitation should be measured following an antecedent rainfall of approximately two inches in 48 hours (see Sec. 3.1.1.). If the Method is to be used in desert areas where soil binding is minimal, this constraint may be relaxed. Although 3-hour, 24-hour, and 72-hour precipitation also correlated well with debris yield, maximum 1-hour precipitation yielded the highest correlation.

Lower correlations were also obtained between unit debris yield and mean channel gradient, mean bifurcation ratio (method 1), Hypsometric-Analysis Index, the transport efficiency factor, elongation ratio, and drainage density. An initially high correlation between total stream length (especially as measured by method 2), mean bifurcation ratio (method 2), Hypsometric-Analysis Index, and measured unit debris yield proved less significant upon the inclusion of factors such as relief ratio and the size of the drainage area. These parameters are defined in Section 3.2.

Despite an expected negative correlation between drainage area and unit debris yield, consistently positive correlations were indicated by statistical analysis. This is probably because of the high degree of intercorrelation between relief ratio and drainage area in the regression analysis. Because relief ratio in smaller watersheds (in this analysis) was consistently higher than that of larger watersheds, drainage area apparently functions as an offset for the differences in unit debris yield unaccounted for by the relief ratio variable. Given equality in both the hydrologic/meteorologic (Q or P) and Fire Factor (FF) variables, unit debris yield does decline with increasing drainage area because the relief ratio consistently declines at a higher rate than the drainage area increases. Thus, the unit debris yield for large watersheds is less than that of smaller watersheds. This is consistent with the actual data used in the analysis, as well as other research.

5.2. Development of Fire Factors. The occurrence of wildfire plays a significant role in the augmentation of erosion rates from Southern California watersheds (Refs. 8.7, 8.15, 8.16, 8.21, 8.23 and 8.24). Highly flammable chaparral species, steep slopes, loose sediments, hydrophobic soil conditions created by the intense heat generated by wildfire, and the aggravating influence of dry offshore "Santa Ana" winds provide Southern California with one of the most volatile fire/erosion complexes in the world.

The combination of these factors is evident in the conclusions of Rowe et al (Refs. 8.15 and 8.16), who estimated that a 100% extent wildfire in their study watersheds was responsible for a debris yield 35 times that of the watershed in a "normal" or unburned state. Wells (Ref. 8.26) has documented an event during which debris yield increased by over 100 times its normal rate from an extremely small (0.02 ac), steep local watershed. Although the increase in debris production is undoubtedly less severe in larger, less steep watersheds which possess greater availability of debris storage sites, this example serves to illustrate the powerful influence that wildfire plays in the erosion of Southern California watersheds.

Using the relationship established by Rowe et al., F.E. Tatum (formerly of the Los Angeles District, Corps of Engineers) applied this knowledge to correlate measured debris yield to his computed values by means of a single fire curve. The Tatum curve relates the percentage increase in debris yield attributable to fire to the elapsed time following wildfire occurrence (Ref. 8.23) and was used as the basis for the preliminary Fire Factor curve examined in the current analysis. This curve assumed that watersheds of unequal size and gradient respond (or recover) at the same rate over a period of time in terms of debris yield. This technique, associated with watersheds of small areal extent, acknowledges fire and its associated effects as a major component in a debris yield estimation method. A similar treatment by Ferrell (Ref. 8.7) indicated that debris yield rates following a complete watershed burn approach 20 times the normal rate.

Poor correlation with measured debris yield was obtained when percent recovery (as defined by the individual "Fire Factor" curves of Ferrell, Tatum, and Rowe et al.) were used as preliminary

Fire Factors in the current analysis. It was especially apparent that recently burned watersheds of greater than 3 mi^2 in area exhibit a proportionally smaller increase in unit debris yield when compared to watersheds of smaller areal extent. Thus, two curves were developed, one for watersheds 0.1 to 3.0 mi^2 in area, and another for watersheds larger than 3.0 mi^2 in area.

The magnitude of increase in debris yield in larger watersheds impacted less than one year after burn was on the order of two to ten times the normal rate (as opposed to 20-30 times the normal rate given by Rowe et al. and Ferrell), when applied to single flood events. Several variations of the Fire Factor curves were tested before arriving at the final Fire Factor relationships. Each trial curve was adjusted in a manner that minimized the residuals (the amount that wasn't explained by the equation), such that the remaining residuals for a given time after burn and drainage area were clearly not attributable to wildfire impact (i.e., presented no clear trend relating to time since burn or extent burned).

The final Fire Factor curves are presented in Figures 2 and 3. These curves represent a 100% burn condition. It would be desirable to have a single Fire Factor curve for Equations 1 to 5 (see Sec. 5.3 for Equations). However, because of the fundamental difference in the hydrologic variable in Equation 1 (precipitation) versus the hydrologic variable in Equations 2 to 5 (runoff), it should not be expected that the curves will be consistent at 3 mi^2 (the interface between Equation 1 and Equation 2).

5.3. Development of The Predictive Equations. The variables selected for use in the final equations were relief ratio (RR), drainage area (A), unit peak flow (Q) or 1-hour precipitation (P), and the non-dimensional Fire Factor (FF). Each of these variables was determined to be significant at the 95 percent confidence level.

5.3.1. <u>Equation 1</u>. Regression Equation 1 was selected by statistical criteria for use in watersheds from 0.1 to 3.0 mi^2 in area for which peak flow data is not available. Equation 1 takes the form:

$$\boldsymbol{LOG\ Dy = 0.65\ (LOG\ P) + 0.62\ (LOG\ RR) + 0.18\ (LOG\ A) + 0.12\ (FF)} \quad \ldots\ \textbf{Eq. 1}$$

where:

- Dy = Unit Debris Yield (yd^3/mi^2)
- P = Maximum 1-Hour Precipitation (inches, taken to two places after the decimal point, times 100)
- RR = Relief Ratio (ft/mi)
- A = Drainage Area (ac)
- FF = Non-Dimensional Fire Factor

The coefficient of multiple determination ($\bar{R}^2$) for this equation is 0.987. All factors in this equation are significant at the 0.99 level of confidence (see Table 3 for "F" test values). A total of 349 observations from 80 watersheds were used in the final development of this equation.

5.3.2. <u>Equation 2</u>. Regression Equation 2 was selected by statistical criteria for use in watersheds of 3 mi^2 to 10 mi^2 in area for which peak flow data is available. This equation may also be used for drainage areas less than 3 mi^2 if peak data is available, using Fire Factors determined independently (for example vegetation is such that unburned conditions may be assumed). Do not extrapolate the curves in Figure 3. Equation 2 takes the form:

$$LOG\ Dy = 0.85\ (LOG\ Q) + 0.53\ (LOG\ RR) + 0.04\ (LOG\ A) + 0.22\ (FF) \quad \ldots \textbf{ Eq. 2}$$

where:

Q = Unit Peak Runoff ($ft^3/s/mi^2$);
All other factors are as defined above.

5.3.3. <u>Equation 3</u>. Regression Equation 3, selected for use in watersheds of 10 to 25 mi^2 in area and for which peak flow data is available takes the form:

$$LOG\ Dy = 0.88\ (LOG\ Q) + 0.48\ (LOG\ RR) + 0.06\ (LOG\ A) + 0.20\ (FF) \quad \ldots \textbf{ Eq. 3}$$

5.3.4. <u>Equation 4</u>. Regression Equation 4, selected for use in watersheds of 25 to 50 mi^2 in area and for which peak flow data is available takes the form:

$$LOG\ Dy = 0.94\ (LOG\ Q) + 0.32\ (LOG\ RR) + 0.14\ (LOG\ A) + 0.17\ (FF) \quad \ldots \textbf{ Eq. 4}$$

5.3.5. <u>Equation 5</u>. Regression Equation 5, selected for use in watersheds of 50 to 200 mi^2 in area and for which peak flow data is available takes the form:

$$LOG\ Dy = 1.02\ (LOG\ Q) + 0.23\ (LOG\ RR) + 0.16\ (LOG\ A) + 0.13\ (FF) \quad \ldots \textbf{ Eq. 5}$$

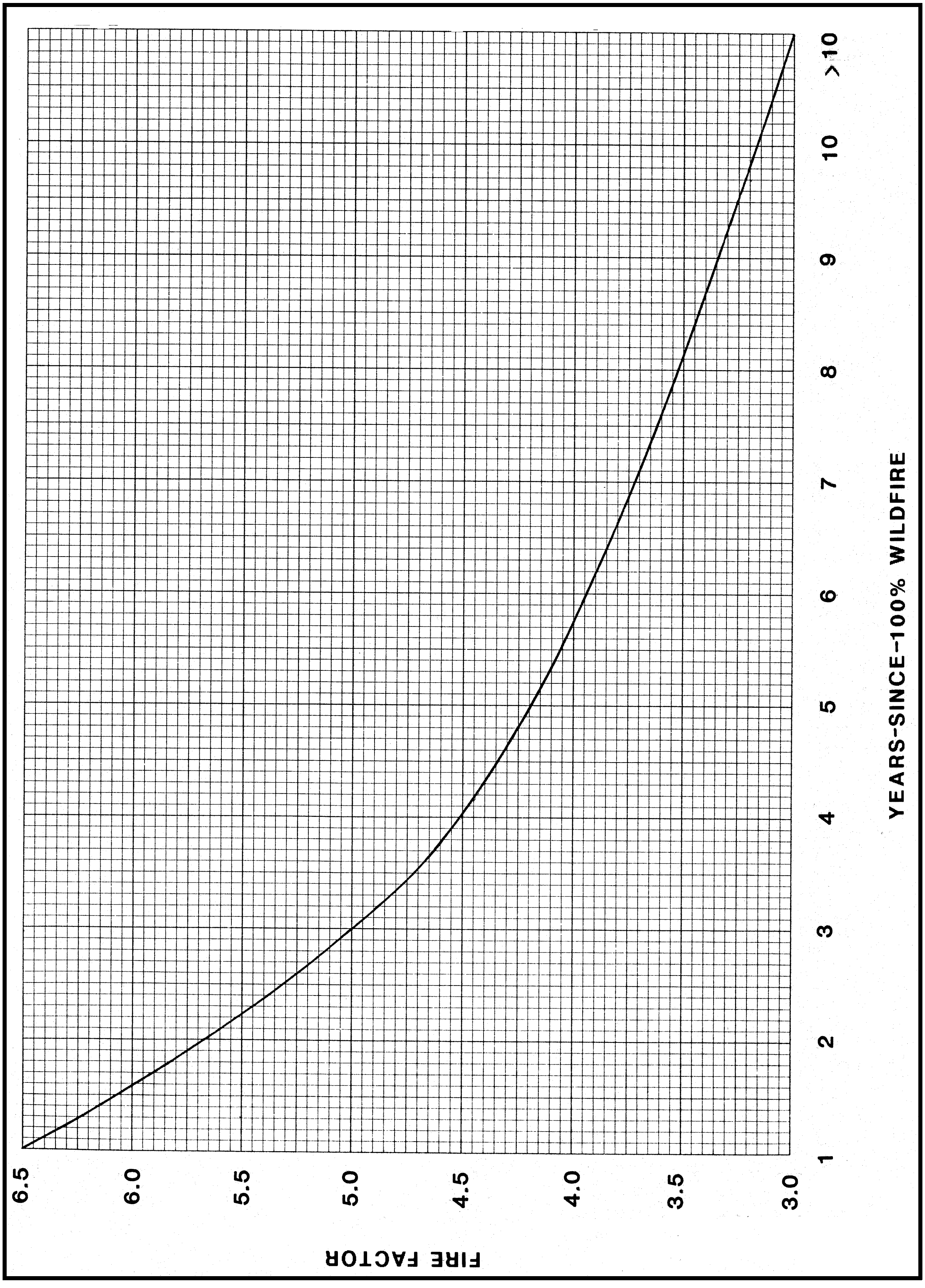


Figure 2: Fire Factor Curve for Watersheds 0.1 to 3.0 mi²

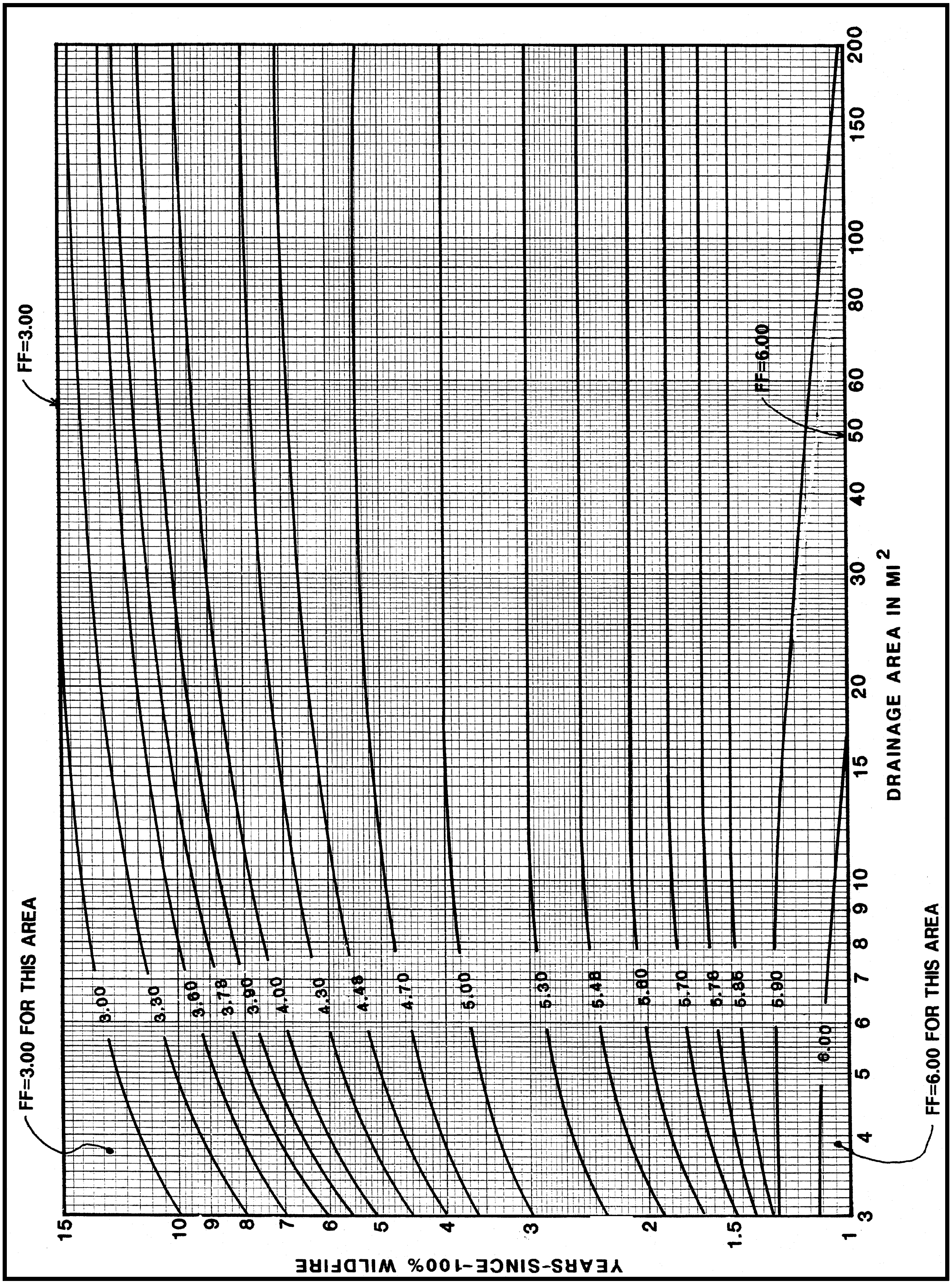


Figure 3: Fire Factor Curves for Watersheds 3.0 to 200 mi²

The coefficients of multiple determination for Equations 2 to 5 were all in excess of 0.99. The RR, Q, and FF variables are significant at the 0.99 level of confidence, while the A variable is significant at the 0.95 level of confidence (see Table 3). A total of 187 observations from 7 watersheds were used in the development of these equations. Equation 2 may be used for watersheds with a drainage area of 0.1 to 3.0 mi^2 for which runoff data exists. If recorded runoff data is used, care must be used to ensure that the runoff data is of high quality, and that the adopted peak unit runoff values are not the result of "debris flow" or landslide heightening of the recorded flow.

Note that some discontinuity exists between Equations 1 and 2 at the drainage area size juncture. When dealing with borderline cases, such as a watershed of 3.0 mi^2 in size for which both precipitation and runoff data exist, it is advised that debris yield be calculated through the use of both Equations 1 and 2. The higher of the two results should be used.

5.4. Development and Use of the Adjustment-Transposition (A-T) Factor. The use of regression equations developed from data pertaining to a group of watersheds historically demonstrating extremely high unit yields will result in overestimation of debris yield when applied to areas with less volatile erosional activity. Recognition of this limitation, and the importance of several unquantifiable geomorphic and geologic parameters was taken into account by the development of an adjustment and transposition variable (A-T Factor). This factor takes into account the importance of surficial geology, soils, and hillslope and channel geomorphology. Because there are few debris yield measurements available on an event basis for debris retention structures in low erosion areas, the A-T Factor was developed using readily available average annual sediment yield data. Although this factor is subjective in both development and application, there was no practical alternative that permitted quantification of these variables.

Watersheds of the San Gabriel Range from which the regression equations were developed would use an A-T Factor of 1.0. Watersheds in areas of less debris yield potential than the San Gabriel Mountains, such as the Peninsular Ranges of San Diego and Orange Counties would have A-T Factors less than 1.0. Should a watershed clearly possess a higher debris yield potential than the San Gabriel Mountains, an A-T Factor greater than 1.0 would be used. The calculation of the A-T Factor is further discussed in Appendix B and its use is illustrated in Example 3 of Appendix D. The unit debris yield is calculated using the appropriate equation and then multiplied by the A-T Factor to give the adjusted unit debris yield. The adjusted unit debris yield is then multiplied by the drainage area to determine the debris volume for the watershed.

5.5. Measures of Confidence. The regression equations presented herein give debris yield estimates that should be considered as "expected debris yield" under a given set of conditions. Prediction of debris yield then, should include measures of confidence or associated risk. This is accomplished in this study through the use of the standard deviation (SD) of the estimate. The statistical summary for Equation 1 (see Table 3) gives a standard deviation of 0.465 log units. This indicates that we can be 67% confident that the "true" value is within 0.465 log units (1 SD) above or below the estimate, and we are 95% confident that the "true" debris yield will fall within 0.93 log units (2 SD) above or below the estimate. Similarly, the summary for Equation 2 (which is very similar to the statistics for Equations. 3-5) indicates that we are 67% confident that the "true" debris yield is within 0.242 log units (1 SD) above or below the estimates and that 95% confident that it is within 0.484 log units (2 SD) above or below the estimate.

6. COINCIDENT FREQUENCY ANALYSIS.

6.1. Introduction. The regression equations developed in this analysis include two determined variables (drainage area and relief ratio) and two estimated variables (discharge or precipitation and Fire Factor). The magnitudes of discharge (or precipitation) and the fire condition are associated with an exceedance probability and because the two are independent of each other, any combination of the two can occur. Therefore, in order to predict the exceedance probability of debris potential of a certain magnitude for any watershed, all possible combinations of wildfire and flooding must be evaluated. This is because more than one combination of wildfire and flooding may result in the same debris yield. This entire range of possibilities is the basis for the total probability theorem (Ref. 8.3, pg. 58).

6.2. Theory. There are several applications of the total probability theorem in hydrologic analysis problems encountered in Corp's studies. The application discussed here has been termed "coincident frequency analysis". The end product is a debris yield exceedance frequency relationship.

The total probability theorem is presented in most statistics texts as:

$$P[A] = \sum_{i=1}^{n} P[A|B_i] \cdot P[B_i]$$

where:

P[A] = the "total" exceedance probability of event A,
$P[A|B_i]$ = the conditional probability of event A given that event B_i has occurred,
B_i = a set of <u>mutually exclusive</u> (only 1 B event can occur at a time), <u>collectively exhaustive</u> (for every A event, there is a corresponding B event) events, and $P[B_i]$ = the exceedance probability of event B_i.

In this analysis, A represents the occurrence of debris yield of a given quantity and B represents a wildfire condition. For calculation purposes, interval probabilities of B_i are used and treated as discrete probabilities. For example, the interval probability of the fire condition being from 2 to 3 Years-Since-100% Wildfire is equal to the incremental difference (probability for 3 Years-Since-100% Wildfire minus the probability for 2 Years-Since-100% Wildfire) and is treated as a discrete probability for 3 Years-Since-100% Wildfire. The range of possible fire conditions (Years-Since-100% Wildfire - B_i) should include the year of occurrence of wildfire (time = 0) to complete recovery (usually 10-15 years after a 100% wildfire) and be divided into i intervals. The number of intervals (i) should provide adequate definition of the Years-Since-100% Wildfire frequency relationship (recommended 1-year intervals).

For each B_i, there is only 1 flow - F_i (or precipitation value - P_i) that produces a specified debris yield (A). (This connection is determined using the debris response relationships presented later in this section.) So the probability of debris yield (A), given the specific fire condition (B_i), being greater than or equal to the specified magnitude is equal to the probability of the discharge being greater than or equal to the flow (F_i) that produces that debris yield (A), given the specific fire condition (B_i). That is:

$$P[A|B_i] = P[F_i|B_i]$$

The flow (F_i) is independent of the wildfire condition (B_i), assuming the impact of debris on the magnitude of the flow is small relative to the magnitude of the flow. Since F_i is independent of B_i, the probability of F_i, given B_i has occurred, is equal to the probability of F_i. This is defined as:

$$P[F_i|B_i] = P[F_i]$$

Therefore, all other factors being equal, the probability of the debris yield (P[A]) being greater than or equal to a specified magnitude (A), given the specific fire condition (B_i), is equal to the probability of a flow greater than or equal to F_i, where F_i is the flow corresponding to the debris yield A, given the specific fire condition (B_i). Thus:

$$P[A|B_i] = P[F_i]$$

By substitution, the actual calculation for total probability then becomes:

$$P[A] = \sum_{i=1}^{n} P[F_i] \cdot P[B_i]$$

In other words, the probability of debris yield (P[A]) equaling or exceeding a specified magnitude (A) is equal to the summation of a product of pairs made up of one exceedance probability ($P[F_i]$) and one interval probability ($P[B_i]$). Using the debris response relationships, which define the unique correlation between discharge and fire condition, the complete debris yield frequency relationship can be determined by iteratively solving the above equation for a range of specified debris yields

6.3. Data Requirements. A Coincident Frequency Analysis (CFA) computer program was developed by the Hydrologic Engineering Center of the Corps of Engineers at Davis, California. This program evaluates the coincident frequency of occurrence of two independent events, in this case, wildfire and flooding, using the theory discussed above. Appendix C presents the input description, user's manual, and test input and output examples for using the CFA program.

The CFA program requires 4 types of data: Years-Since-100% Wildfire frequency, discharge frequency, debris response relationships, and evaluation values which are used to define the debris yield frequency relationship.

6.3.1. Years-Since-100% Wildfire Frequency Relationship (entered as years versus exceedance frequency; see Table A-3, Appendix A). This represents the exceedance frequency of Years-Since-100% Wildfire occurrence. Appendix A presents a comprehensive description of the procedure for deriving a Years-Since-100% Wildfire frequency relationship. The number of values should adequately define the Years-Since-100% Wildfire relationship (the CFA program will accept up to 20 pairs of values). An example of the Years-Since-100% Wildfire frequency relationship could look like this:

Frequency*	Years-Since-100% Wildfire (B_i)
0	0
0.1	1
0.3	2
0.7	3
1.4	4
2.2	5
3.2	6
4.6	7
7.2	8
12.0	9
13.1	10
16.7	11
24.1	12
34.5	13
49.0	14
100	15

* The frequency for which Years-Since-100% Wildfire is equaled or exceeded. Cumulative. This is not P[B_i]; P[B_i is the incremental difference for each Year-Since-100% Wildfire.

6.3.2. Discharge Frequency (or Precipitation Frequency) Relationship (entered as discharge per square mile - or 1-hour precipitation times 100 - versus exceedance frequency). The relationship (for discharge) could be developed analytically using the Corps of Engineers Flood Frequency Analysis computer program, which is based on Bulletin 17B guidelines. The number of values should adequately define the discharge (or precipitation) frequency relationship (the CFA program will accept up to 20 pairs of values). Values for a unit discharge frequency relationship might look like this:

Frequency* ($P[F_i]$**)	Discharge ($ft^3/s/mi^2$) (F_i)
0.2	1489
0.5	1000
1	719
2	499
5	288
10	176
20	96
30	61
40	40
50	29
60	19
70	13
80	8.0
90	3.9
95	2.2

* The frequency for which unit discharge is equaled or exceeded. Cumulative.
** Probability is frequency divided by 100.

6.3.3. <u>Debris Response Relationships for each Years-Since-100% Wildfire Occurrence</u> (entered as unit discharge (ft³/s/mi²) or precipitation (inches x 100) versus debris yield (yd³/mi²)). These relationships reflect the debris yield (A) for the watershed for a range of unit discharge values (F_i) or 1-hour precipitation values (P_i) for each interval of the Years-Since-100% Wildfire occurrence (B_i). The number of values should adequately define the debris response relationships (the CFA program will accept up to 20 pairs of values). The debris yield is calculated using the appropriate regression equation for the range of unit discharges (or precipitation values) developed as described in 6.3.2. above, using the Fire Factors associated with each Year-Since-100% Wildfire value discussed in 6.3.1. above. Examples of debris response relationships might look like these.

Years-Since-100% Wildfire (B_i)	Unit Discharge (ft³/s/mi²)								
	Q = 1489	Q = 1000	Q = 719	Q = 499	Q = 288	Q = 176	Q = 96	Q = 29	Q = 2.2
	Debris yield (yd³/mi²) (A)								
1	185,417	127,559	93,585	66,325	39,612	24,877	14,025	4,515	405
2	161,677	111,227	81,603	57,833	34,540	21,692	12,230	3,937	353
3	140,977	96,986	71,155	50,429	30,118	18,915	10,664	3,433	308
4	125,357	86,240	63,271	44,841	26,781	16,819	9,482	3,053	274
5	115,465	79,435	58,278	41,303	24,667	15,492	8,734	2,812	252
6	106,770	73,453	53,890	38,193	22,810	14,325	8,076	2,600	233
7	99,896	68,724	50,420	35,734	21,341	13,403	7,556	2,433	218
8	93,100	64,049	46,990	33,303	19,889	12,491	7,042	2,267	203
9	87,791	60,396	44,310	31,404	18,755	11,779	6,641	2,138	192
10	83,397	57,373	42,093	29,832	17,817	11,189	6,308	2,031	182
11	79,607	54,766	40,180	28,476	17,007	10,681	6,022	1,939	174
12	73,901	50,841	37,300	26,435	15,788	9,915	5,590	1,800	161
13	68,336	47,012	34,491	24,444	14,599	9,168	5,169	1,664	149
14	63,190	43,472	31,894	22,604	13,500	8,478	4,780	1,539	138
15	57,299	39,419	28,920	20,496	12,241	7,688	4,334	1,395	125

6.3.4. <u>Response Frequency Parameter (Evaluation) Values</u>. This a set of debris yield values input by the user (or can be generated by the CFA program) which will be used to define the debris frequency curve. The number of values should be enough to adequately define the debris frequency relationship (the CFA program has a maximum of 30 values).

6.4. Example Calculation. The following example hand calculation is included to illustrate application of the coincident frequency theory described above. Differences will result between the hand calculations and the CFA program calculations primarily due to the methods used for interpolation and integration.

In the hand calculation, the intervals for Years-Since-100% Wildfire are chosen using the values provided on the probability distribution. Interval probabilities are determined using linear interpolation and numerically integrated using the "trapezoidal rule" (Ref. 8.5).

The CFA program improves on this by using cubic spline interpolation to define a smooth curve through all of the frequency curves and Gauss Quadratures for numerical integration (Ref. 8.5) to obtain a more accurate estimate of the total probability than is obtained by the trapezoidal rule. Three points (Gauss Quadratures) are used to obtain the exceedance probability of the intervals rather than only the two end points used by the trapezoidal rule. The CFA program then uses cubic spline interpolation to obtain the conditional probability values at the quadrature points within each interval. The more values used in the hand calculations, the better the agreement would be.

Using the example data above, the procedure for calculating the total probability for a debris yield greater than or equal to 10,000 yd^3/mi^2 is:

Step 1/. Using the debris response relationships (6.3.3. above), determine (using linear interpolation) the discharge necessary to produce 10,000 yd^3/mi^2 (A) for each Year-Since-100% Wildfire. Then, use the discharge (or precipitation) relationship (6.3.2 above) to determine the frequency of the discharges, as shown below:

Years-Since-100% Wildfire [B_i]	Discharge ($ft^3/s/mi^2$) F_i	Frequency*	Probability** P[F_i}
1	67	28.0	.280
2	78	24.7	.247
3	89	21.5	.215
4	101	19.0	.190
5	111	17.3	.173
6	120	15.7	.157
7	129	14.5	.145
8	139	13.3	.133
9	148	12.4	.124
10	156	11.6	.116
11	164	10.9	.109
12	177	9.9	.099
13	193	8.9	.089
14	210	7.9	.079
15	233	6.8	.068

* The frequency for which discharge is equaled or exceeded. Cumulative.
** Probability is frequency divided by 100.

Step 2/. Determine the incremental exceedance probabilities for each duration of the Years-Since-100% Wildfire relationship from the Years-Since-100% Wildfire frequency relationship (6.3.1.).

Years-Since-100% Wildfire $[B_i]$	Probability	
	Cumulative (from 6.3.1)	Incremental ($P[B_i]$)
0	.000	.000
1	.001	.001
2	.003	.002
3	.007	.004
4	.014	.007
5	.022	.008
6	.032	.010
7	.046	.014
8	.072	.026
9	.120	.048
10	.131	.011
11	.167	.036
12	.241	.074
13	.345	.104
14	.490	.145
15	1.000	.510

Step 3/. Determine the total probability for a debris yield greater than or equal to 10,000 yd^3/mi^2 (A) using the equation below:

$$P[A] = \sum_{i=1}^{n} P[F_i] \cdot P[B_i]$$

This would result in a table such as:

Years-Since-100% Wildfire	$P[F_i]$	$P[B_i]$	$P[F_i]* P[B_i]$
1	0.280	0.001	0.00028
2	0.247	0.002	0.00049
3	0.215	0.004	0.00086
4	0.190	0.007	0.00133
5	0.173	0.008	0.00138
6	0.157	0.010	0.00157
7	0.145	0.014	0.00203
8	0.133	0.026	0.00346
9	0.124	0.048	0.00594
10	0.116	0.011	0.00128
11	0.109	0.036	0.00393
12	0.099	0.074	0.00733
13	0.089	0.104	0.00924
14	0.079	0.145	0.01149
15	0.068	0.510	0.03485
Sum (P[A]) ==> 0.0854780 (Frequency = 8.5)			

This calculation represents one point on the debris yield frequency curve. The complete debris yield frequency relationship is determined by iteratively solving the above equation for a set of debris yields (evaluation values) covering the range of possible yields. Note: the accuracy of the hand calculations will approach the results from the CFA program by increasing the number of debris yield values in the set.

6.5. Program Output. The Coincident Frequency Analysis program output consists of:

a. a reprint of the input data.

b. the computed percent chance exceedance values for the response values (evaluation values). This is a range of debris yields (input by the user) and their corresponding exceedance frequencies which define the debris yield frequency curve.

c. a table of interpolated debris yield results equaled or exceeded for frequencies of 0.2, 0.5, 1.0, 2.0, 5.0, 10.0, 20.0, 30.0, 40.0, 50.0, 60.0, 70.0, 80.0, 90.0, 95.0, and 99.0 percent.

Note: There are two options in CFA which allow the user to increase the amount of output in order to trace the results through intermediate calculations.

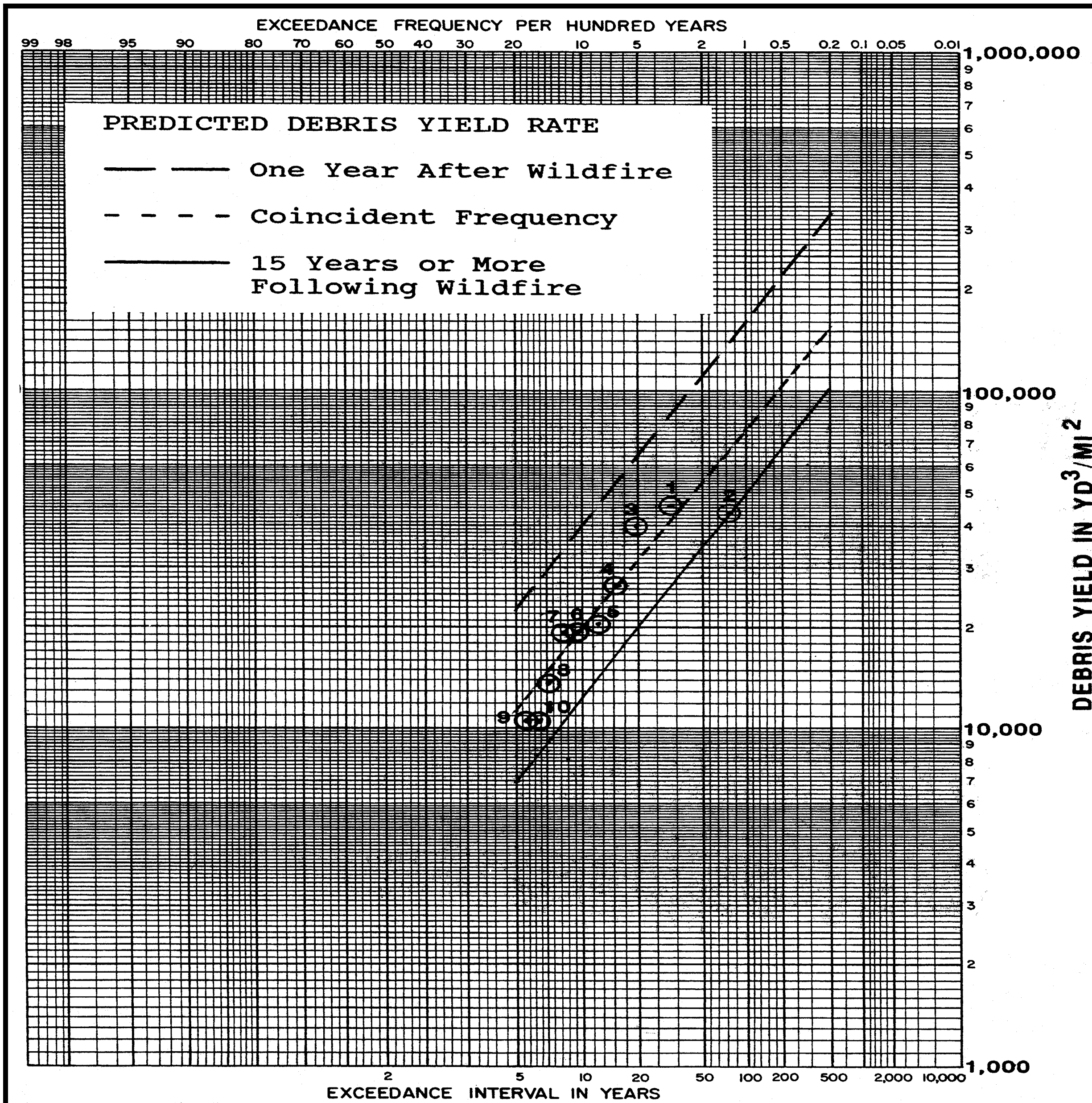
A more thorough description of the Coincident Frequency Analysis computer program, as well as example input and output files, are included in Appendix C.

A sample of the results of two Coincident Frequency Analyses performed on watersheds that possess long-term debris yield records are presented in Figures 4 and 5. Note that the actual debris yield values (plotted using median plotting positions) correspond closely to the expected debris frequency curve computed using the Coincident Frequency Analysis program. Note: the 1-Year-Since-100% Wildfire and the 15-Years-Since-100% Wildfire curves are plotted for comparison purposes. These curves were determined using the debris response data in the table in Section 6.3.3. for 1- and 15-Years-Since-100% Wildfire and the discharge-frequency relationship presented in Section 6.3.2.

7. SUMMARY, CONCLUSIONS, AND LIMITATIONS.

The equations presented herein yielded the highest $\bar{R}^2$ values of all trials as well as using the group of variables indicated as possessing the greatest significance in explaining variation in unit debris yield. Although errors in estimation may still occur, the equations presented here will provide significantly better reliability compared to methods presently in use for coastal draining streams in Southern California. By methods presently available, evaluation of the entire array of variables which influence debris yield from Coastal Southern California watersheds is impossible. Because factors such as the potential mobility of debris in storage within the watershed continue to defy quantification, debris yield estimates are expected to vary somewhat from recorded data, depending on the stage of a given cut-and-fill cycle, the time elapsed since the last major storm occurred, and other factors. Only by application of the on-site Adjustment-Transposition (A-T) Factor can certain unquantifiable parameters be evaluated and included in the analysis of an individual watershed.

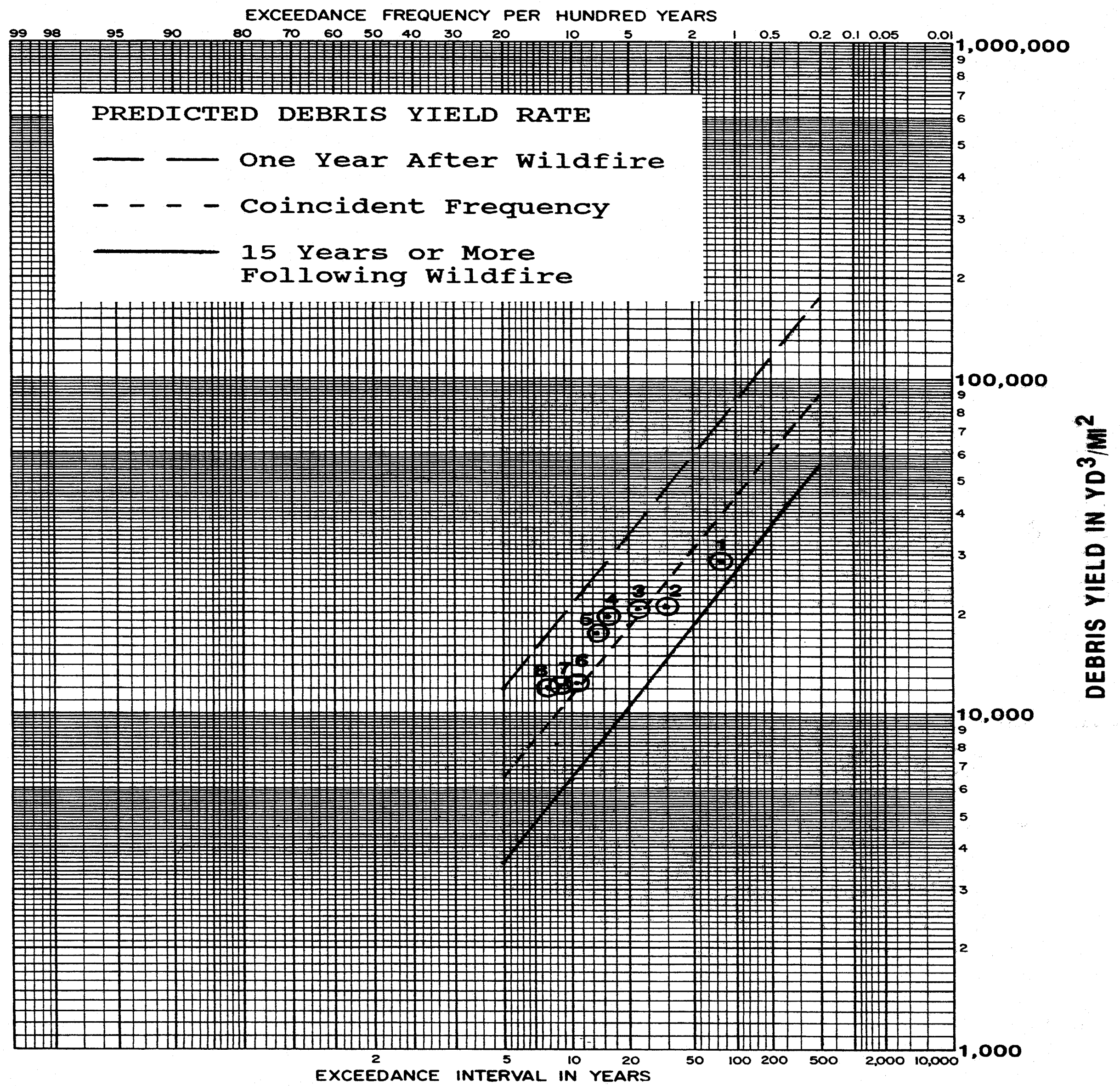
The predictive yield equations presented herein were derived from recorded data for basins and dams located at the mouths of canyons. For locations that are downstream from canyon mouths, it would be prudent to evaluate the sediment transport capability of the stream in the reach immediately upstream from the site to ensure that the stream is capable of transporting the estimated debris quantity. If not, then consideration should be given to using the transport capacity of the design flood as the adopted basin inflow debris estimate.



Ranked Debris Yield Events

1 March 1927
2 March 1938
3 January 1969
4 January 1954
5 January 1940
6 March 1943
7 March 1954
8 November 1965
9 February 1969
10 March 1978

Figure 4: Debris-Frequency Curves
Santa Anita Dam
Drainage Area = 10.8 mi²



Ranked Debris Yield Events

1 January 1969
2 March 1938
3 March 1978
4 September 1961
5 November 1965
6 August 1966
7 November 1956
8 January 1934

Figure 5: Debris-Frequency Curves
San Dimas Dam
Drainage Area = 16.2 mi^2

Recognition of the role that human interference plays in the increase or decrease in debris yield rates is important. Destruction of channel or hillslope vegetation, grazing, homesite construction, road building, and other factors may have a substantial effect on erosion from a given watershed. On-site evaluation of these impacts, and the geomorphology and soils of the watershed, should routinely supplement application of the recommended regression equations.

This procedure does not address the hazard associated with major landslides, nor those associated with overland mudflows.

Applications outside the San Gabriel Mountains should be conducted with caution and should include full investigation of all available local information and thorough field inspection.

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TABLE 1: SIMPLE CORRELATION COEFFICIENTS FOR METEOROLOGIC AND PHYSIOGRAPHIC PARAMETERS *

Parameter	Coeff.	Parameter	Coeff.
Max 15-Minute Rainfall	0.172	Drainage Density 1	0.951
Max 30-Minute Rainfall	0.682	Drainage Density 2	0.989
Max 1-Hour Rainfall	0.967	Hypsometric Index	0.889
Max 3-Hour Rainfall	0.963	Total Channel Length 1	0.529
Max 6-Hour Rainfall	0.404	Total Channel Length 2	0.973
Max 24-Hour Rainfall	0.524	Mean Bifurcation Ratio 1	0.259
Max 72-Hour Rainfall	0.730	Mean Bifurcation Ratio 2	0.986
Mean Annual Rainfall	0.087	Elongation Ratio	0.895
Max 24-Hour Inflow	0.629	Transport Factor T-1	0.986
Max 72-Hour Inflow	0.611	Mean Channel Gradient	0.247
Peak Inflow	0.989	Drainage Area	0.976
Fire Factor	0.984	Relief Ratio	0.993

* Simple correlation coefficients for meteorologic and physiographic parameters were determined by regressing each parameter individually, with each value log transformed (base 10) to linearize the relationship.

Parameters are defined in Section 3.

TABLE 2: STATISTICAL COMPARISON OF SOUTHERN CALIFORNIA DEBRIS/SEDIMENT YIELD ESTIMATION METHODS

	Variable	Correlation Coeff.	$\Delta\bar{R}^2$	$\bar{R}^2$	Applicable Basin Area (mi^2)
Anderson	q	0.93	0.88		4.5 - 202
1949	D	0.11	0.02	0.90	
(Ref. 8.1)	C	-0.10	0.01		
Scott et Al.	Pe	0.61	0.50		3.3 - 425
1968	I	0.23	0.04	0.86	
(Ref. 8.19)	K1	0.62	0.33		
Flaxman	p/t	-0.44	0.10	0.92	0.01 - 50
1972	R	0.82	0.40		
(Ref. 8.8)	K2	-0.30	0.09		
	K3	0.56	0.33		
LAD, COE	P	0.65	0.98	0.987	0.1 - 3.0
Eq. 1	RR	0.62	0.003		
(See Sec. 5)	FF	0.12	0.001		
	A	0.18	0.001		
LAD, COE	Q	0.88	0.98	0.99	10 - 25
Eq. 3	RR	0.48	0.01		
(See Sec. 5)	FF	0.20	0.001		
	A	0.06	0.001		

$\bar{R}^2$ = the coefficient of multiple determination adjusted for degrees of freedom, or a measure of the relative worth of a regression equation.

Variables:
q = Maximum yearly unit peak discharge ($ft^3/s/mi^2$)
D = Density of non-incised channels (ft/ac)
C = Cover density of vegetative litter (%)
Pe = Effective precipitation (inches)
I = Probable maximum 24-hour precipitation (inches)
K1 = Surface aggregation ratio (see Ref. 8.1)
p/t = $\dfrac{\text{Long-term average annual precipitation (inches)}}{\text{Average annual temperature (°F)}}$
R = Weighted average catchment slope between contours (%)
K2 = Percent of soil particles coarser that 1.0 mm (by weight) in the top 2 inches of the soil profile (%)
K3 = Soil aggregation variable of the pH of the soil and the amount of clay in the top 2 inches of soil
P = Maximum 1-hour precipitation (inches to two decimal places times 100) for the applicable storm event
RR = Relief ratio (ft/mile); (see explanatory text)
FF = Fire Factor (dimensionless); (see explanatory text)
A = Drainage area of watershed (ac)
Q = Unit peak discharge for applicable storm event ($ft^3/s/mi^2$)

TABLE 3: STATISTICAL SUMMARY

EQUATION 1 - Log Dy = 0.65 (Log P) + 0.62 (Log RR) + 0.18 (Log A) + 0.12 (FF)

Variable	B	Std Error of B	F
RR	0.620	0.069	80.325
P	0.654	0.095	47.760
FF	0.119	0.021	32.538
A	0.182	0.040	20.820

Multiple R	0.99377
$\bar{R}^2$	0.98747
Std Deviation	0.46531

EQUATION 2 - Log Dy = 0.85 (Log Q) + 0.53 (Log RR) + 0.22 (FF) + 0.04 (Log A)

Variable	B	Std Error of B	F
RR	0.481	0.085	32.21
Q	0.877	0.057	233.09
FF	0.201	0.051	15.57
A	0.062	0.036	2.98

Multiple R	0.99831
$\bar{R}^2$	0.99644
Std Deviation	0.24218

Note: statistics for Equations. 3-5 are similar.

B = the correlation coefficient of the independent variable.

F = a measure of the significance of the variable; an F of greater than or equal to 2.0 indicates significance at the 0.95 confidence interval, and greater than 4 indicates significance at 0.99 confidence level.

R = multiple correlation coefficient; the square root of the unadjusted coefficient of multiple determination.

$\bar{R}^2$ = the coefficient of multiple determination adjusted for degrees of freedom, or a measure of the relative worth of a regression equation.

RR = the relief ratio of a watershed.

A = the drainage area of a watershed.

P = the maximum 1-hour precipitation times 100.

FF = the "Fire Factor", or a measure of the impact of wildfires within the watershed.

Q = the unit peak discharge from a watershed.

TABLE 4: EXAMPLE OF DEBRIS APPORTIONMENT WITH RESPECT TO MULTIPLE EVENTS

(San Gabriel Reservoir Watershed was used in this Example)
Drainage Area = 201 mi²

Survey Period	Measured Debris Yield* (ac-ft)	Significant Flood Events Between Surveys	Peak Discharge ($ft^3/s/mi^2$)	Percent of Debris Due To Event (%)
Nov 1948- Nov 1951	110	Mar 1949 Feb 1950 Apr 1951	172 481 176	21.5 56.5 22.0 100.0
Nov 1951- Jan 1953	275	Jan 1952 Nov 1952	7683 585	92.0 8.0 100.0
Jan 1953- May 1954	127	Jan 1954	3592	100.0
May 1954- Aug 1958	189	All of 1955 Jan 1956 Jan 1957 Apr 1958	< 50 2677 3420 8900	0.0 18.0 23.0 59.0 100.0
Aug 1958- Sep 1961	248	Jan 1959 Nov 1960	3773 695	84.0 16.0 100.0

* Accumulated debris between survey dates

APPENDIX A

HOW TO USE FIRE FACTORS

AND

HOW TO DETERMINE THE

YEARS-SINCE-100% WILDFIRE

FREQUENCY RELATIONSHIPS

FOR USE IN THE

COINCIDENT FREQUENCY ANALYSIS

COMPUTER PROGRAM

APPENDIX A

HOW TO USE FIRE FACTORS AND DETERMINE THE YEARS-SINCE-100% WILDFIRE FREQUENCY RELATIONSHIPS

INTRODUCTION.

"*Fire Factor*", as used in this report, is the name given the relationship between debris yield and the time after burn for a given drainage basin. It is a dimensionless parameter that relates the relative increase in debris yield caused by wildfires. The occurrence of wildfire plays a significant role in the quantity of debris produced by any particular watershed. The Fire Factors developed in this analysis displayed a high correlation to debris yield (see Table 1, main text) for watersheds in the San Gabriel Mountains. The Fire Factor curves (see Figures A-1 and A-2) relate the Fire Factor to the Years-Since-100% Wildfire occurrence, and the drainage area of the watershed.

The Los Angeles District Method for Prediction of Debris Yield can be applied for several different purposes including: 1) determining the debris yield potential from a hypothetical flood event (e.g., the 1% or 100-year flood) given a specific fire condition (e.g., 1 year since 100% wildfire); or 2) determining the debris yield from a historic flood event for a specific wildfire condition; or 3) estimating the debris yield frequency relationship based on the total probabilities of independent random flood flows (or rainfall) and wildfire.

For the first two purposes, the Fire Factors are used directly in the appropriate regression equations. This approach might be used after a wildfire occurrence to estimate the size of emergency debris basins or estimate sediment volumes for transport analysis. When wildfire plays an insignificant role in the production of debris yield, such as in desert watersheds where vegetal cover is minimal, the Fire Factor is fixed at a "normal" or unburned value of 3.0.

The third purpose for application of the Debris Method utilizes the Coincident Frequency Analysis (CFA) computer program to estimate debris yield and takes into account the likelihood of wildfires of varied areal extent in conjunction with flood events of various magnitudes. Estimates of debris yield from the CFA results are used to determine the design size of single event debris basins and detention basins.

Fire Factors are determined from the actual fire history of the watershed(s). The fire history may be compiled by contacting local flood control agencies, the County Forester or Fire Warden, or other local agencies. It is most important to know the fire history of the watershed of interest for at least the past 15 to 20 years and preferably the last 50 years, including the approximate extent (percent) of the watershed burned during each event and the location of each burn relative to previous burns. The longer the history, the better the results.

DEBRIS YIELD FOR GIVEN FLOOD EVENT FOR SPECIFIC FIRE CONDITION.

If the intent of the investigator is to determine the debris yield from a hypothetical or actual historic flood event given a specific fire condition (first and second purposes above), the Fire Factor is determined in the following manner:

Step 1/. Determine the drainage area of the subject watershed (in mi^2 and ac).

Step 2/. Determine the fire history for the watershed, <u>if desired</u>, to get an idea of the significance of wildfire in the watershed.

Step 3/. If step 2 is omitted, only the Fire Factor for the specific fire event need be determined. If the investigator determines that wildfire plays an insignificant role in debris production, the Fire Factor can be set at 3.0. If step 2 is not omitted, determine the Fire Factor for each year in the fire history. When determining the fire history, remember to locate each burn relative to previous burns in the watershed. A table such as Table A-1 can be developed showing the year and Fire Factor along with the percent burn for each wildfire occurrence. Following Table A-1 is an example of how to calculate the Fire Factors for years with partial burns.

- If the drainage area of the watershed is less than 3.0 mi^2, use Figure A-1 to determine the Fire Factor(s) for 100% burn.

- If the drainage area of the watershed is between 3.0 and 200 mi^2, use Figure A-2 to determine the Fire Factor(s) for 100% burn.

Step 4/. Use the Fire Factor for the given flood event and the specified fire condition in the appropriate regression equation with the appropriate A-T Factor to determine the debris yield for the watershed.

TABLE A-1: EXAMPLE OF FIRE FACTOR HISTORY

Santa Paula Creek Watershed Application
Drainage Area = 42.9 mi²

Year	Percent Burned	Fire Factor	Year	Percent Burned	Fire Factor	Year	Percent Burned	Fire Factor
1911	1%	3.03	1941	0	3.37	1971	0	3.25
1912	0	3.03	1942	0	3.34	1972	20%	3.81
1913	0	3.02	1943	0	3.30	1973	0	3.71
1914	0	3.02	1944	0	3.22	1974	0	3.63
1915	0	3.02	1945	0	3.11	1975	0	3.53
1916	0	3.02	1946	0	3.00	1976	0	3.46
1917	0	3.01	1947	0	3.00	1977	0	3.42
1918	0	3.01	1948	0	3.00	1978	0	3.37
1919	0	3.01	1949	0	3.00	1979	0	3.32
1920	6%	3.19	1950	0	3.00	1980	0	3.26
1921	17%	3.67	1951	2%	3.06	1981	0	3.20
1922	1%	3.62	1952	0	3.05	1982	0	3.18
1923	16%	4.03	1953	0	3.05	1983	0	3.16
1924	20%	4.48	1954	0	3.04	1984	0	3.12
1925	0	4.31	1955	0	3.04	1985	70%	5.13
1926	0	4.17	1956	0	3.03			
1927	0	4.03	1957	0	3.03			
1928	0	3.91	1958	0	3.03			
1929	0	3.82	1959	0	3.02			

TABLE A-1 (cont.): EXAMPLE OF FIRE FACTOR HISTORY

Year	Percent Burned	Fire Factor	Year	Percent Burned	Fire Factor	Year	Percent Burned	Fire Factor
1930	0	3.73	1960	0	3.02			
1931	0	3.65	1961	0	3.02			
1932	38%	4.69	1962	6%	3.20			
1933	0	4.45	1963	0	3.17			
1934	0	4.25	1964	0	3.15			
1935	0	4.02	1965	0	3.12			
1936	0	3.84	1966	0	3.11			
1937	0	3.66	1967	11%	3.42			
1938	0	3.55	1968	0	3.37			
1939	0	3.49	1969	0	3.33			
1940	0	3.44	1970	0	3.28	75 Events		

Example of Fire Factor Calculations - for Partial Burns

! The maximum and minimum Fire Factor values are 6.0 and 3.0, respectively, for a watershed of 3.0 to 200 mi^2 in area (Fig. A-2).

! The watershed used in this example is considered to be "fully-recovered" from the effects of wildfire after 15 years (42.9 mi^2).

! History (Table A-1) shows that the example watershed was fully recovered from all previous fires in 1950 and then suffered a 2% extent burn in 1951 and a 6% burn in 1962.

! Since the watershed suffered a 2% burn in 1951, with no additional wildfires in the period 1952 through 1961, the Fire Factors for this time period are calculated as follows:

<u>1951</u> 1) 98% of the watershed has a "normal" (unburned) Fire Factor of 3.0

2) 2% of the watershed has a (100% burn) 1 year after burn Fire Factor of 6.0 (from Figure A-2)

Thus, the weighted Fire Factor for 1951 is: 0.98 (3.0) + 0.02 (6.0) = 3.06

1952 1) 98% of the watershed has a "normal"(unburned) Fire Factor of 3.0

2) 2% of the watershed has a "2 years after burn" Fire Factor of 5.65 (from Fig. A-2)

Thus, the weighted Fire Factor for 1952 is: 0.98 (3.0) + 0.02 (5.65) = 3.05

<u>1953</u> 1) 98% of the watershed has a "normal" (unburned) Fire Factor of 3.0

2) 2% of the watershed has a "3 years after burn" Fire Factor of 5.30 (from Fig. A-2)

Thus, the weighted Fire Factor for 1953 is: 0.98 (3.0) + 0.02 (5.30) = 3.05

! The Fire Factor for the years 1954 to 1961 are determined in the same manner.

! In 1962, the watershed suffered a 6% burn over a different part of the watershed than that which occurred in 1951. The combined effect of the two wildfires is determined in the following manner:

Example of Fire Factor Calculations - for Partial Burns (cont.)

1962   1) 92% of the watershed has a "normal" (unburned) Fire Factor of 3.0

2) 2% of the watershed has a "11 years after burn" Fire Factor of 3.84 (Figure A-2)

3) 6% of the watershed has a "1 years after burn" Fire Factor of 6.00 (Figure A-2)

Thus, the weighted Fire Factor for 1962 is: 0.92 (3.0) + 0.02 (3.84) + 0.06 (6.00) = 3.20

1963   1) 92% of the watershed has a "normal" unburned) Fire Factor of 3.0

2) 2% of the watershed has a "12 years after burn" Fire Factor of 3.65 (Figure A-2)

3) 6% of the watershed has a "2 years after burn" Fire Factor of 5.65 (Figure A-2)

Thus, the weighted Fire Factor for 1963 is: 0.92 (3.0) + 0.02 (3.65) + 0.06 (5.65) = 3.17

! The Fire Factor for the years 1964 and 1965 are determined in the same manner. In 1966, the 2% of the basin burned in 1951 has fully recovered, and the Fire Factor for the year 1966 is calculated as:

1966   1) 94% of the watershed has a "normal" (unburned) Fire Factor of 3.0

2) 6% of the watershed has a "5 years after burn" Fire Factor of 4.79 (Figure A-2)

Thus, the weighted Fire Factor for 1966 is: 0.94 (3.0) + 0.06 (4.79) = 3.11

! In 1967, the watershed suffered a 11% burn over a different part of the watershed than that which occurred in 1962. The combined effect of the two wildfires is determined the same way as above.

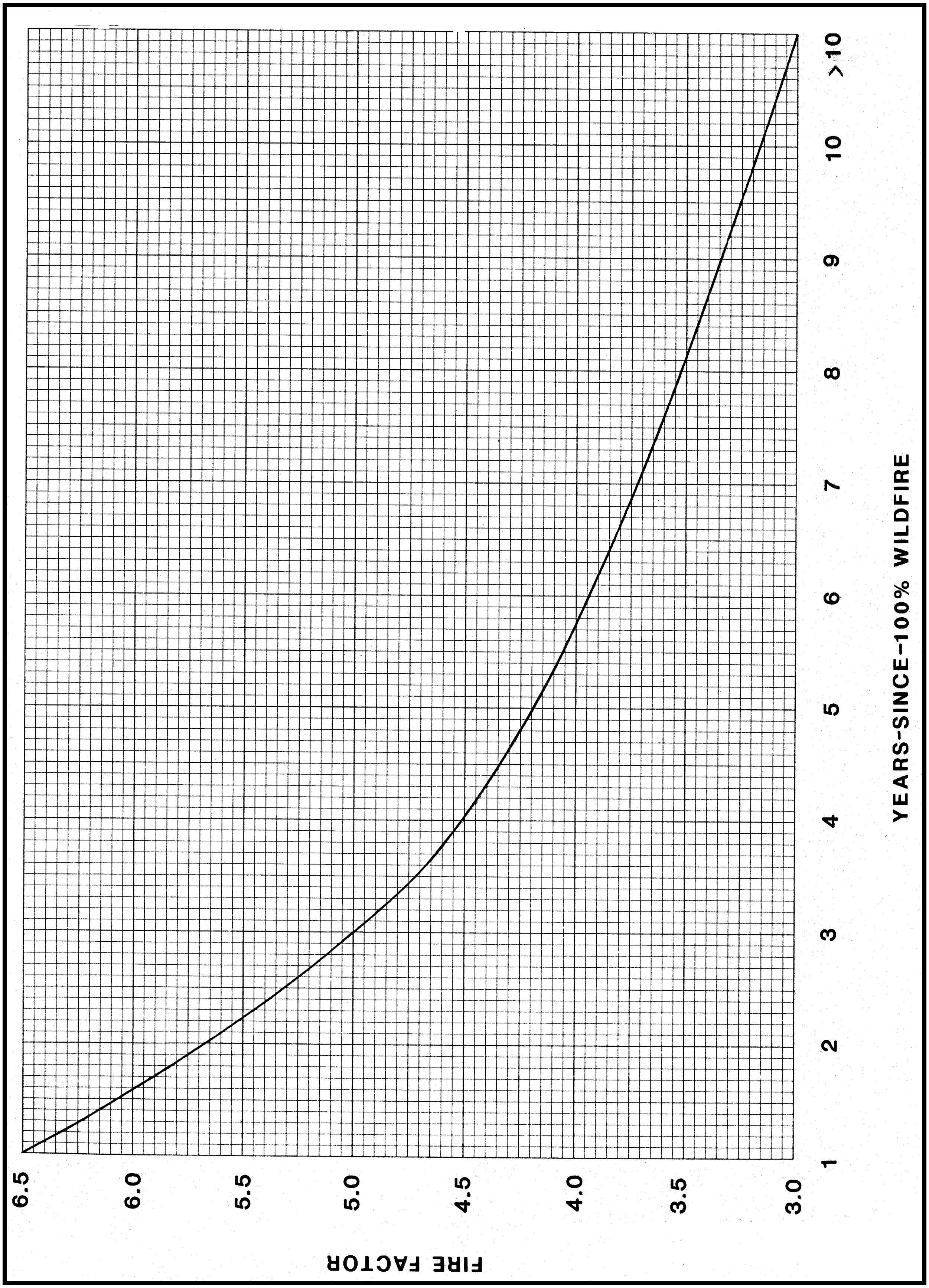

Figure A-1: Fire Factor Curve for Watersheds 0.1 to 3.0 mi²

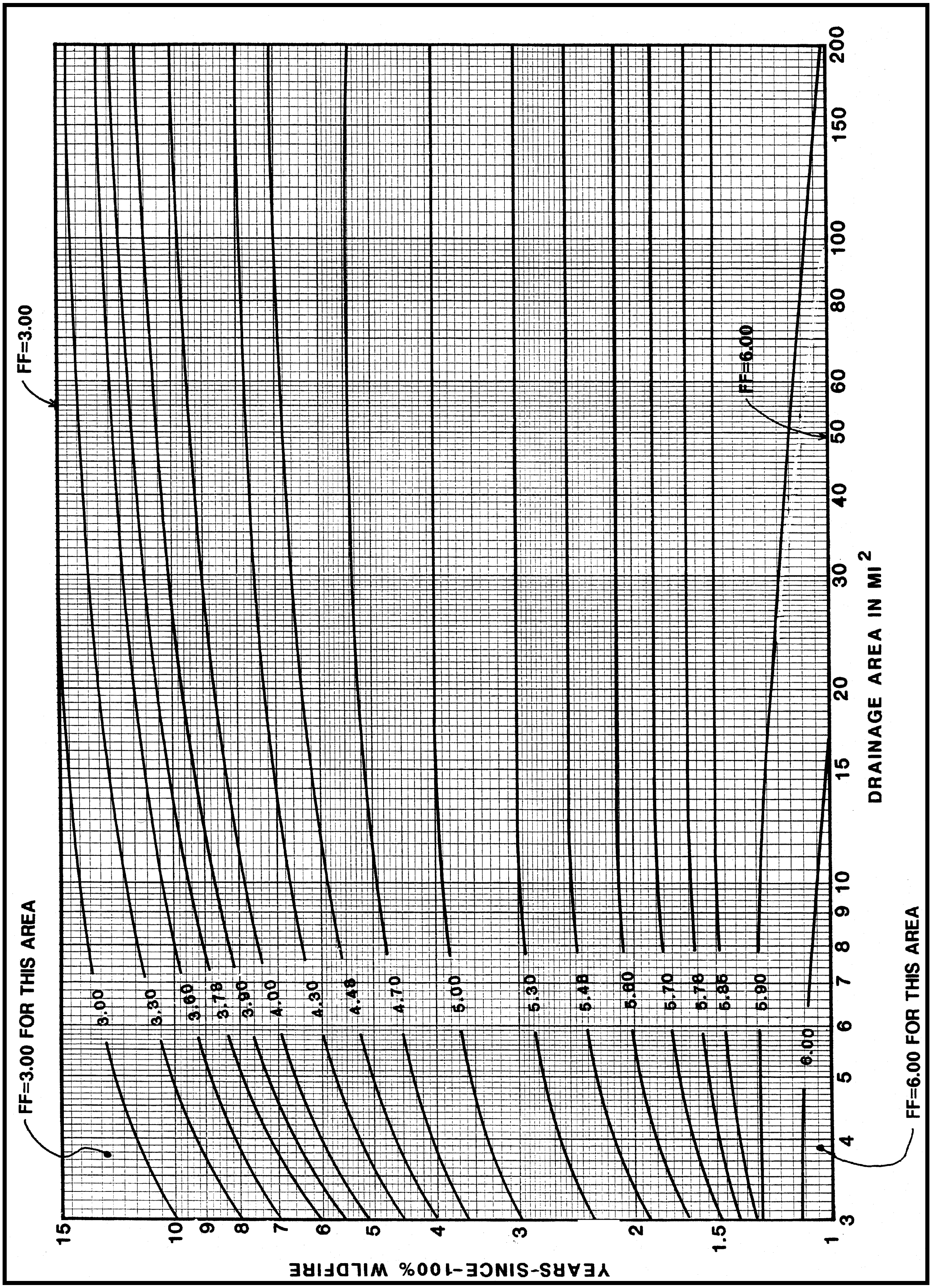

Figure A-2: Fire Factor Curves for Watersheds 3.0 to 200 mi²

DEBRIS YIELD FREQUENCY RELATIONSHIP BASED ON TOTAL PROBABILITIES OF 100% WILDFIRE AND FLOODING (USING CFA).

If the intent of the investigator is to determine the debris yield for a hypothetical frequency event (third purpose above) using the total exceedance probabilities of 100% wildfire and flooding, a Years-Since-100% Wildfire Frequency Relationship must be developed. This relationship is derived in the following manner:

Step 1/. Determine the drainage area of the subject watershed (in mi^2 and ac).

Step 2/. Determine the fire history for the watershed. Remember to locate each burn relative to previous burns in the watershed.

Step 3/. Determine the Fire Factor for each year of the history. A table such as Table A-1 should be developed showing the year and Fire Factor along with the percent burn for each wildfire occurrence.

- If the drainage area of the watershed is less than 3.0 mi^2, use Figure A-1 to determine the Fire Factor for 100% burn.

- If the drainage area of the watershed is between 3.0 and 200 mi^2, use Figure A-2 to determine the Fire Factor for 100% burn.

<u>Note</u>: Refer to example following Table A-1 for computation of Fire Factor for years with partial burns.

Step 4/. Determine a Fire Factor frequency chart. Rank the Fire Factors (from high to low) and assign each Fire Factor an exceedance frequency based on the median plotting position formula:

$$\frac{m - 0.3}{N + 0.4} \times 100$$

where:

m = the ordered sequence of Fire Factor values ranging from 1 to N

N = number of items in the data set

An example of a Fire Factor frequency chart is shown in Table A-2.

Step 5/. Derive a fire duration curve for the subject watershed. Plot the Fire Factor values versus Percent Time Fire Factor is Equaled or Exceeded (frequency) in Table A-2 on linear graph paper (10 x 10 x 1 inch recommended) and draw a smooth curve through the plotted points. Following the general shape of the smooth curve, extrapolate both ends, if necessary, so that Fire Factors of 6.00 and 3.00 have estimated exceedance frequencies. An example of a fire duration curve for the Santa Paula Creek watershed is shown on Figure A-3.

Step 6/. Determine a Fire Factor versus Years-Since-100% Wildfire table. Set up the table for durations of 1 Year-Since-100% Wildfire to full recovery (10-15 years depending on drainage area size). Use Figure A-2 to determine the Fire Factor for each Year-Since-100% Wildfire (42.9 mi²). This is shown in the first two columns of Table A-3.

Step 7/. Determine the percent of time the Fire Factor is equaled or exceeded for the Fire Factors from step 6 using the fire duration curve from step 5. As a check, the probability of the watershed having suffered a 100% burn less than 1 year earlier should be quite small, while the probability of the watershed being in a "normal" or unburned state should be quite high. Expand Table A-3 to include a column for percent time Fire Factor is equaled or exceeded (see column 3, Table A-3). Columns 1 and 3 of Table A-3 represent the Years-Since-100% Wildfire frequency relationship.

Step 8/. Enter the percent time Fire Factor is equaled or exceeded and the corresponding Years-Since-100% Wildfire on DT and DP records in the CFA computer program input file.

In the absence of any fire history, Fire Factors and the percent of time the Fire Factor is equaled or exceeded can be obtained from the generalized fire duration curves on Figure A-4. These curves were developed from a number of coastal Southern California watersheds ranging from Santa Barbara County to Orange County and are not meant to be used outside the principle area of application (see Figure 1, main text). The curves were developed by placing the watersheds into size groups as shown on Figure A-4 (0.1-3.0 mi², 3.0-10 mi², 10-25 mi², 25-100 mi², 100-200 mi²), determining the fire history for each watershed, calculating the Fire Factors for each year in the fire history, and computing a ratio of the number of occurrences for Fire Factors to the total number of years. Keep in mind that at the ends of the drainage area ranges, there will be discontinuities. These curves should be used with great caution.

TABLE A-2: FIRE FACTOR FREQUENCY CHART

Santa Paula Creek Watershed Application

Rank	Fire Factor	Percent of Time FF Equaled or Exceeded [a]	Rank	Fire Factor	Percent of Time FF Equaled or Exceeded [a]	Rank	Fire Factor	Percent of Time FF Equaled or Exceeded [a]
1	5.13	0.9	31	3.37	40.7	61	3.02	80.5
2	4.69	2.3	32	3.34	42.0	62	3.02	81.8
3	4.48	3.6	33	3.33	43.4	63	3.02	83.2
4	4.45	4.9	34	3.32	44.7	64	3.02	84.5
5	4.31	6.2	35	3.30	46.0	65	3.02	85.8
6	4.25	7.6	36	3.28	47.3	66	3.02	87.1
7	4.17	8.9	37	3.26	48.7	67	3.02	88.5
8	4.03	10.2	38	3.25	50.0	68	3.01	89.8
9	4.03	11.5	39	3.22	51.3	69	3.01	91.1
10	4.02	12.9	40	3.20	52.7	70	3.01	92.4
11	3.91	14.2	41	3.19	54.0	71	3.00	93.8
12	3.84	15.5	42	3.19	55.3	72	3.00	95.1
13	3.82	16.8	43	3.18	56.6	73	3.00	96.4
14	3.81	18.2	44	3.17	58.0	74	3.00	97.7
15	3.73	19.5	45	3.16	59.3	75	3.00	99.1
16	3.71	20.8	46	3.15	60.6			
17	3.67	22.1	47	3.12	61.9			
18	3.66	23.5	48	3.12	63.3			

TABLE A-2 (cont.): FIRE FACTOR FREQUENCY CHART

Santa Paula Creek Watershed Application

Rank	Fire Factor	Percent of Time FF Equaled or Exceeded [a]	Rank	Fire Factor	Percent of Time FF Equaled or Exceeded [a]	Rank	Fire Factor	Percent of Time FF Equaled or Exceeded [a]
19	3.65	24.8	49	3.11	64.6			
20	3.63	26.1	50	3.11	65.9			
21	3.62	27.5	51	3.06	67.2			
22	3.55	28.8	52	3.05	68.6			
23	3.53	30.1	53	3.05	69.9			
24	3.49	31.4	54	3.04	71.2			
25	3.46	32.8	55	3.04	72.5			
26	3.44	34.1	56	3.03	73.9			
27	3.42	35.4	57	3.03	75.2			
28	3.42	36.7	58	3.03	76.5			
29	3.37	38.1	59	3.03	77.9			
30	3.37	39.4	60	3.03	79.2			

Exceedance Frequencies calculated using median plotting positions x 100.
[a] m = 1 to 75 & N = 75

TABLE A-3: EXAMPLE OF FIRE FACTOR DETERMINATION FOR YEARS-SINCE-100% WILDFIRE

Santa Paula Creek Watershed
Drainage Area = 42.9 mi²

Years-Since-100% Wildfire Occurrence	Fire Factor [a]	Percent Time Fire Factor is Equaled or Exceeded [b]
1 year after	6.00	0.1[c]
2 years after	5.65	0.3[c]
3 years after	5.30	0.7[c]
4 years after	5.00	1.4
5 years after	4.79	2.2
6 years after	4.59	3.2
7 years after	4.42	4.6
8 years after	4.24	7.2
9 years after	4.09	12.0
10 years after	3.96	13.1
11 years after	3.84	16.7
12 years after	3.65	24.1
13 years after	3.45	34.5
14 years after	3.25	49.0
15 years after	3.00	100.0

[a] From Figure A-2 for 42.9 mi².
[b] From Fire Duration Curve for Santa Paula Creek (Fig. A-3).
[c] From Extrapolation of the Fire Duration Curve for Santa Paula Creek.

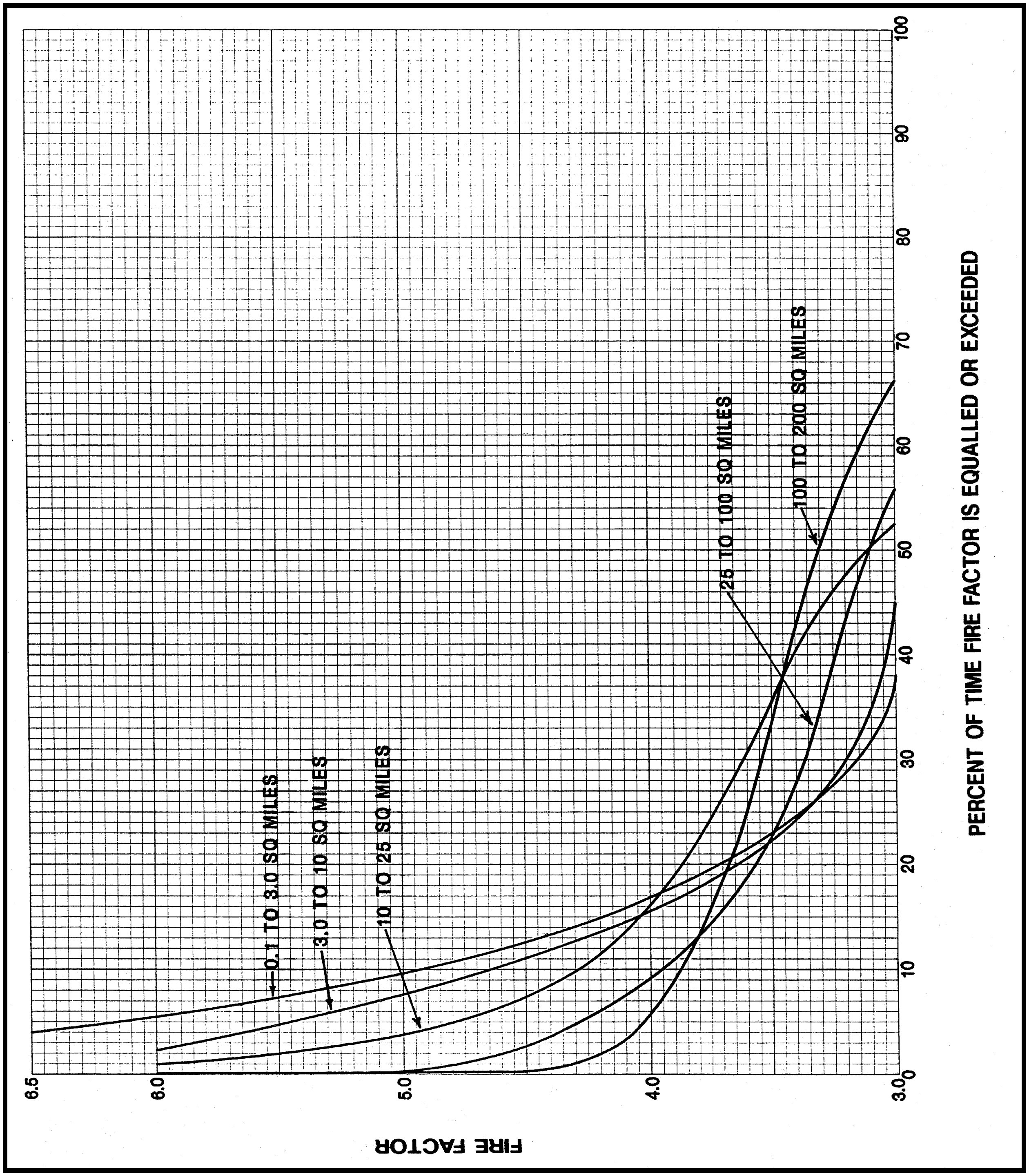

Figure A-4: Generalized Fire-Duration Curves
For Drainage Areas 0.1 to 200 mi^2

APPENDIX B

HOW TO DETERMINE THE

ADJUSTMENT-TRANSPOSITION

FACTOR

APPENDIX B

HOW TO DETERMINE ADJUSTMENT-TRANSPOSITION (A-T) FACTORS

Introduction. The Adjustment-Transposition (A-T) Factor was developed to account for the difference in geomorphology between the subject watershed and the original watersheds from which the regression equations were generated. This factor considers the surficial geology, soils, and hillslope and channel morphology. Watersheds of the San Gabriel Mountains from which the regression equations were developed have an A-T Factor of 1.0. Watersheds in areas with higher debris potential would have an A-T Factor greater than 1.0, while areas of lesser debris yield capacity would have an A-T Factor less than 1.0.

Four techniques for calculating the A-T Factor are provided below. Preliminary data collection should consist of finding all sediment and/or debris records for the subject watershed or, in the absence of these, for all nearby watersheds possessing similar geology, climate, and topography. Any available topographic, soil, and land use maps should be collected. After determining a preliminary estimate of the A-T Factor, a field investigation of the watershed should be performed. The following techniques also make use of the drainage area size and the average annual precipitation for the subject watershed.

To use the A-T Factor, first calculate the unadjusted unit debris yield (Log Dy) using the appropriate regression equation. After taking the anti-log of Dy, multiply the result by the A-T Factor to determine the "adjusted" debris yield.

TECHNIQUE 1 - SEDIMENT/DEBRIS RECORD FOR SUBJECT WATERSHED CONTAINS SINGLE EVENT DEBRIS YIELD VALUES.

If the sediment/debris record contains single event debris yield values (short term debris measurement clearly related to a single flood event), a direct comparison may be made between the volume the subject watershed actually yielded under the precipitation/runoff conditions contained in the record pertaining to that event, and the volume that would be calculated using the appropriate unadjusted regression equation under the same hydrologic and fire conditions. Simply divide the measured debris yield for the subject watershed by the debris yield calculated using the appropriate regression equation. The result will be the A-T Factor for the subject watershed. If there is information for several events, an average or weighted average can be calculated.

$$\frac{\text{Actual Subject Watershed Debris Yield}}{\text{Unadjusted Regression Equation Debris Yield}} = \text{A-T Factor}$$

If, for example, the subject watershed yielded 60,000 yds^3/mi^2 for a peak runoff event of 100 $ft^3/s/mi^2$, and the regression equation yields a value of 80,000 yds^3/mi^2 under the same hydrologic and fire conditions, the A-T Factor would be 60,000 divided by 80,000 or 0.75.

TECHNIQUE 2 - SEDIMENT/DEBRIS RECORD FOR SUBJECT WATERSHED CONTAINS PERIODIC SURVEY RESULTS ONLY.

If the only sediment/debris records that exist for the subject watershed are in the form of accumulated sediment values from the results of periodic surveys, obtain all of the long-term sediment records and determine the average annual sediment yield. Divide the average annual sediment yield by the average annual precipitation for the watershed. Average annual precipitation values for the subject watershed may be found by contacting the applicable county flood control agency, from National Weather Service publications, or may be calculated by the investigator using available precipitation gauge data and an appropriate area-averaging method (isohyetal, Thiessen polygons, etc.). The result is the "average annual sediment yield/average annual precipitation (AASY/AAP) ratio".

Using this technique, the A-T Factor is determined in the following manner:

Step 1/. Determine the drainage area of the subject watershed.

Example (Ex.). Drainage Area = 40 mi^2

Step 2/. Determine the average annual sediment yield of the subject watershed from available periodic survey data.

Ex. Average Annual Sediment Yield = 1.69 ac-ft/mi^2/yr

Step 3/. Determine the average annual precipitation for the subject watershed.

Ex. Average Annual Precipitation = 25 in.

Step 4/. Determine the AASY/AAP ratio. Divide the average annual sediment yield by the average annual precipitation.

Ex. AASY/AAP Ratio (for 40 mi^2) = 1.69 ac-ft/mi^2/yr / 25 in = 0.07 ac-ft/mi^2/yr/in

Step 5/. Determine the AASY/AAP ratio for an equivalent regression watershed in the San Gabriel Mountains from Figure B-1, using the drainage area of the subject watershed.

Ex. AASY/AAP Ratio for Equivalent Watershed San Gabriel Mountains (for 40 mi^2) = 0.101

Step 6/. Determine the A-T Factor for the subject watershed. Take the subject watershed's AASY/AAP ratio (0.07) and divide by the equivalent regression watershed AASY/AAP ratio (0.101).

Ex. A-T Factor for the Subject Watershed = 0.07 / 0.101 = .67

TECHNIQUE 3 - NO SEDIMENT/DEBRIS RECORD AVAILABLE FOR SUBJECT WATERSHED. NEARBY WATERSHEDS HAVE PERIODIC SURVEY RESULTS.

If there are no sediment/debris records available for the subject watershed, but nearby watersheds have records with data from periodic surveys, obtain all of the long-term sediment records dealing with nearby reservoirs or debris basins and determine the average annual sediment yield for each. Eliminate any watersheds which are felt to have questionable records, significant upstream sediment traps, etc.

Using this technique, the A-T Factor is determined in the following manner:

Step 1/. Determine the drainage area of each watershed.

Ex. Drainage Area = 14 mi^2
Ex. Drainage Area = 56 mi^2
Ex. Drainage Area = 200 mi^2

Step 2/. Determine the average annual sediment yield for each watershed with periodic survey data.

Ex. Average Annual Sediment Yield = 2.0 ac-ft/mi^2/yr
Ex. Average Annual Sediment Yield = 1.4 ac-ft/mi^2/yr
Ex. Average Annual Sediment Yield = 1.5 ac-ft/mi^2/yr

Step 3/. Determine the average annual precipitation for each watershed.

Ex. Average Annual Precipitation = 29 in.
Ex. Average Annual Precipitation = 27 in.
Ex. Average Annual Precipitation = 27 in.

Step 4/. Determine the AASY/AAP ratio for each watershed. Divide average annual sediment yield by the average annual precipitation of the watershed to determine a ratio and plot these values on Figure B-1.

Ex. AASY/AAP Ratio (for 14 mi^2) = 2.0 /29 = .07
Ex. AASY/AAP Ratio (for 56 mi^2) = 1.4 /27 = .05
Ex. AASY/AAP Ratio (for 200 mi^2) = 1.5 /27 = .06

Step 5/. Establish a best-fit curve through the points using either regression or graphical techniques, and draw this on Figure B-1. This the new "local area curve".

Ex. Figure B-2 shows an example of what this should look like.

Step 6/. Determine the AASY/AAP yield ratios for the new local area curve and the subject watershed from the original regression watershed curve on Figure B-2 for the subject watershed's drainage area size.

Ex. AASY/AAP Ratio from New Local Area Curve (for 42.9 mi^2) = <u>.062</u>

AASY/AAP Ratio from Original Regression Watershed Curve (for 42.9 mi^2) = <u>.100</u>

Step 7/. Determine the A-T Factor for the subject watershed. Divide the value from the new local area curve by the value from the original regression watershed curve.

Ex. A-T Factor for the Subject Watershed = (for 42.9 mi^2) = .062 / .100 = <u>.62</u>

TECHNIQUE 4 - NO RECORDS AVAILABLE FOR SUBJECT WATERSHED OR NEARBY WATERSHEDS.

In the absence of any applicable records of any kind for the subject or nearby watersheds, Table B-1, in conjunction with a detailed field analysis, can be used to determine an approximate A-T Factor. Table B-1 was developed from average annual sediment yield estimation methods currently in use in Southern California, including the Pacific Southwest Inter-Agency Conference (PSIAC) method. Application of this technique must be supported by comparison with San Gabriel Mountain watersheds which were included in the regression equations. Estimates made by use of this technique may possess larger errors in estimation than would result from the application of Techniques 1, 2, or 3. However, this technique provides an alternative approach when sediment or debris yield records are not available at all, or when there are not enough nearby watersheds with data to construct a "local area curve" (Technique 3).

For example, assume it is necessary to apply the regression equation to a watershed for which no sediment or debris yield records exist, and which has only one nearby watershed for which these records exist. Since there are not enough comparative watersheds to establish a local area curve on Figure B-1, a field investigation in both watersheds is required to determine the similarities between them.

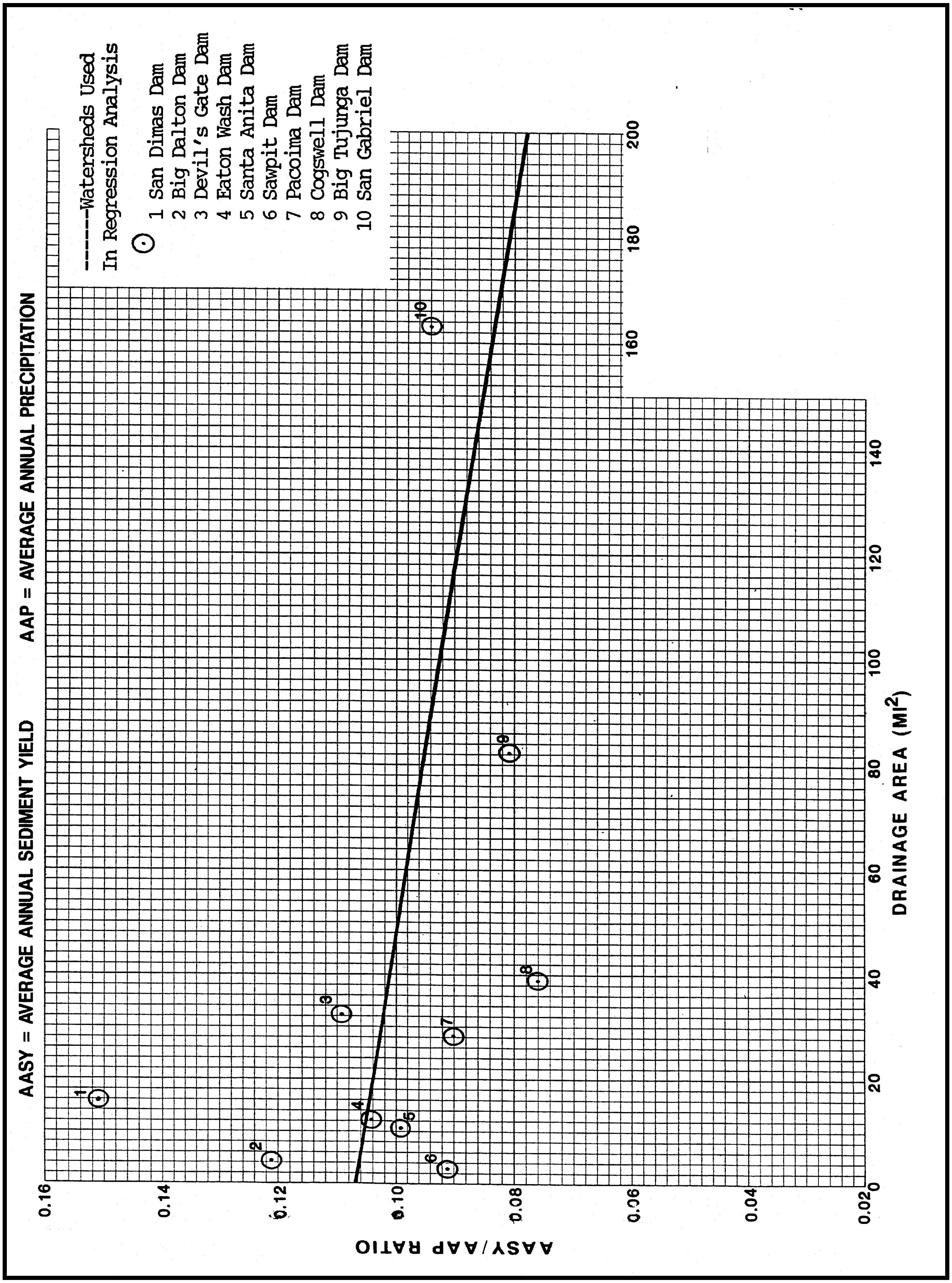

Figure B-1: AASY/AAP Ratios For Drainage Areas 0.0 to 200 mi²

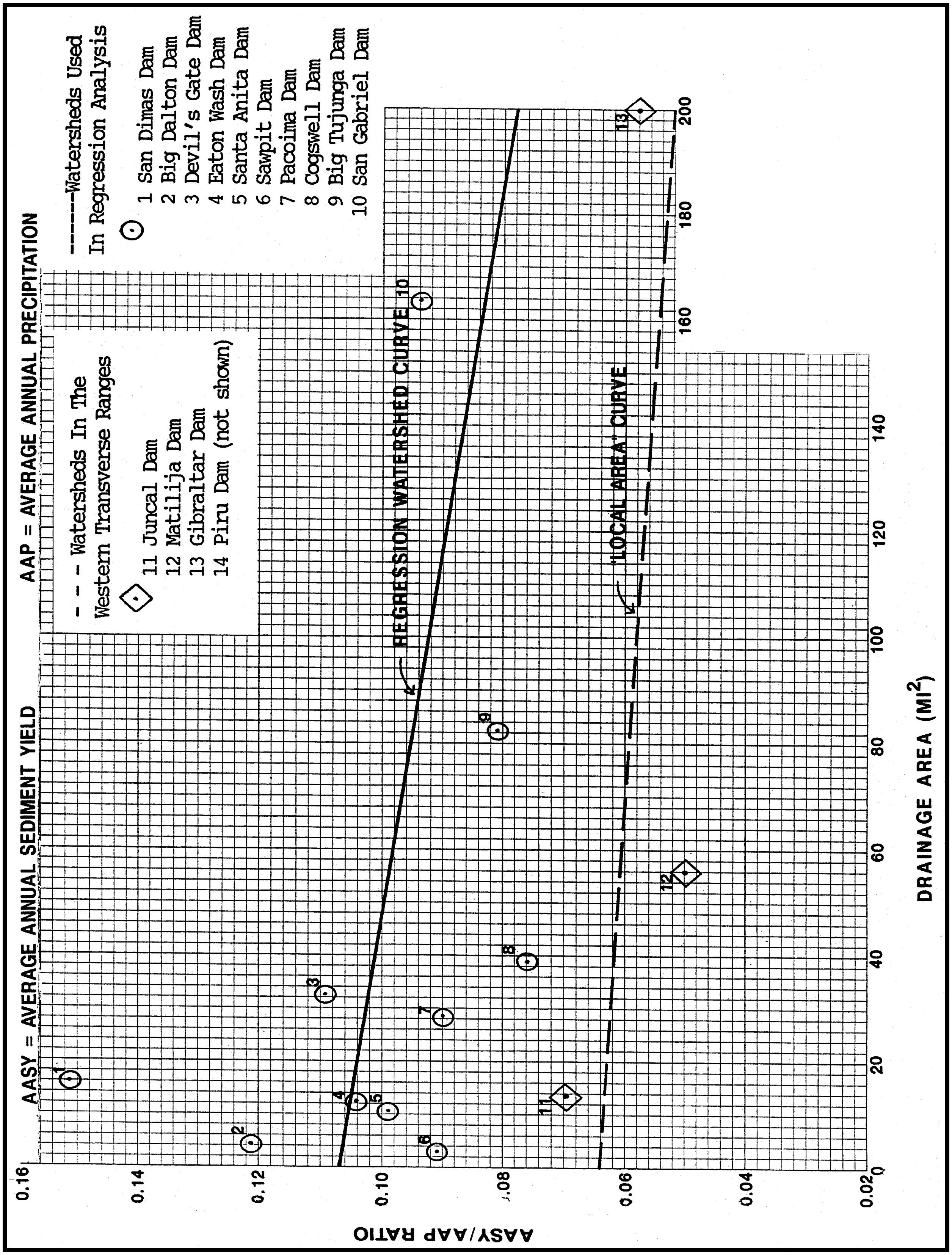

Figure B-2: AASY/AAP Ratios For Drainage Areas 0.0 to 200 mi²
With Local Area Curve

TABLE B-1: ADJUSTMENT-TRANSPOSITION FACTOR TABLE

	A-T Subfactor				
	0.25	0.20	0.15	0.10	0.05
Parent Material			Subfactor Group 1		
Folding	Severe		Moderate		Minor
Faulting	Severe		Moderate		Minor
Fracturing	Severe		Moderate		Minor
Weathering	Severe		Moderate		Minor
Soils			Subfactor Group 2		
Soils	Non-cohesive		Partly Cohesive		Highly Cohesive
Soil Profile	Minimal Soil Profile		Some Soil Profile		Well-developed Soil Profile
Soil Cover	Much Bare Soil in Evidence		Some Bare Soil in Evidence		Little Bare Soil in Evidence
Clay Colloids	Few Clay Colloids		Some Clay Colloids		Many Clay Colloids
Channel Morphology			Subfactor Group 3		
Bedrock Exposures	Few Segments in Bedrock		Some Segments in Bedrock		Many Segments in Bedrock
Bank Erosion	>30% of Banks Eroding		10-30% of Banks Eroding		<10% of Banks Eroding
Bed and Bank Materials	Non-cohesive Bed and Banks		Partly Cohesive Bed and Banks		Mildly Cohesive Bed and Banks
Vegetation	Poorly Vegetated		Some Vegetation		Much Vegetation
Headcutting	Many Headcuts		Few Headcuts		No Headcutting
Hillslope Morphology			Subfactor Group 4		
Rills and Gullies	Many and Active		Some Signs		Few Signs
Mass Movement	Many Scars Evident		Few Signs Evident		No Signs Evident
Debris Deposits	Many Eroding Deposits		Some Eroding Deposits		Few Eroding Deposits
The A-T Factor Is the Sum of the A-T Subfactors from All 4 Subfactor Groups.					

The one nearby watershed with records has an average annual sediment yield of 1.1 ac-ft/mi^2/yr. Field analysis indicated that the nearby watershed is similar in many respects to the subject watershed. Using Technique 2 and Figure B-1 gives a tentative A-T Factor of 0.80.

Field observations indicates that the nearby watershed appears to possess the following geomorphic characteristics. The A-T Factor is the summation of the subfactors from each of the four subgroups in Table B-1.

a). Moderate to severe folding, fracturing, faulting, and weathering of parent material (Subfactor Group 1 = <u>0.20</u>).

b). Partly cohesive soils with some soil profile development, some bare soil in evidence, and the soil appears to possess some clay colloids (Subfactor Group 2 = <u>0.15</u>).

c). Channel morphology exhibits extremely active erosion, with greater than 50% of all channels actively eroding both bed and banks, few segments in bedrock, extremely unstable bed and bank materials, little protective vegetation, and numerous headcuts in evidence (Subfactor Group 3 = <u>0.25</u>).

d). Hillslopes are heavily rilled with some gullying, a few mass movement scars, and a number of actively-eroding colluvial/alluvial deposits (Subfactor Group 4 = <u>0.20</u>).

Adding these four Subfactor Group values together (0.20 + 0.15 + 0.25 + 0.20) results in an A-T Factor of <u>0.80</u>. This value corroborates the sediment yield record value of <u>0.80</u>.

It must be recognized that Technique 4 is the most subjective of any of the A-T techniques. Estimates determined using this technique should be documented, and if possible, verified by use of one of the earlier techniques.

APPENDIX C

HOW TO USE THE

COINCIDENT FREQUENCY ANALYSIS

PROGRAM

APPENDIX C

HOW TO USE THE COINCIDENT FREQUENCY ANALYSIS (CFA) PROGRAM

Introduction.

Information on acquiring the Coincident Frequency Analysis computer program made be obtained by contacting the Hydrologic Engineering Center in Davis, California. The telephone number and address are listed on page C-5.

In order to evaluate the total probabilities of independent flood and wildfire events, coincident frequency analysis is used to establish the probabilities of varied debris yield volumes in conjunction with the fire history and discharge/precipitation frequency of a watershed. The Coincident Frequency Analysis program was developed by the Hydrologic Engineering Center of the Corps of Engineers at Davis, California. This program evaluates the total probabilities of occurrence of two independent events, in this case, those of wildfire and flood events.

It must be recognized that the coincident frequency values generated by the computer program are not the maximum debris yield values to be expected, but rather the expected "mean" debris response, and as such are highly dependent on accurate frequency input for both hydrologic data and fire frequencies.

The following is a step-by-step procedure for setting up an input file for use with the Coincident Frequency Analysis program. The procedure assumes the user is already familiar with the COE Debris Method and has previously prepared the appropriate input data (see Example 3, Part 3C in Appendix D).

Located in this appendix following the step-by-step procedure is the users manual for the CFA program and following this are the input and output for 4 test examples provided by HEC.

Four types of data are used as input for the CFA program; 1) Years-Since-100% Wildfire frequency, 2) discharge frequency, and 3) debris response relationships, along with 4) evaluation data.

PROCEDURE FOR SETTING UP A CFA INPUT FILE

Step 1/. Enter alphanumeric information identifying the location of analysis, project name, file name, user name, date, and any other pertinent information on TI records. Any number of TI records may be used but at least one is required.

Step 2/. Enter the Years-Since-100% Wildfire relationship using DS, DT, and DP records. Refer to Appendix A for determining Years-Since-100% Wildfire frequency relationships (see Table A-3, Appendix A for example).

The DS record contains the number of coordinates used to describe the duration relationship in field 1, followed by an alphanumeric description such as "YEARS-SINCE-100% WILDFIRE".

The DT record contains values for percent of time equaled or exceeded.

The DP record contains the values of Years-Since-100% Wildfire occurrence corresponding to the percent of time equaled or exceeded values on the DT record.

Step 3/. Enter the precipitation or discharge frequency data using FS, FR, and FP records (see Table D-3 for example of data).

The FS record contains the number of pairs used to describe the discharge frequency relationship in field 1 followed by an alphanumeric description such as "PEAK FLOW (FT3/S/MI2) - EXISTING CONDITION".

The FR record contains percent chance exceedance values.

The FP record contains flow values in $ft^3/s/mi^2$ corresponding to percent chance exceedance on FR record.

Step 4/. Enter the debris response relationships for Years-Since-100% Wildfire using RS, RD, RF, and RP records.

The RS record contains the number of sets of discharge versus debris response relationships in field 1 (max. 30) followed by an alphanumeric description such as "DEBRIS YIELD IN CU YD/SQ MI".

The RD record contains the number of pairs that will be used to describe the debris response relationship followed by the set number for the number of sets on the RS record.

The RF record contains the unit peak flow values (in ft^3/mi^2) beginning with the lowest value and monotonically decreasing.

The RP record contains the debris response (in yd^3/mi^2) corresponding to values on the RF record (the values will monotonically decrease if they correspond to values on RF record).

Step 5/. Enter an array of evaluation values on an VS and VR records. The program will use these values to define the debris frequency relationship. The values should cover the range of possible debris yields (max. = 30).

The VS record contains the number of evaluation values (max =30) in field one, followed by an alphanumeric description of the response variable name such as "YIELD" left justified in field two followed by an alphanumeric description of the response variable units such as "YD3/MI^2" (left justified).

The VR record contains values of the response parameter to be evaluated. Successive values must monotonically increase or decrease.

Step 6/. Enter a ED record as an end-of-data indicator.

CFA

COINCIDENT-FREQUENCY ANALYSIS

User's Manual

(Preliminary)

December 1989

U.S. Army Corps of Engineers
Water Resources Support Center

The Hydrologic Engineering Center
609 Second Street
Davis, California 95616

(916) 756-1104

COINCIDENT-FREQUENCY ANALYSIS PROGRAM

This preliminary version of the Coincident-Frequency Analysis Program was written by Harold E. Kubik. The procedures contained in the program are described in lecture outline 64, handout 39, and workshop 25 that is part of the Statistical Methods in Hydrology training course. At this time the program can only analyze situations where the frequency and duration parameters can be assumed to be independent.

The Hydrologic Engineering Center (HEC) plans to add capabilities to the program in the future. Assistance may be provided by John Peters at
(916) 756-1104.

INPUT DESCRIPTION
COINCIDENT-FREQUENCY ANALYSIS
(CFA)

I. Title Information (Required).

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	TI	Record identifier.
1-10	TITLE	Char	Character or alphanumeric information to identify the location of the analysis. Any number of TI records may be provided, but at least one is required.

II. Job Specifications (Optional).

This record defines the transformation that is made to the frequency parameter before the curve fitting procedures are applied, sets number of decimal places and significant figures, and sets amount of diagnostic output. If this record is not provided, the default values under the variable names will be used.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	JI	Record identifier.

1	LOGTF (0)	0	The frequency parameter (FP record) is not transformed, recommended for stage-frequency curves.
		1	Logarithmic transformation (base 10) will be made, recommended for flow-frequency curves.
2	NDEC (2)	+	Number of decimal places in the table of results; 0, 1, 2, or 3 allowed. If blank, default value of 2 will be used.
3	NSIG (5)		Number of significant figures in table of results.
		-1	No rounding will be done.
		0	Round to five (5) significant figures.
		+	Round values to NSIG significant figures.
4	IDGST (0)	0	No diagnostic output.
		1	Interpolated values will be output during the computational steps.
		2	Diagnostic output will be provided for each interpolated value. Caution, will create a lot of output.

III. Duration Data.

This set of records is used to input the duration curve for the less influential variable. Either a set of DT and DP records must be provided or a ZR record that reads the data from DSS.

A. Duration Data Specifications (Required).

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	DS	Record identifier.

1	NDPTS	+	Number of coordinates used to describe the duration curve. Data are input on DT and DP records. Must be zero, or blank, if data are read from DSS.(Maximum of 30 points.)
2-10	LOCIDD	Char	Location of the less influential variable.

B. Percent of Time Exceeded Ordinates (Optional).

This record is provided if NDPTS is positive.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	DT	Record identifier.
1-10	PTIME	+	Percent of time that the duration parameter is exceeded. Values must monotonically increase or decrease.

C. Duration Parameter Ordinates (Optional).

This record is provided if NDPTS is positive.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	DP	Record identifier.
1-10	DPAR	+	Duration parameter values that correspond to the percent of time exceeded ordinates provided on the previous record (DT).

D. DSS Input Pathname (Optional).

This record is provided if NDPTS is blank or zero.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	ZR	Record identifier.

1-10	(pathname)	Char	DSS pathname of duration data. Must be complete pathname or pathname parts if this is the first ZR record. Subsequent ZR records need only provide those pathname parts that are different.

IV. Frequency Data.

This set of records is used to input the frequency curve for the more influential variable. Either a set of FR and FP records must be provided or a ZR record that reads data from DSS.

A. Frequency Data Specifications (Required).

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	FS	Record identifier.
1	NFPTS	+	Number of coordinates used to describe the frequency curve. Data are input on FR and FP records. Must be zero, or blank, if data are read from DSS. (Maximum of 20 points.)
		-1	Frequency data are not provided and SFPV values (RF record) provided for the response function are percent chance exceedance values.
2-10	LOCIDF	Char	Location identification of the more influential variable.

B. Exceedance Frequency Ordinates (Optional).

This record is provided if NFPTS is positive.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	FR	Record identifier.
1-10	FREQ	+	Percent chance exceedance values.

C. Frequency Parameter Ordinates (Optional).

This record is provided if NFPTS is positive.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	FP	Record identifier.
1-10	FPAR	+	Frequency parameter values that correspond to the percent chance exceedance values on the previous record (FR). These values must monotonically increase or decrease.

D. DSS Input Pathname (Optional).

This record is provided if NFPTS is blank or zero.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	ZR	Record identifier.
1-10	(pathname)	Char	DSS pathname of frequency data. Must be complete pathname or pathname parts if this is the first ZR record. Subsequent ZR records need only provide those pathname parts that are different.

V. Response Function Data.

These sets of records input the physical relationship between the frequency parameter, the response variable, and the duration parameter. A frequency parameter versus response function is provided for NCURV duration parameter values. If NFPTS (FS record) is equal to (-1), then the frequency parameter record will contain percent chance exceedance values.

A. Response Data Specifications (Required).

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	RS	Record identifier.
1	NCURV	+	Number of sets of frequency parameter -versus- response function curves (RD, RF, and RP records to provide. (Maximum of 30 points.)
		0	Read from DSS (not programmed yet).

		-1	A negative value for NCURV indicates that the response functions can be computed from the duration parameter and the frequency parameter. This is primarily used for lake-stage frequency analysis where the duration parameter is based on mean monthly lake levels and the frequency parameter is wind setup. The wind setup is added to the mean monthly lake level to obtain the response parameter. (Sets of RD, RF, and RP must not be provided.)
2-10	LOCIDR	Char	Location identification of response function parameter.

B. Duration Parameter Value (Optional).

NCURV sets of the records described in paragraphs B, C, and D are provided if NCURV is positive.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	RD	Record identifier.
1	NRPTS	+	Number of coordinates used to describe the frequency parameter -versus- response function relationship that is defined for the duration parameter SDPV. (Maximum of 20 points.)
2	SDPV	+	Value of the duration parameter on which the following response function (defined in paragraphs C and D) has been based. The NCURV values of SDPV for the successive sets must monotonically increase or decrease.

C. Frequency Parameter Values (Optional).

FIELD	VARIABLE	VALUE	DESCRIPTION

0	ID	RF	Record identifier.
1-10	SFPV	+	NRPTS values of the frequency parameter. If NFPTS is (-1), the SFPV values are percent chance exceedance.

D. Response Parameter Values (Optional).

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	RP	Record identifier.
1-10	RFUN	+	NRPTS values of the response parameter that correspond to the SFPV values on the previous record. These values must monotonically increase or decrease.

VI. Evaluation Data.

This set of records provides for writing results to DSS and allows the input of values of the response parameter that will be used to develop the frequency curve of the response parameter. Be sure that the input values include the full range of expected values otherwise inaccurate extrapolations may take place.

A. Evaluation Specifications (Required)

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	VS	Record identifier.
1	NEVAL	+	Number of evaluation values of the response parameter. (Maximum of 30 values.)
		0	The evaluation values will be computed by the program. The nominal number of values will be set to the maximum size of the array, currently dimensioned for 30 values.
		-#	The evaluation values will be computed by the program. The

nominal number of values will be set to #.

A. Evaluation Specifications, VS record (Continued).

FIELD	VARIABLE	VALUE	DESCRIPTION
2	RPNAME	Char	Response variable name left justified. Only the first 4 characters are used in the table heading and written to DSS.
3	RPUNIT	Char	Response variable units left justified. All 8 characters are used in the table heading and written to DSS.

A. Evaluation Specifications, VS record (Continued).

FIELD	VARIABLE	VALUE	DESCRIPTION
4	RPMIN	+	Minimum value for range of response variable to use in computing evaluation values. If both RPMIN and RPMAX are blank, the values will be computed from the input data.
5	RPMAX	+	Maximum value for range. See description of RPMIN.

B. Evaluation Values (Optional).

This record is provided if NEVAL is positive.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	VR	Record identifier.
1-10	EVAL	+	Values of the response parameter to be evaluated. Successive values must monotonically increase or decrease.

VII. DSS OUTPUT PATHNAME (Optional)

This record is provided if results are to be written to DSS.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	ZW	Record identifier.
1-10	(pathname)	Char	DSS pathname to write results. Must be complete pathname or pathname parts if this is the first ZW record. Subsequent ZW records need only provide those pathname parts that are different.

VIII. END-OF-DATA INDICATOR (Required).

ED records are used to separate data sets. Another data set may follow or the job will terminate if no other records are found.

FIELD	VARIABLE	VALUE	DESCRIPTION
0	ID	ED	End-of-data indicator for data set. Program will process data and output results before attempting to read the next data set.

SUMMARY OF INPUT RECORDS

COINCIDENT-FREQUENCY ANALYSIS

(CFA)

I. Title Information:

* TI, TITLE
(One or more title records of character information).

II. Job Specifications:

J1	LOGTF	NDEC	NSIG	JTRAC
0	2	5	0	(Default values if no J1 record).

III. Duration Data:

. . . Specifications:
* DS NDPTS LOCIDD
+# (Number of Duration data on each DT and DP record).
0 (Duration data will be read from DSS).

. . . Percent of Time Values:
DT PTIME (If NDPTS positive, NDPTS values).

. . . Duration Parameter Values:
DP DPAR (See DT record).

. . . DSS Input Pathname:
ZR (If NDPTS is blank or zero, DSS pathname for data).

IV. Frequency Relationship:

. . . Specifications:
* FS NFPTS LOCIDF
+# (Number of Frequency data on each FR and FP record).
0 (Frequency data will be read from DSS).
-1 (Frequency data not input, response values [RF] are frequency data).

. . . Exceedance Frequency Values:
FR FREQ (If NFPTS is positive, NFPTS values).

. . . Frequency Parameter Values:
FP FPAR (See FR record).

. . . DSS Input Pathname:
ZR (If NDPTS is blank or zero, DSS pathname for data).

V. Response Function Data:

. . . Specifications:
* RS NCURV LOCIDR
+# (Number of sets of RD, RF and RP records).
0 (DSS read not programmed yet).
-1 (Response functions computed, no RD, RF, RP records needed).

. . . Duration Parameter Value:
RD NRPTS SDPV (If NCURV is positive, NCURV sets of RD, RF and RP records).

. . . Frequency Parameter Values:
RF SFPV (If NCURV is positive, NRPTS values).

. . . Response Parameter Values:
RP RFUN (See RD record).

VI. Evaluation Data:

. . . Specifications:
* VS NEVAL RPNAME RPUNIT RPMIN RPMAX
+# (Number of Evaluation values on VR record).
0 (Evaluation values will be computed by program, around 30).
-# (Nominal number of values desired, cannot exceed 30).

. . . Evaluation Values:
VR EVAL (If NEVAL is positive, NEVAL values).

VII. DSS Output Pathname:
ZW (Pathname if DSS write of results is desired).

VIII. End-of-Data Indicator:
* ED

Another data set may follow or the job will terminate if no other records found.

* Indicates a required record.

TEST NO. 1

Input for Test No. 1

```
TI TEST NO. 1 COINCIDENT FREQUENCY WORKSHOP P-25
TI INPUT IS STAGE-DURATION CURVE, FLOW-FREQUENCY CURVE AND
TI   CONDITIONAL BACKWATER CURVES
J1     1
DS    10  MAIN RIVER STAGES AT B
DT   .01     10.    10.8     30.     39.     50.    62.5     70.    84.5   99.99
DP  62.8     62.    61.4     60.    58.6     56.    53.3     52.    50.5    49.2
FS     7  FLOW-FREQUENCY AT A
FR 99.99     90.     50.     10.      1.      .1     .01
FP  1500    3000    4200    6000    8000   10000   12000
RS     6  RESPONSE -- STAGES AT C
RD     4     50.
RF  1500    3000    6000   10000
RP    52      55      60      65
RD     4    53.33
RF  1500    3000    6000   10000
RP    55    57.7    62.2    67.7
RD     4      56
RF  1500    3000    6000   10000
RP  57.5      60      64      68
RD     4    58.6
RF  1500    3000    6000   10000
RP  59.6    62.2    65.8    69.3
RD     4    61.4
RF  1500    3000    6000   10000
RP    62    64.5    67.6    70.7
RD     4      62
RF  1500    3000    6000   10000
RP  62.5      65      68      71
VS    16   STAGEFEET
VR    55      56      57      58      59      60      61      62      63      64
VR    65      66      67      68      69      70
ED
```

Output for Test No. 1

```
 ************************************      *************************************
 *               CFA                *      *                                   *
 *  COINCIDENT FREQUENCY ANALYSIS   *      *   U.S. ARMY CORPS OF ENGINEERS    *
 *     PROGRAM DATE:  DEC 1989      *      * THE HYDROLOGIC ENGINEERING CENTER *
 *     VERSION DATE: 18SEP1990      *      *         609 SECOND STREET         *
 *     RUN  DATE   AND   TIME:      *      *      DAVIS, CALIFORNIA 95616      *
 *        19 SEP 90    08:33:29     *      *          (916) 756-1104           *
 *                                  *      *                                   *
 ************************************      *************************************

  INPUT FILE NAME: CFA.DAT
 OUTPUT FILE NAME: CFA.OUT
  DSSIN FILE NAME: CFA
 DSSOUT FILE NAME: CFA

    -----DSS---ZOPEN:  Existing File Opened,  File: CFA.DSS
                       Unit:  71;  DSS Version: 6-EA
```

```
** TITLE INFORMATION **
TI TEST NO. 1 COINCIDENT FREQUENCY WORKSHOP P-25
TI INPUT IS STAGE-DURATION CURVE, FLOW-FREQUENCY CURVE AND
TI   CONDITIONAL BACKWATER CURVES

** JOB SPECIFICATIONS **
   LOGTF    NDEC    NSIG   JTRAC
J1     1

** DURATION CURVE DATA **
DS    10  MAIN RIVER STAGES AT B
DT   .01     10.    10.8     30.     39.     50.    62.5     70.    84.5   99.99
DP  62.8     62.    61.4     60.    58.6     56.    53.3     52.    50.5    49.2

** FREQUENCY CURVE DATA **
FS     7  FLOW-FREQUENCY AT A
FR 99.99     90.     50.     10.      1.      .1     .01
FP  1500    3000    4200    6000    8000   10000   12000

** RESPONSE FUNCTION CURVES **
RS     6  RESPONSE -- STAGES AT C

CURVE  1
RD     4    50.000
RF  1500    3000    6000   10000
RP    52      55      60      65

CURVE  2
RD     4    53.300
RF  1500    3000    6000   10000
RP    55    57.7    62.2    67.7

CURVE  3
RD     4    56.000
RF  1500    3000    6000   10000
RP  57.5      60      64      68

CURVE  4
RD     4    58.600
RF  1500    3000    6000   10000
RP  59.6    62.2    65.8    69.3

CURVE  5
RD     4    61.400
RF  1500    3000    6000   10000
RP    62    64.5    67.6    70.7

CURVE  6
RD     4    62.000
RF  1500    3000    6000   10000
RP  62.5      65      68      71

** EVALUATION DATA **
   NEVAL  RPNAME   RPUNIT      PRMIN     PRMAX
VS   16     STAGE FEET           .00       .00
VR    55      56      57      58      59      60      61      62      63      64
VR    65      66      67      68      69      70

** END OF INPUT DATA **

ED++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

-COMPUTED PERCENT CHANCE EXCEEDANCE VALUES-
```

RESPONSE VALUES

55.00	56.00	57.00	58.00	59.00	60.00	61.00	62.00
63.00	64.00	65.00	66.00	67.00	68.00	69.00	70.00

FREQUENCY VALUES

97.55	94.05	87.78	80.17	72.07	64.35	57.33	50.99
44.62	36.62	26.77	15.98	7.23	2.44	.62	.13

-INTERPOLATED FREQUENCY VALUES-

FREQ	RESPONSE STAGE IN FEET
.2	69.74
.5	69.15
1.0	68.67
2.0	68.16
5.0	67.37
10.0	66.63
20.0	65.62
30.0	64.69
40.0	63.60
50.0	62.16
60.0	60.61
70.0	59.26
80.0	58.02
90.0	56.69
95.0	55.79
99.0	54.14 *

* - INDICATES EXTRAPOLATED VALUE(S)

JOB COMPLETE

TEST NO. 2

Input for Test No. 2

```
TI TEST NO. 2 INTERIOR PONDING EXAMPLE
TI INPUT IS STAGE- DURATION CURVE AND RESPONSE CURVES CONDITIONED ON
TI   PERCENT CHANCE EXCEEDANCE
TI IGNORE RESULTING FREQUENCY CURVE BELOW 565 FT.
DS    11 MISSISSIPPI RIVER STAGES AT MOLINE,ILL  APR-JUN
DT   .01     .12     .22     .50    1.10    2.20    4.30   10.50   23.00   61.00
DT 99.99
DP   572     570     569     568     567     566     565     564     563     562
DP   561
FS    -1 FREQUENCY CURVE NOT REQUIRED, RESPONSE IS VERSUS EXCEEDANCE FREQUENCY
RS     5 MAXIMUM POND ELEVATION (APR-JUN) VS FREQUENCY FOR GIVEN MISS. STAGE
RD    10     562
RF    50      40      30      20      10       5       2       1      .5      .2
RP 565.0   565.1   565.2   565.5   566.0   566.5   567.0   567.3   567.5   567.8
RD    10     564
RF    50      40      30      20      10       5       2       1      .5      .2
RP 566.0   566.1   566.3   566.6   566.8   567.1   567.4   567.7   567.9   568.1
RD    10     566
RF    50      40      30      20      10       5       2       1      .5      .2
RP567.35   567.4  567.45   567.5   567.6   567.8   568.1   568.3   568.5   568.7
RD    10     568
RF    50      40      30      20      10       5       2       1      .5      .2
RP 568.4  568.45   568.5   568.6   568.7   568.9   569.2   569.4   569.6   570.0
RD    10     570
RF    50      40      30      20      10       5       2       1      .5      .2
RP568.85   568.9   569.0   569.2   569.4   569.7   570.1   570.3   570.6   570.9
VS     7ELEVATONFEET
VR   565     566     567     568     569     570     571
ED
```

Output for Test No. 2

```
 ************************************      *************************************
 *               CFA                *      *                                   *
 *  COINCIDENT FREQUENCY ANALYSIS   *      *   U.S. ARMY CORPS OF ENGINEERS    *
 *     PROGRAM DATE:  DEC 1989      *      * THE HYDROLOGIC ENGINEERING CENTER *
 *     VERSION DATE: 18SEP1990      *      *         609 SECOND STREET         *
 *     RUN  DATE   AND   TIME:      *      *      DAVIS, CALIFORNIA 95616      *
 *        19 SEP 90    08:33:29     *      *          (916) 756-1104           *
 *                                  *      *                                   *
 ************************************      *************************************


  INPUT FILE NAME: CFA.DAT
 OUTPUT FILE NAME: CFA.OUT
  DSSIN FILE NAME: CFA
 DSSOUT FILE NAME: CFA


 ** TITLE INFORMATION **
```

```
TI TEST NO. 2 INTERIOR PONDING EXAMPLE
TI INPUT IS STAGE- DURATION CURVE AND RESPONSE CURVES CONDITIONED ON
TI   PERCENT CHANCE EXCEEDANCE
TI IGNORE RESULTING FREQUENCY CURVE BELOW 565 FT.

** DURATION CURVE DATA **
DS     11 MISSISSIPPI RIVER STAGES AT MOLINE,ILL  APR-JUN
DT   .01     .12     .22     .50    1.10    2.20    4.30   10.50   23.00   61.00
DT 99.99
DP   572     570     569     568     567     566     565     564     563     562
DP   561

** FREQUENCY CURVE DATA **
FS     -1 FREQUENCY CURVE NOT REQUIRED, RESPONSE IS VERSUS EXCEEDANCE FREQUENCY

** RESPONSE FUNCTION CURVES **
RS      5 MAXIMUM POND ELEVATION (APR-JUN) VS FREQUENCY FOR GIVEN MISS. STAGE

CURVE  1
RD    10   562.000
RF    50      40      30      20      10       5       2       1      .5      .2
RP 565.0   565.1   565.2   565.5   566.0   566.5   567.0   567.3   567.5   567.8

CURVE  2
RD    10   564.000
RF    50      40      30      20      10       5       2       1      .5      .2
RP 566.0   566.1   566.3   566.6   566.8   567.1   567.4   567.7   567.9   568.1

CURVE  3
RD    10   566.000
RF    50      40      30      20      10       5       2       1      .5      .2
RP567.35   567.4  567.45   567.5   567.6   567.8   568.1   568.3   568.5   568.7

CURVE  4
RD    10   568.000
RF    50      40      30      20      10       5       2       1      .5      .2
RP 568.4  568.45   568.5   568.6   568.7   568.9   569.2   569.4   569.6   570.0

CURVE  5
RD    10   570.000
RF    50      40      30      20      10       5       2       1      .5      .2
RP568.85   568.9   569.0   569.2   569.4   569.7   570.1   570.3   570.6   570.9

** EVALUATION DATA **
   NEVAL  RPNAME   RPUNIT      PRMIN     PRMAX
VS     7  ELEVATON FEET          .00       .00
VR   565     566     567     568     569     570     571

** END OF INPUT DATA **


ED++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++


 -COMPUTED PERCENT CHANCE EXCEEDANCE VALUES-

    RESPONSE VALUES
   565.00   566.00   567.00   568.00   569.00   570.00   571.00

    FREQUENCY VALUES
    61.54    21.40     6.95     1.29      .12      .01      .00

 -INTERPOLATED FREQUENCY VALUES-
      FREQ     RESPONSE
```

```
            ELEVATON IN FEET
      .2        568.79
      .5        568.42
     1.0        568.12
     2.0        567.77
     5.0        567.23
    10.0        566.70
    20.0        566.06
    30.0        565.71
    40.0        565.46
    50.0        565.24
    60.0        565.03
    70.0        564.82 *
    80.0        564.57 *
    90.0        564.23 *
    95.0        563.95 *
    99.0        563.42 *

 * - INDICATES EXTRAPOLATED VALUE(S)

JOB COMPLETE
```

TEST NO. 3

Input for Test No. 3

```
TI TEST NO. 3  LAKE LEVEL EXAMPLE FROM HANDOUT-39
TI RESPONSE FUNCTIONS COMPUTED BY ADDING WIND SETUP TO DURATION CURVE VALUES
TI EVALUATION POINTS (VR RECORD) COMPUTED BY PROGRAM
DS    10 LAKE MICHIGAN-HURON DURATION CURVE
DT   99.     94.     85.     70.     50.     30.     15.      6.      1.     .08
DP -1.10     -.4     .38    1.17    1.94    2.67    3.33    3.93    4.65    5.20
FS     9 ANNUAL WIND SETUP AT GREEN BAY, WISCONSIN
FR   99.     95.     80.     50.     20.     10.      5.      2.      1.
FP  1.16    1.57    2.06    2.58    3.09    3.35    3.58    3.83    3.99
RS    -1 TOTAL LAKE LEVEL
VS   -10   STAGEFEET
ED
```

Output for Test No. 3

```
 ************************************      ************************************
 *               CFA                *      *                                  *
 *  COINCIDENT FREQUENCY ANALYSIS   *      *   U.S. ARMY CORPS OF ENGINEERS   *
 *     PROGRAM DATE:  DEC 1989      *      * THE HYDROLOGIC ENGINEERING CENTER *
 *     VERSION DATE: 18SEP1990      *      *         609 SECOND STREET        *
 *     RUN  DATE   AND   TIME:      *      *      DAVIS, CALIFORNIA 95616     *
 *        19 SEP 90    08:33:30     *      *          (916) 756-1104          *
 *                                  *      *                                  *
 ************************************      ************************************

  INPUT FILE NAME: CFA.DAT
 OUTPUT FILE NAME: CFA.OUT
  DSSIN FILE NAME: CFA
 DSSOUT FILE NAME: CFA

 ** TITLE INFORMATION **
 TI TEST NO. 3  LAKE LEVEL EXAMPLE FROM HANDOUT-39
 TI RESPONSE FUNCTIONS COMPUTED BY ADDING WIND SETUP TO DURATION CURVE VALUES
 TI EVALUATION POINTS (VR RECORD) COMPUTED BY PROGRAM

 ** DURATION CURVE DATA **
 DS    10 LAKE MICHIGAN-HURON DURATION CURVE
 DT   99.     94.     85.     70.     50.     30.     15.      6.      1.     .08
 DP -1.10     -.4     .38    1.17    1.94    2.67    3.33    3.93    4.65    5.20

 ** FREQUENCY CURVE DATA **
 FS     9 ANNUAL WIND SETUP AT GREEN BAY, WISCONSIN
 FR   99.     95.     80.     50.     20.     10.      5.      2.      1.
 FP  1.16    1.57    2.06    2.58    3.09    3.35    3.58    3.83    3.99

 ** RESPONSE FUNCTION CURVES **
 RS    -1 TOTAL LAKE LEVEL

          (Note: Response functions have been computed by the program.)

 CURVE  1
 RD     9    -1.100
 RF    1.160    1.570    2.060    2.580    3.090    3.350    3.580    3.830
       3.990
 RP     .060     .470     .960    1.480    1.990    2.250    2.480    2.730
```

```
        2.890

CURVE   2
RD      9     -.400
RF      1.160    1.570    2.060    2.580    3.090    3.350    3.580    3.830
        3.990
RP       .760    1.170    1.660    2.180    2.690    2.950    3.180    3.430
        3.590

CURVE   3
RD      9      .380
RF      1.160    1.570    2.060    2.580    3.090    3.350    3.580    3.830
        3.990
RP      1.540    1.950    2.440    2.960    3.470    3.730    3.960    4.210
        4.370

CURVE   4
RD      9     1.170
RF      1.160    1.570    2.060    2.580    3.090    3.350    3.580    3.830
        3.990
RP      2.330    2.740    3.230    3.750    4.260    4.520    4.750    5.000
        5.160

CURVE   5
RD      9     1.940
RF      1.160    1.570    2.060    2.580    3.090    3.350    3.580    3.830
        3.990
RP      3.100    3.510    4.000    4.520    5.030    5.290    5.520    5.770
        5.930

CURVE   6
RD      9     2.670
RF      1.160    1.570    2.060    2.580    3.090    3.350    3.580    3.830
        3.990
RP      3.830    4.240    4.730    5.250    5.760    6.020    6.250    6.500
        6.660

CURVE   7
RD      9     3.330
RF      1.160    1.570    2.060    2.580    3.090    3.350    3.580    3.830
        3.990
RP      4.490    4.900    5.390    5.910    6.420    6.680    6.910    7.160
        7.320

CURVE   8
RD      9     3.930
RF      1.160    1.570    2.060    2.580    3.090    3.350    3.580    3.830
        3.990
RP      5.090    5.500    5.990    6.510    7.020    7.280    7.510    7.760
        7.920

CURVE   9
RD      9     4.650
RF      1.160    1.570    2.060    2.580    3.090    3.350    3.580    3.830
        3.990
RP      5.810    6.220    6.710    7.230    7.740    8.000    8.230    8.480
        8.640

CURVE  10
RD      9     5.200
RF      1.160    1.570    2.060    2.580    3.090    3.350    3.580    3.830
        3.990
RP      6.360    6.770    7.260    7.780    8.290    8.550    8.780    9.030
        9.190
```

```
** EVALUATION DATA **
   NEVAL  RPNAME   RPUNIT      PRMIN     PRMAX
VS  -10     STAGE FEET           .00       .00

         (Note: Evaluation values have been computed by the program.)

VR     .000    1.000    2.000    3.000    4.000    5.000    6.000    7.000
      8.000    9.000   10.000

** END OF INPUT DATA **

ED++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

-COMPUTED PERCENT CHANCE EXCEEDANCE VALUES-

    RESPONSE VALUES
      .00     1.00     2.00     3.00     4.00     5.00     6.00     7.00
     8.00     9.00    10.00

    FREQUENCY VALUES
    99.98    99.17    94.28    82.40    62.50    37.37    15.60     3.84
      .44      .01      .00


-INTERPOLATED FREQUENCY VALUES-
      FREQ     RESPONSE
              STAGE IN FEET
        .2         8.27
        .5         7.95
       1.0         7.67
       2.0         7.35
       5.0         6.84
      10.0         6.37
      20.0         5.76
      30.0         5.30
      40.0         4.90
      50.0         4.50
      60.0         4.10
      70.0         3.66
      80.0         3.14
      90.0         2.44
      95.0         1.91
      99.0         1.07


JOB COMPLETE
```

TEST NO. 4

Input for Test No. 4

```
TI TEST NO. 4 LAKE LEVEL DATA WITH DSS READ AND WRITE
DS     0 LAKE MICHIGAN-HURON DURATION CURVE
ZR/CFA TEST NO. 4/LAKE LEVELS/FREQ-ELEV//1974/DURATION CURVE/
FS     0 ANNUAL WIND SETUP AT GREEN BAY, WISCONSIN
ZR F=FREQUENCY CURVE
RS    -1 TOTAL LAKE LEVEL
VS     0    ELEVFEET
ZW/CFA TEST NO. 4/LAKE LEVELS///1974/CFA OUTPUT/
ED
```

Output for Test No. 4

```
 ************************************      *************************************
 *              CFA                 *      *                                   *
 *  COINCIDENT FREQUENCY ANALYSIS   *      *   U.S. ARMY CORPS OF ENGINEERS    *
 *     PROGRAM DATE:  DEC 1989      *      * THE HYDROLOGIC ENGINEERING CENTER *
 *     VERSION DATE: 18SEP1990      *      *         609 SECOND STREET         *
 *     RUN  DATE   AND   TIME:      *      *      DAVIS, CALIFORNIA 95616      *
 *        19 SEP 90    08:33:31     *      *          (916) 756-1104           *
 *                                  *      *                                   *
 ************************************      *************************************

  INPUT FILE NAME: CFA.DAT
 OUTPUT FILE NAME: CFA.OUT
  DSSIN FILE NAME: CFA
 DSSOUT FILE NAME: CFA


 ** TITLE INFORMATION **
 TI TEST NO. 4 LAKE LEVEL DATA WITH DSS READ AND WRITE

 ** DURATION CURVE DATA **
 DS     0 LAKE MICHIGAN-HURON DURATION CURVE
 ZR/CFA TEST NO. 4/LAKE LEVELS/FREQ-ELEV//1974/DURATION CURVE/


 --ZREAD:  /CFA TEST NO. 4/LAKE LEVELS/FREQ-ELEV//1974/DURATION CURVE/


 DT     .250    1.250    6.000   15.000   30.000   50.000   70.000   85.000
      94.000   98.750   99.750
 DP  581.620  581.120  580.320  579.700  579.110  578.340  577.580  577.000
     576.450  575.720  575.430

 ** FREQUENCY CURVE DATA **
 FS     0 ANNUAL WIND SETUP AT GREEN BAY, WISCONSIN
 ZR F=FREQUENCY CURVE


 --ZREAD:  /CFA TEST NO. 4/LAKE LEVELS/FREQ-ELEV//1974/FREQUENCY CURVE/



 FR     .200     .500    1.000    2.000    5.000   10.000   20.000   50.000
```

```
     80.000   90.000   95.000   99.000
FP    4.560    4.190    3.920    3.650    3.290    3.010    2.730    2.280
      1.950    1.800    1.700    1.530

** RESPONSE FUNCTION CURVES **
RS    -1 TOTAL LAKE LEVEL

         (Note: Response functions have been computed by the program.)

CURVE  1
RD    12   581.620
RF    4.560    4.190    3.920    3.650    3.290    3.010    2.730    2.280
      1.950    1.800    1.700    1.530
RP  586.180  585.810  585.540  585.270  584.910  584.630  584.350  583.900
    583.570  583.420  583.320  583.150

CURVE  2
RD    12   581.120
RF    4.560    4.190    3.920    3.650    3.290    3.010    2.730    2.280
      1.950    1.800    1.700    1.530
RP  585.680  585.310  585.040  584.770  584.410  584.130  583.850  583.400
    583.070  582.920  582.820  582.650

CURVE  3
RD    12   580.320
RF    4.560    4.190    3.920    3.650    3.290    3.010    2.730    2.280
      1.950    1.800    1.700    1.530
RP  584.880  584.510  584.240  583.970  583.610  583.330  583.050  582.600
    582.270  582.120  582.020  581.850

CURVE  4
RD    12   579.700
RF    4.560    4.190    3.920    3.650    3.290    3.010    2.730    2.280
      1.950    1.800    1.700    1.530
RP  584.260  583.890  583.620  583.350  582.990  582.710  582.430  581.980
    581.650  581.500  581.400  581.230

CURVE  5
RD    12   579.110
RF    4.560    4.190    3.920    3.650    3.290    3.010    2.730    2.280
      1.950    1.800    1.700    1.530
RP  583.670  583.300  583.030  582.760  582.400  582.120  581.840  581.390
    581.060  580.910  580.810  580.640

CURVE  6
RD    12   578.340
RF    4.560    4.190    3.920    3.650    3.290    3.010    2.730    2.280
      1.950    1.800    1.700    1.530
RP  582.900  582.530  582.260  581.990  581.630  581.350  581.070  580.620
    580.290  580.140  580.040  579.870

CURVE  7
RD    12   577.580
RF    4.560    4.190    3.920    3.650    3.290    3.010    2.730    2.280
      1.950    1.800    1.700    1.530
RP  582.140  581.770  581.500  581.230  580.870  580.590  580.310  579.860
    579.530  579.380  579.280  579.110

CURVE  8
RD    12   577.000
RF    4.560    4.190    3.920    3.650    3.290    3.010    2.730    2.280
      1.950    1.800    1.700    1.530
RP  581.560  581.190  580.920  580.650  580.290  580.010  579.730  579.280
    578.950  578.800  578.700  578.530
```

```
CURVE  9
RD    12   576.450
RF    4.560    4.190    3.920    3.650    3.290    3.010    2.730    2.280
      1.950    1.800    1.700    1.530
RP  581.010  580.640  580.370  580.100  579.740  579.460  579.180  578.730
    578.400  578.250  578.150  577.980

CURVE 10
RD    12   575.720
RF    4.560    4.190    3.920    3.650    3.290    3.010    2.730    2.280
      1.950    1.800    1.700    1.530
RP  580.280  579.910  579.640  579.370  579.010  578.730  578.450  578.000
    577.670  577.520  577.420  577.250

CURVE 11
RD    12   575.430
RF    4.560    4.190    3.920    3.650    3.290    3.010    2.730    2.280
      1.950    1.800    1.700    1.530
RP  579.990  579.620  579.350  579.080  578.720  578.440  578.160  577.710
    577.380  577.230  577.130  576.960

** EVALUATION DATA **
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VS    0      ELEV FEET           .00       .00

         (Note: Evaluation values have been computed by the program.)

VR  576.500  577.000  577.500  578.000  578.500  579.000  579.500  580.000
    580.500  581.000  581.500  582.000  582.500  583.000  583.500  584.000
    584.500  585.000  585.500  586.000  586.500


** WRITE DSS PATHNAME/PARTS **
ZW/CFA TEST NO. 4/LAKE LEVELS///1974/CFA OUTPUT/


** END OF INPUT DATA **



ED++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++



-COMPUTED PERCENT CHANCE EXCEEDANCE VALUES-

    RESPONSE VALUES
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   580.50   581.00   581.50   582.00   582.50   583.00   583.50   584.00
   584.50   585.00   585.50   586.00   586.50

    FREQUENCY VALUES
   100.00    99.99    99.60    98.23    95.34    89.40    79.71    68.00
    54.98    42.54    29.56    18.22    10.00     5.05     2.17      .77
      .23      .06      .02      .00      .00


-INTERPOLATED FREQUENCY VALUES-
      FREQ     RESPONSE
               ELEV IN FEET
        .2       584.56
        .5       584.18
       1.0       583.88
```

```
      2.0        583.54
      5.0        583.01
     10.0        582.50
     20.0        581.91
     30.0        581.48
     40.0        581.10
     50.0        580.70
     60.0        580.31
     70.0        579.92
     80.0        579.49
     90.0        578.96
     95.0        578.54
     99.0        577.77

--ZWRITE: /CFA TEST NO. 4/LAKE LEVELS/FREQ-ELEV//1974/CFA OUTPUT/



JOB COMPLETE


   -----DSS---ZCLOSE Unit:  71,   File: CFA.DSS
              Pointer Utilization:   .25
              Number of Records:      3
              File Size:      6.7  Kbytes
              Percent Inactive:    .0


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 NORMAL STOP IN CFA
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APPENDIX D

EXAMPLE APPLICATIONS

APPENDIX D
EXAMPLE APPLICATIONS

Example 1: Application of Equation 1.
Expected Debris Yield From a Small Watershed For a Specified Precipitation Event.

Problem: Determine the expected unit debris yield and volume of debris to Bailey Canyon Debris Basin in the San Gabriel Mountains (see Figure D-1) resulting from a flood equivalent to that experienced during the storm period of February 5-22, 1979. The predicted debris yield results will be compared to that actually measured at this site for the same flood event.

Step 1/. Determine the maximum 1-hour precipitation (P) applicable to the flood event and multiply by 100.

> Analysis of Los Angeles County Department of Public Works records indicated a maximum 1-hour precipitation for this site of 0.50 inches, as measured at gauge #63. The maximum 1-hour precipitation multiplied by 100 is 50.

Step 2/. Draw the drainage boundary and determine the area of the watershed (A) in mi^2 and ac.

> Using a standard 1:24,000 USGS topographic map and a planimeter, the area of the watershed was determined to be 0.6 mi^2, or 384 ac.

Step 3/. Determine the relief ratio (RR) of the watershed.

> Locate the highest point in the watershed at the end of the longest watercourse (4005 ft), and the lowest point (1170 ft) at the existing debris basin site; determine the difference between these two in feet. Next, determine the length of the longest watercourse, in miles (1.59 mi). Express the difference between the high and low elevations (in ft) and the length of the longest watercourse (in mi) as a ratio. In this example:
>
> 4005 - 1170 = 2835 ft, divided by 1.59 mi = 1783 ft/mi

Step 4/. Determine the Fire Factor (FF) for the subject watershed.

> Using Figure 2 from the main text because the drainage area is less than 3 mi^2, and knowing that the watershed suffered a 100% extent burn less than 1 year earlier (in October 1978), we see that the Fire Factor for a drainage area of 0.60 mi^2 less than one year after a 100% burn is 6.50. (Remember, we are determining debris yield for the flood of February 5-22, 1979.)

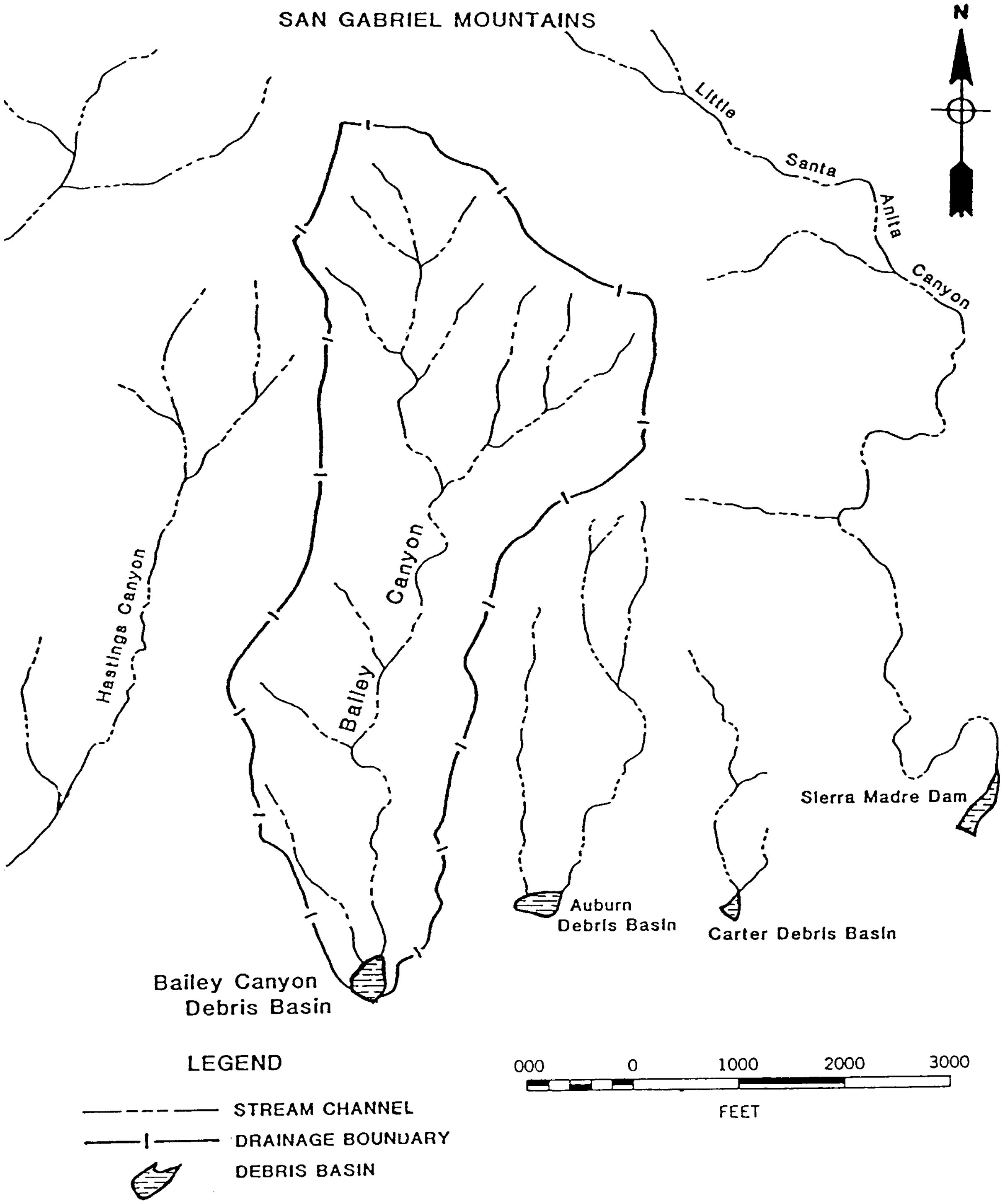

Figure D-1: Example Application 1
Bailey Canyon Debris Basin, Sierra Madre, Ca.
Drainage Area = 384 acres

Step 5/. Determine the Adjustment-Transposition Factor (A-T).

Since the watershed is located within the area in which the regression analysis data was obtained, the A-T Factor is assumed to be 1.00.

Step 6/. Calculate the Log (Base 10) of the factors P, RR, and A. FF and A-T are dimensionless and are used as is.

From STEP 1, Log (P)	= Log (50)	= 1.70
From STEP 2, Log (A)	= Log (384)	= 2.58
From STEP 3, Log (RR)	= Log (1783)	= 3.25
From STEP 4, FF		= 6.50
From STEP 5, A-T		= 1.00

Step 7/. Since the drainage area is less than 3.0 mi^2, the use of Equation 1 is appropriate. Solve for unit debris yield using the above values:

$$\text{Log Dy} = 0.65 (\text{Log P}) + 0.18 (\text{Log A}) + 0.62 (\text{Log RR}) + 0.12 (\text{FF})$$
$$\text{Log Dy} = 0.65 (1.70) + 0.18 (2.58) + 0.62 (3.25) + 0.12 (6.50)$$
$$\text{Log Dy} = 1.104 + 0.465 + 2.016 + 0.780$$
$$\text{Log Dy} = \underline{4.365}$$

Step 8/. Calculate the antilog of Dy

AntiLog Dy = $\underline{23{,}186\ yd^3/mi^2}$

Step 9/. Multiply the resulting Dy by the A-T Factor to get the adjusted unit debris yield for the basin.

Adjusted Dy = 1.0 (23,186) = $\underline{23{,}186\ yd^3/mi^2}$

Step 10/. Multiply the adjusted unit debris yield by the drainage area to determine the volume of debris.

23,186 yd^3/mi^2 x 0.60 mi^2 = total debris yield of $\underline{13{,}911\ yd^3}$

Actual debris inflow to Bailey Canyon debris basin during this period was $\underline{13{,}974\ yd^3}$, while predicted debris yield was $\underline{13{,}911\ yd^3}$.

Example 2: Application of Equation 3.
Expected Debris Yield from an Intermediate-sized Watershed for a Specified Flood Event.

Problem: Determine the expected unit debris yield and volume of debris to Santa Anita Dam in the San Gabriel Mountains (see Figure D-2) resulting from a flood equivalent to that experienced during the period of January 18-26, 1969, and compare to observed debris yield.

Step 1/. Determine the maximum unit peak flow (Q) from the watershed for the storm period in question in $ft^3/s/mi^2$.

Records obtained from the Los Angeles County Department of Public works indicate that the peak flow during this period was 5500 ft^3/s on January 25, 1969. Expressing this as unit peak inflow results in a value of 509 $ft^3/s/mi^2$.

Step 2/. Draw the drainage boundary and determine the area (A) of the watershed in both mi^2 and ac.

Using a standard 1:24,000 USGS topographic map and a planimeter, the area of the watershed was determined to be 10.8 mi^2, or 6912 ac.

Step 3/. Determine the relief ratio (RR) of the watershed.

Locate the highest point in the watershed at the end of the longest watercourse (5595 ft), and the lowest point (1463 ft) at the existing debris basin site; determine the difference between these two in feet. Next, determine the length of the longest watercourse, in miles (4.74 mi). Express the difference between the high and low elevations (in ft) and the length of the longest watercourse (in mi) as a ratio. In this example:

5595 - 1463 = 4132 ft, divided by 4.74 mi = 871 ft/mi

Step 4/. Determine the Fire Factor (FF) for the subject watershed.

Because the drainage area is greater than 3 mi^2, use Figure 3 from the main text. This watershed suffered a 100% extent wildfire approximately 15 years prior to the event in question. Since no wildfires of greater than 5% extent have impacted the watershed during the intervening time period, the Fire Factor was determined to be 3.00 for a drainage area of 10.8 mi^2.

Step 5/. Determine the Adjustment-Transposition Factor (A-T).

Since this watershed is located within the area in which the regression analysis data was obtained, the A-T Factor is assumed to be 1.00.

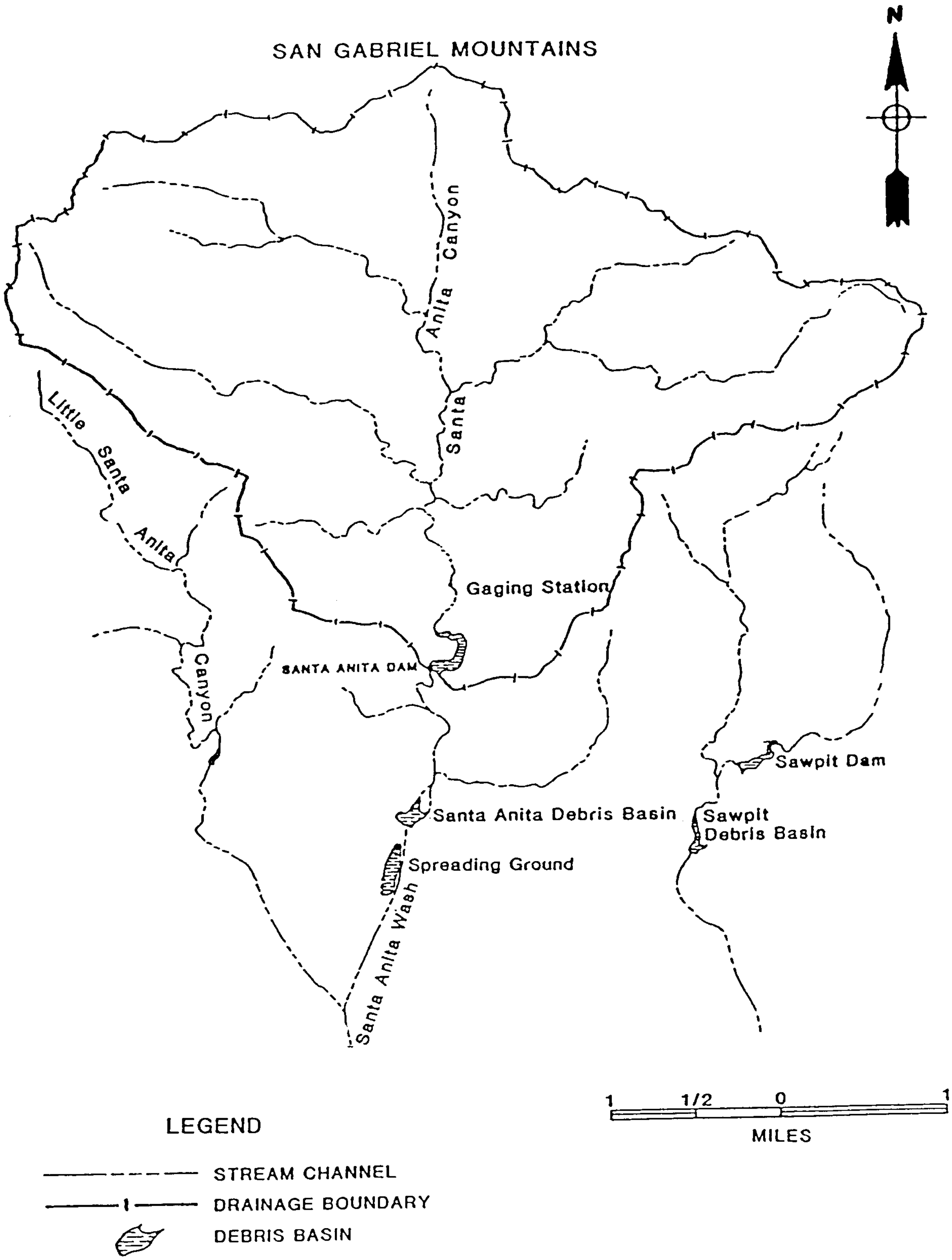

Figure D-2: Example Application 2
Santa Anita Dam, Sierra Madre, Ca.
Drainage Area = 10.8 mi^2

Step 6/. Calculate the Log (Base 10) of the factors Q, RR, and A. FF and A-T are dimensionless and are used as is.

From STEP 1, Log (Q)	= Log (509)	= <u>2.71</u>
From STEP 2, Log (A)	= Log (6912)	= <u>3.84</u>
From STEP 3, Log (RR)	= Log (871)	= <u>2.94</u>
From STEP 4, FF		= <u>3.00</u>
From STEP 5, A-T		= <u>1.00</u>

Step 7/. Since peak flow data is available for this watershed pertaining to the event in question, and the drainage area of the watershed is between 10 and 25 mi^2, the use of Equation 3 is appropriate. Solve for unit debris yield using the above values.

$$\text{Log Dy} = 0.88\,(\text{Log Q}) + 0.06\,(\text{Log A}) + 0.48\,(\text{Log RR}) + 0.20\,(\text{FF})$$
$$\text{Log Dy} = 0.88\,(2.71) + 0.06\,(3.84) + 0.48\,(2.94) + 0.20\,(3.00)$$
$$\text{Log Dy} = 2.382 + 0.230 + 1.411 + 0.600$$
$$\text{Log Dy} = \underline{4.624}$$

Step 8/. Calculate the antilog of Dy

$$\text{AntiLog Dy} = \underline{42{,}043\ yd^3/mi^2}$$

Step 9/. Multiply the resulting Dy by the A-T Factor to get the adjusted unit debris yield for the basin.

$$\text{Adjusted Dy} = 1.0\,(42{,}043) = \underline{42{,}043\ yd^3/mi^2}$$

Step 10/. Multiply the adjusted unit debris yield by the drainage area to determine the volume of debris.

$$42{,}043\ yd^3/mi^2 \times 10.8\ mi^2 = \text{total debris volume of } \underline{454{,}061\ yd^3}$$

Actual debris yield to this structure was determined by the Los Angeles County Department of Public Works to be approximately <u>440,000 yd^3</u>. Actual debris volumes are well within one standard deviation of the estimate, reflecting the adequacy of the calculated factors, the peak flow estimates and the estimated Fire and A-T Factors.

Example 3: Application of Equation 4 and Coincident Frequency Analysis.
Expected Debris Yield from a Larger Watershed with an A-T Factor Other than 1.0.

Problem: Determine the expected unit debris yield frequency relationship for Santa Paula Creek watershed. This example differs from the previous two in that Santa Paula Creek (see Figure D-3) requires an A-T Factor other than 1.0, and due to a lack of any complete debris yield data, requires a somewhat more complicated procedure for determining the A-T Factor. A coincident frequency analysis approach is considered necessary to evaluate the expected unit debris yield from the watershed for different wildfire and flood conditions.

Part 3a: Application of A-T Factor Technique 3 to Santa Paula Creek Watershed.

This part of Example 3 problem utilizes Technique 3 for determining the A-T Factor (see Appendix B, How To Determine The Adjustment-Transposition Factor). The unadjusted equation (A-T Factor = 1.0) is not directly applicable to the Santa Paula Creek watershed due to differences in vegetation cover, channel morphology, and differences in the potential mobility of debris in storage within the watershed itself.

Four watersheds in close proximity to Santa Paula Creek possess long-term sediment yield records, as well as being quite similar to Santa Paula Creek watershed in vegetation, topography, climate, and geomorphology. One of these watersheds, Matilija Creek, has been studied in some detail by Corps of Engineers personnel during a recent analysis of wildfire impacts following the Wheeler Fire of August 1985.

A simple linear regression of average annual sediment yield to average annual precipitation ratios (AASY/AAP; see Appendix B for derivation) was performed on the data from the four nearby watersheds and compared to the original regression line (Figure B-1, Appendix B). The comparison is shown on Figure D-4 (same as Figure B-2). Dividing the AASY/AAP ratio from the local area curve for 42.9 mi^2 by the AASY/AAP ratio from the original regression curve for 42.9 mi^2 gives an A-T Factor of 0.60.

Part 3b: Application of A-T Factor Technique 4 to Santa Paula Creek Watershed.

As stated in Part 3A, the unadjusted equation (A-T Factor = 1.0) is not directly applicable to the Santa Paula Creek watershed due to differences in vegetation cover, channel morphology, and differences in the potential mobility of debris in storage within the watershed itself. This part of Example 3 problem utilizes Technique 4 for determining the A-T Factor (see Appendix B, How To Determine The Adjustment/ Transposition Factor).

A field analysis of the watershed revealed a number of differences between the watersheds used in the regression analysis and the study watershed. A discussion of these follows:

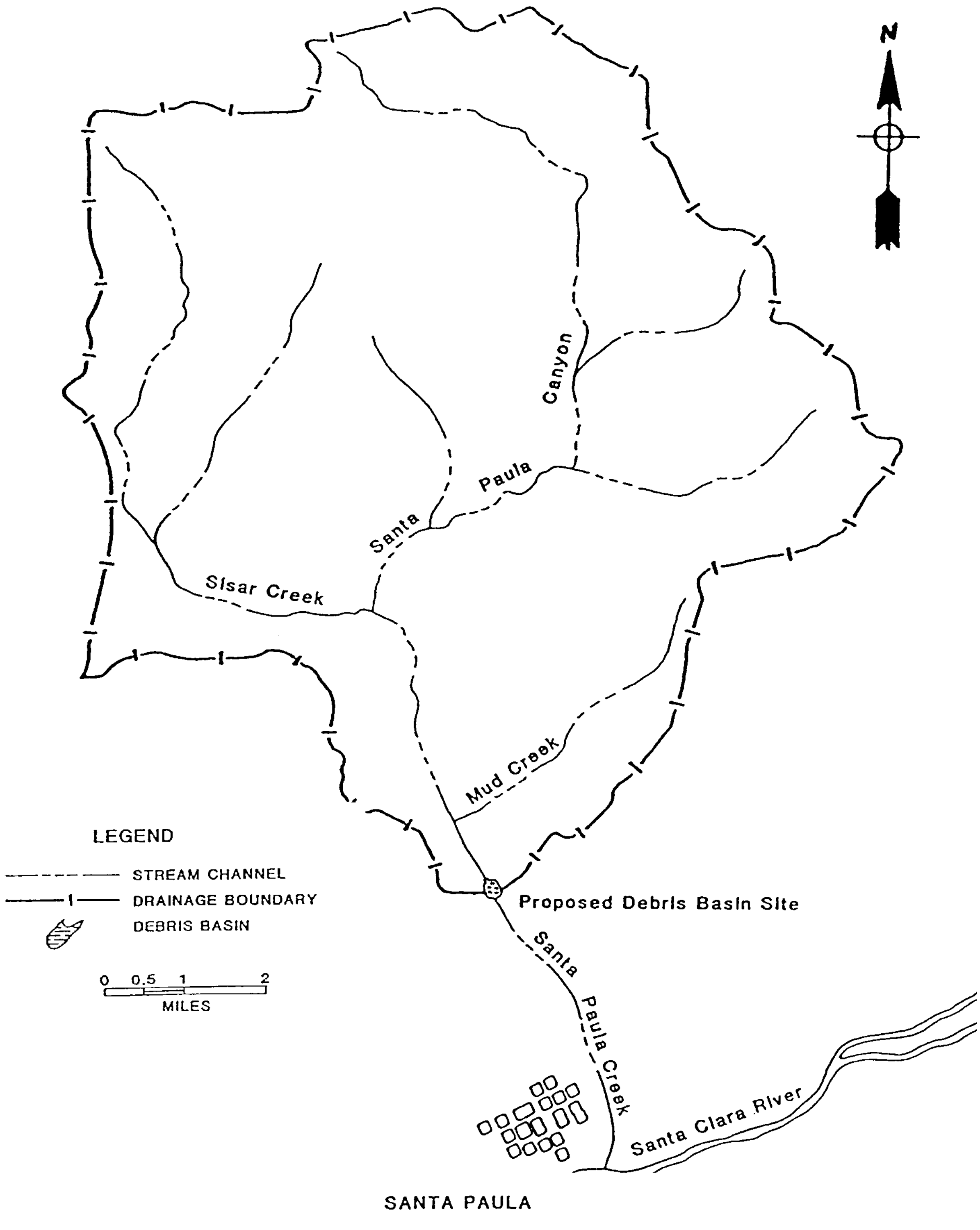

Figure D-3: Example Application 3
Santa Paula Creek, Santa Paula, Ca.
Drainage Area = 42.9 mi^2

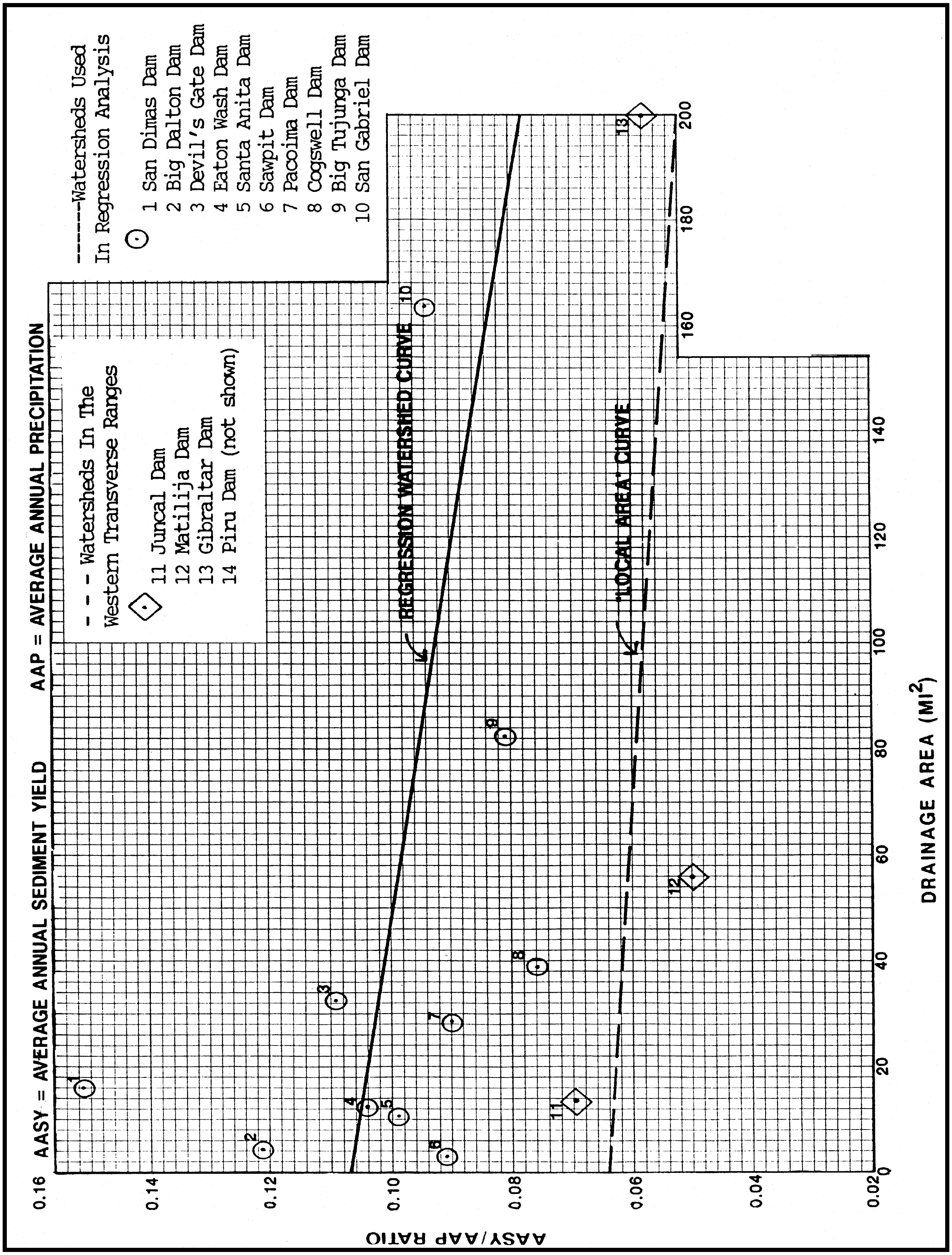

Figure D-4: AASY/AAp Ratios For Drainage Areas 0.0 to 200 mi²
With Local Area Curve

1/. The parent material of Santa Paula Creek watershed is somewhat different from the materials of the San Gabriel Range. It appears that there is, in general, less severe folding, fracturing, and faulting of the parent material in the study watershed than is evident in the regression watersheds. This is not to say that the rocks of Santa Paula are not highly modified and contorted by tectonic forces that have acted on this area, but that parent materials in the San Gabriel Range appear, in many cases, to be almost completely pulverized and much more susceptible to erosive processes than those of the Santa Paula Creek Watershed.

From Table D-1 (same as Table B-1), we determined the Parent Material factor (Subfactor Group 1) to be approximately 0.15.

2/. Although the type and structure of soils in the Santa Paula watershed appear to be quite similar to those of the regression watersheds, the Santa Paula Creek soils are better protected against raindrop impact and rill formation due to a large proportion of grasses covering the soil surface in the study watershed. Under normal vegetation cover, the study watershed will yield less debris per unit area to the processes of sheetflow and rill formation than an equivalent watershed in the San Gabriel range (regression watersheds). This results in lesser amounts of debris being delivered to debris storage sites during minor to moderate storm events, and hence, lesser amounts of debris available for movement during major storm events. Under conditions in which the vegetative cover is burned, the study watershed will respond in a manner similar to that of the regression watersheds, although at a lesser rate because of the lower availability of debris in storage, greater stability in the channel system, and better cementation in the soil profile.

From Table D-1, we determined the Soils factor (Subfactor Group 2) to be approximately 0.15.

3/. The proportion of channel banks actively experiencing erosion is minimal within the upper reaches of Santa Paula Creek and its tributaries. This is in direct contrast to watersheds used in the regression analysis. Although it was estimated that over 50% of the lower channel reaches appear to be eroding, less than 10% of the more numerous upper reaches show any signs of active or recent erosion. This is in contrast to channel systems typical of the regression analysis watersheds in which over 80% of the entire channel system displays signs of active or recent erosion.

From Table D-1, we determined the Channel Morphology factor (Subfactor Group 3) to be approximately 0.15.

4/. The proportion of upland areas in the study watershed that are presently experiencing erosion due to mass movement (i.e., slumping, rockfall, soil slippage, etc.), rilling, or gullying is minimal when compared to regression watersheds. Although the Mud Creek watershed appears to be much worse, the overall debris contribution of these areas is considerably less than is evident in watersheds which were included in the regression analysis. Although mass movement and sheetflow erosion has undoubtedly contributed large amounts of debris to the channel system during times past, at present this source cannot be considered to play a primary role in the supply of debris to the channel system.

TABLE D-1: ADJUSTMENT-TRANSPOSITION FACTOR TABLE

	A-T Subfactor				
	0.25	0.20	0.15	0.10	0.05
Parent Material			Subfactor Group 1		
Folding	Severe		Moderate		Minor
Faulting	Severe		Moderate		Minor
Fracturing	Severe		Moderate		Minor
Weathering	Severe		Moderate		Minor
Soils			Subfactor Group 2		
Soils	Non-cohesive		Partly Cohesive		Highly Cohesive
Soil Profile	Minimal Soil Profile		Some Soil Profile		Well-developed Soil Profile
Soil Cover	Much Bare Soil in Evidence		Some Bare Soil in Evidence		Little Bare Soil in Evidence
Clay Colloids	Few Clay Colloids		Some Clay Colloids		Many Clay Colloids
Channel Morphology			Subfactor Group 3		
Bedrock Exposures	Few Segments in Bedrock		Some Segments in Bedrock		Many Segments in Bedrock
Bank Erosion	>30% of Banks Eroding		10-30% of Banks Eroding		<10% of Banks Eroding
Bed and Bank Materials	Non-cohesive Bed and Banks		Partly Cohesive Bed and Banks		Mildly Cohesive Bed and Banks
Vegetation	Poorly Vegetated		Some Vegetation		Much Vegetation
Headcutting	Many Headcuts		Few Headcuts		No Headcutting
Hillslope Morphology			Subfactor Group 4		
Rills and Gullies	Many and Active		Some Signs		Few Signs
Mass Movement	Many Scars Evident		Few Signs Evident		No Signs Evident
Debris Deposits	Many Eroding Deposits		Some Eroding Deposits		Few Eroding Deposits
The A-T Factor Is the Sum of the A-T Subfactors from All 4 Subfactor Groups.					

From Table D-1, we determined that the Hillslope Morphology factor (Subfactor Group 4) is approximately 0.15.

Adding these factors together, use of Technique 4 from Appendix B would indicate an A-T Factor of 0.60. This value agrees with the A-T Factor derived using Technique 3 in Part 3A of this example.

Part 3c: Determination of Frequency Debris Yield For Santa Paula Creek Watershed Using Coincident Frequency Analysis.

For the purpose of evaluating the potential debris yield of the Santa Paula Creek watershed, Equation 4 was selected on the basis of drainage area and the availability of flow frequency data. In order to evaluate the total probabilities of independent fire/flood events in the Santa Paula watershed, a coincident frequency analysis was performed (HEC computer program, Coincident Frequency Analysis - CFA).

Four types of data are used as input for the CFA program; Years-Since-100% Wildfire frequency, discharge frequency, and debris response relationships, along with evaluation data (see Chapter 6 for a more detailed explanation of the input data and Appendix C for a discussion on how to use the CFA program).

The frequency of wildfires was quantified through the use of the Fire Factor curves presented in Figure 3 in the main text (for 42.9 mi^2) and placed in a Fire Factor frequency chart as described in Appendix A (How To Determine Fire Factors). The Years-Since-100% Wildfire frequency relationship is presented in Table D-2.

The unit discharge frequency data was determined using the discharge frequency curve shown on Figure D-5. This data is shown in Table D-3.

Adjusted debris response relationships were then calculated using Equation 4 and A-T Factor of 0.60 for intervals of 1-15 years since 100% wildfire. These relationships are listed in Table D-4.

A range of debris yield values (30) from 100 to 190,000 yd^3/mi^2 was input to be used as evaluation data and to define the debris frequency relationship. The CFA input file is shown in Table D-5.

The final results consist of a table relating the debris yield of Santa Paula Creek watershed to the total exceedance frequencies of wildfire and flooding for 0.2, 0.5, 1.0, 2.0, 5.0, 10.0, 20.0, 30.0, 40.0, 50.0, 60.0, 70.0, 80.0, 90.0, 95.0, and 99.0 per cent. The output is presented in Table D-6.

The results indicate that for a total fire/flood frequency of 1.00 (an event which has a 1% chance of being equaled or exceeded in any given year), the debris yield at the proposed debris basin site would be about 35,600 yds^3/mi^2 (from Table D-6) or a total of approximately 1,525,000 yds^3(35,600 yds^3/mi^2 x 42.9mi^2.

TABLE D-2: YEARS-SINCE-100% WILDFIRE FREQUENCY RELATIONSHIP

Frequency*	Years-Since-100% Wildfire (B_i)
0	0
0.1	1
0.3	2
0.7	3
1.4	4
2.2	5
3.2	6
4.6	7
7.2	8
12.0	9
13.1	10
16.7	11
24.1	12
34.5	13
49.0	14
100	15

The frequency for which Years-Since-100% Wildfire is equaled or exceeded. Cumulative. This is not P[B_i]; P[B_i is the incremental difference for each Year-Since-100% Wildfire.

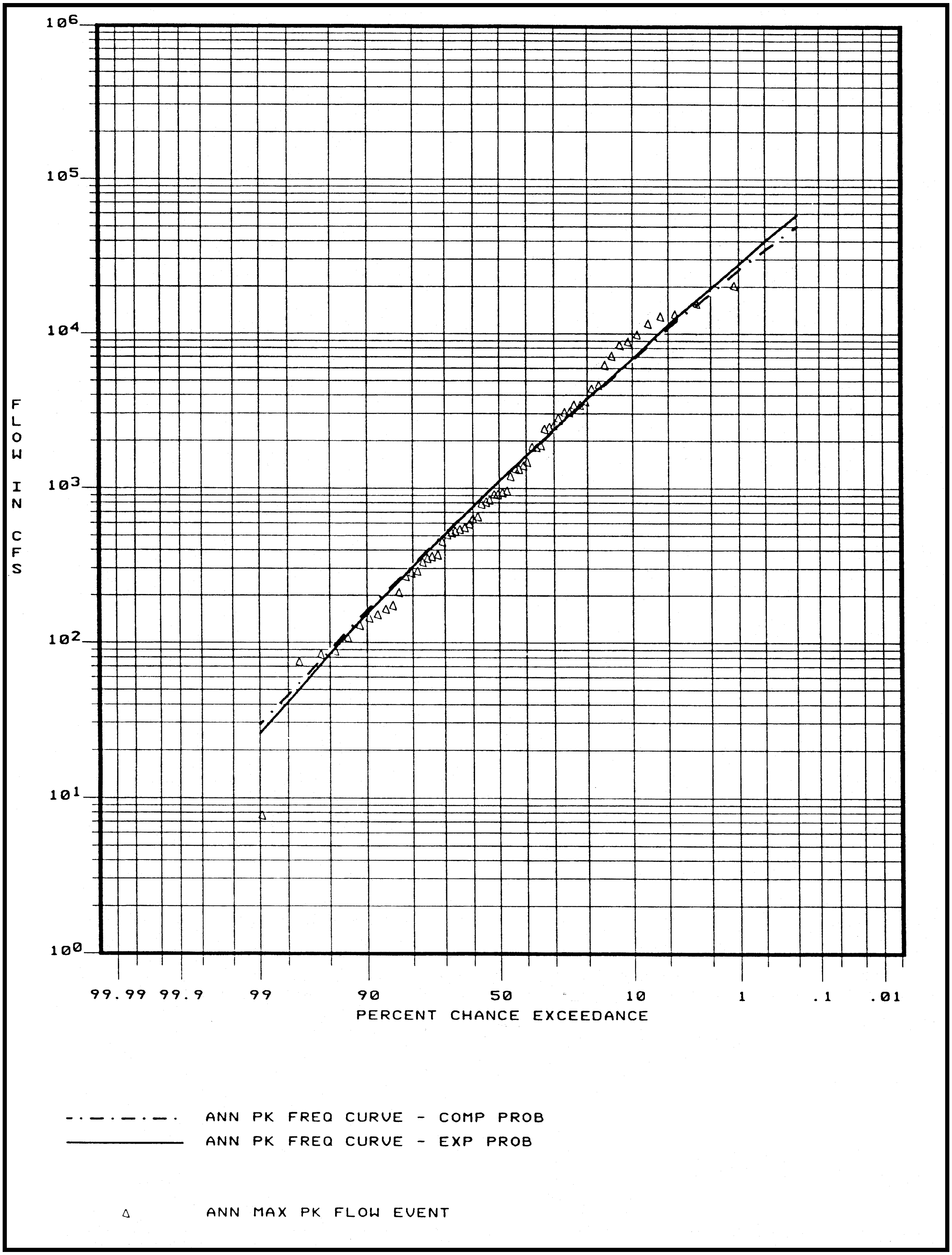

Figure D-5: Santa Paula Creek
Discharge-Frequency Curve

TABLE D-3: UNIT DISCHARGE FREQUENCY RELATIONSHIP

Frequency* ($P[F_i]$**)	Discharge (ft^3s/mi^2) (F_i)
0.2	1489
0.5	1000
1	719
2	499
5	288
10	176
20	96
30	61
40	40
50	29
60	19
70	13
80	8.0
90	3.9
95	2.2

* The frequency for which unit discharge is equaled or exceeded. Cumulative.
** Probability is frequency divided by 100.

TABLE D-4: ADJUSTED DEBRIS YIELDS

As Calculated For Santa Paula Creek Watershed
Drainage Area = 42.9 mi²

ADJUSTMENT-TRANSPOSITION FACTOR (A-T) = 0.60

Years-Since-100% Wildfire	Frequency of Exceedance (Per 100 Years)								
	0.2	0.5	1.0	2.0	5.0	10.0	20.0	50.0	95.0
	Debris Yield (yd³/mi²)								
1	185,452	125,559	93,548	66,363	39,586	24,917	14,094	4,575	405
2	161,708	111,227	81,571	57,866	34,517	21,727	12,290	3,989	353
3	141,004	96,986	71,127	50,457	30,098	18,945	10,716	3,478	308
4	125,381	86,240	63,246	44,867	26,763	16,846	9,529	3,093	274
5	115,486	79,435	58,255	41,326	24,651	15,516	8,777	2,849	252
6	106,790	73,453	53,869	38,214	22,795	14,348	8,116	2,634	233
7	99,915	68,724	50,401	35,754	21,327	13,424	7,594	2,465	218
8	93,117	64,049	46,972	33,322	19,876	12,511	7,077	2,297	203
9	87,807	60,396	44,293	31,421	18,743	11,798	6,673	2,166	192
10	83,413	57,373	42,076	29,849	17,805	11,207	6,339	2,058	182
11	79,622	54,766	40,164	28,492	16,996	10,698	6,051	1,964	174
12	73,915	50,841	37,285	26,450	15,778	9,931	5,618	1,823	161
13	68,349	47,012	34,477	24,458	14,589	9,183	5,195	1,686	149
14	63,202	43,472	31,881	22,616	13,491	8,492	4,803	1,559	138
15	57,310	39,419	28,909	20,508	12,233	7,700	4,356	1,414	125

TABLE D-5: INPUT FILE FOR TEST NO. 1
Using Santa Paula Creek Watershed Data

```
TI   LOS ANGELES DISTRICT DEBRIS METHOD ........................ FILE = TEST.DAT
TI   COINCIDENT FREQUENCY ANALYSIS ............................ TEST FILE NO. 1
TI   USING SANTA PAULA DEBRIS BASIN DATA ...................... D.A. = 42.9 SQ MI
TI   DS, DT & DP IS YEARS-SINCE-WILDFIRE FREQUENCY RELATIONSHIP
TI   FS, FR & FP IS DISCHARGE FREQUENCY RELATIONSHIP
TI   RD, RF & RP IS DEBRIS RESPONSE RELATIONSHIP ...................... JAN 1992
J1      1
DS     15    YEARS SINCE FIRE
DT    0.1      0.3      0.7      1.4      2.2      3.2      4.6      7.2     12.0     13.1
DT   16.7     24.1     34.5     49.0      100
DP      1        2        3        4        5        6        7        8        9       10
DP     11       12       13       14       15
FS     15    PEAK FLOW CFS PER SQ MILE SANTA PAULA WATERSHED 42.9 SQ MILES
FR    0.2      0.5        1        2        5       10       20       30       40       50
FR     60       70       80       90       95
FP   1489     1000      719      499      288      176       96       61       40       29
FP     19       13      8.0      3.9      2.2
RS     15    DEBRIS YIELD RATE IN YD3 PER SQ MILE
RD      9        1
RF   1489     1000      719      499      288      176       96       29      2.2
RP185452   127559    93548    66363    39586    24917    14094     4575      405
RD      9        2
RF   1489     1000      719      499      288      176       96       29      2.2
RP161708   111227    81571    57866    34517    21727    12290     3989      353
RD      9        3
RF   1489     1000      719      499      288      176       96       29      2.2
RP141004    96986    71127    50547    30098    18945    10716     3478      308
RD      9        4
RF   1489     1000      719      499      288      176       96       29      2.2
RP125381    86240    63246    44867    26763    16846     9529     3093      274
RD      9        5
RF   1489     1000      719      499      288      176       96       29      2.2
RP115486    79435    58255    41326    24651    15516     8777     2849      252
RD      9        6
RF   1489     1000      719      499      288      176       96       29      2.2
RP106790    73453    53869    38214    22795    14348     8116     2634      233
RD      9        7
RF   1489     1000      719      499      288      176       96       29      2.2
RP 99915    68724    50401    35754    21327    13424     7594     2465      218
RD      9        8
RF   1489     1000      719      499      288      176       96       29      2.2
RP 93117    64049    46972    33322    19876    12511     7077     2297      203
RD      9        9
RF   1489     1000      719      499      288      176       96       29      2.2
RP 87807    60396    44293    31421    18743    11798     6673     2166      192
RD      9       10
RF   1489     1000      719      499      288      176       96       29      2.2
```

```
RP 83413    57373    42076    29849    17805    11207     6339     2058      182
RD     9       11
RF  1489     1000      719      499      288      176       96       29      2.2
RP 79622    54766    40164    28492    16996    10698     6051     1964      174
RD     9       12
RF  1489     1000      719      499      288      176       96       29      2.2
RP 73915    50841    37285    26450    15778     9931     5618     1823      161
RD     9       13
RF  1489     1000      719      499      288      176       96       29      2.2
RP 68349    47012    34477    24458    14589     9183     5195     1686      149
RD     9       14
RF  1489     1000      719      499      288      176       96       29      2.2
RP 63202    43472    31881    22616    13491     8492     4803     1559      138
RD     9       15
RF  1489     1000      719      499      288      176       96       29      2.2
RP 57310    39419    28909    20508    12233     7700     4356     1414      125
VS    30    YIELD YD3/MI²
VR190000   150000   125000   100000    90000    80000    70000    60000    50000    40000
VR 30000    20000    10000     9000     7500     6500     5000     3500     2500     1500
VR  1000      900      800      700      600      500      400      300      200      100
ED
```

TABLE D-6: OUTPUT FILE FOR TEST NO. 1

Using Santa Paula Creek Watershed Data

```
************************************      **************************************
*              CFA                 *      *                                    *
*  COINCIDENT FREQUENCY ANALYSIS   *      *   U.S. ARMY CORPS OF ENGINEERS     *
*     PROGRAM DATE:  DEC 1989      *      * THE HYDROLOGIC ENGINEERING CENTER *
*     VERSION DATE: 18SEP1990      *      *         609 SECOND STREET          *
*     RUN  DATE   AND   TIME:      *      *      DAVIS, CALIFORNIA 95616       *
*        06 JAN 92    08:14:05     *      *           (916) 756-1104           *
*                                  *      *                                    *
************************************      **************************************



 INPUT FILE NAME: TEST.DAT
OUTPUT FILE NAME: TEST.OUT



** TITLE INFORMATION **
TI  LOS ANGELES DISTRICT DEBRIS METHOD ......................... FILE = TEST.DAT
TI  COINCIDENT FREQUENCY ANALYSIS .............................. TEST FILE NO. 1
TI  USING SANTA PAULA DEBRIS BASIN DATA ...................... D.A. = 42.9 SQ MI
TI  DS, DT & DP IS YEARS-SINCE-WILDFIRE FREQUENCY RELATIONSHIP
TI  FS, FR & FP IS DISCHARGE FREQUENCY RELATIONSHIP
TI  RD, RF & RP IS DEBRIS RESPONSE RELATIONSHIP

** JOB SPECIFICATIONS **
   LOGTF    NDEC    NSIG   JTRAC
J1     1

** DURATION CURVE DATA **
DS    15   YEARS SINCE FIRE
DT   0.1     0.3     0.7     1.4     2.2     3.2     4.6     7.2    12.0    13.1
DT  16.7    24.1    34.5    49.0     100
DP     1       2       3       4       5       6       7       8       9      10
DP    11      12      13      14      15

** FREQUENCY CURVE DATA **
FS    15   PEAK FLOW CFS PER SQ MILE SANTA PAULA WATERSHED 42.9 SQ MILES
FR   0.2     0.5       1       2       5      10      20      30      40      50
FR    60      70      80      90      95
FP  1489    1000     719     499     288     176      96      61      40      29
FP    19      13     8.0     3.9     2.2

** RESPONSE FUNCTION CURVES **
RS    15   DEBRIS YIELD RATE IN YD3 PER SQ MILE

CURVE  1
RD     9     1.000
RF  1489    1000     719     499     288     176      96      29     2.2
RP185452  127559   93548   66363   39586   24917   14094    4575     405

CURVE  2
RD     9     2.000
RF  1489    1000     719     499     288     176      96      29     2.2
```

```
RP161708  111227   81571   57866   34517   21727   12290    3989      353

CURVE  3
RD     9    3.000
RF  1489    1000     719     499     288     176      96      29      2.2
RP141004   96986   71127   50547   30098   18945   10716    3478      308

CURVE  4
RD     9    4.000
RF  1489    1000     719     499     288     176      96      29      2.2
RP125381   86240   63246   44867   26763   16846    9529    3093      274

CURVE  5
RD     9    5.000
RF  1489    1000     719     499     288     176      96      29      2.2
RP115486   79435   58255   41326   24651   15516    8777    2849      252

CURVE  6
RD     9    6.000
RF  1489    1000     719     499     288     176      96      29      2.2
RP106790   73453   53869   38214   22795   14348    8116    2634      233

CURVE  7
RD     9    7.000
RF  1489    1000     719     499     288     176      96      29      2.2
RP 99915   68724   50401   35754   21327   13424    7594    2465      218

CURVE  8
RD     9    8.000
RF  1489    1000     719     499     288     176      96      29      2.2
RP 93117   64049   46972   33322   19876   12511    7077    2297      203

CURVE  9
RD     9    9.000
RF  1489    1000     719     499     288     176      96      29      2.2
RP 87807   60396   44293   31421   18743   11798    6673    2166      192

CURVE 10
RD     9   10.000
RF  1489    1000     719     499     288     176      96      29      2.2
RP 83413   57373   42076   29849   17805   11207    6339    2058      182

CURVE 11
RD     9   11.000
RF  1489    1000     719     499     288     176      96      29      2.2
RP 79622   54766   40164   28492   16996   10698    6051    1964      174

CURVE 12
RD     9   12.000
RF  1489    1000     719     499     288     176      96      29      2.2
RP 73915   50841   37285   26450   15778    9931    5618    1823      161

CURVE 13
RD     9   13.000
RF  1489    1000     719     499     288     176      96      29      2.2
RP 68349   47012   34477   24458   14589    9183    5195    1686      149

CURVE 14
RD     9   14.000
RF  1489    1000     719     499     288     176      96      29      2.2
RP 63202   43472   31881   22616   13491    8492    4803    1559      138

CURVE 15
RD     9   15.000
```

```
RF  1489    1000     719     499     288     176      96      29     2.2
RP 57310   39419   28909   20508   12233    7700    4356    1414     125

** EVALUATION DATA **
   NEVAL  RPNAME   RPUNIT      PRMIN     PRMAX
VS   30     YIELD YD3/MI²       .00       .00
VR190000  150000  125000  100000   90000   80000   70000   60000   50000   40000
VR 30000   20000   10000    9000    7500    6500    5000    3500    2500    1500
VR  1000     900     800     700     600     500     400     300     200     100

** END OF INPUT DATA **
ED++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++


-COMPUTED PERCENT CHANCE EXCEEDANCE VALUES-

    RESPONSE VALUES
   100.00   200.00   300.00   400.00   500.00   600.00   700.00   800.00
   900.00  1000.00  1500.00  2500.00  3500.00  5000.00  6500.00  7500.00
  9000.00 10000.00 20000.00 30000.00 40000.00 50000.00 60000.00 70000.00
 80000.00 90000.00100000.00125000.00150000.00190000.00

    FREQUENCY VALUES
    95.64    94.15    92.29    90.05    87.48    84.55    81.26    77.63
    73.73    69.61    54.01    38.07    29.28    20.89    15.61    13.16
    10.42     9.03     3.04     1.42      .78      .47      .31      .21
      .14      .10      .07      .03      .01      .00

-INTERPOLATED FREQUENCY VALUES-
      FREQ     RESPONSE
              YIELD IN YD3/MI²
        .2     70929.00
        .5     48892.00
       1.0     35559.00
       2.0     25123.00
       5.0     15134.00
      10.0      9271.00
      20.0      5208.90
      30.0      3400.60
      40.0      2347.10
      50.0      1689.10
      60.0      1281.60
      70.0       989.30
      80.0       735.69
      90.0       402.28
      95.0       145.82
      99.0      -328.63 *

 * - INDICATES EXTRAPOLATED VALUE(S)

JOB COMPLETE
```

APPENDIX E

DATA USED IN DEVELOPMENT OF

DEBRIS METHOD EQUATIONS

DATA USED IN DEVELOPMENT OF DEBRIS METHOD EQUATIONS

The final Fire Factor curves presented in this study (see Figures 2 and 3 in the main text) were developed by plotting the residuals yielded by the SPSS package (differences between the actual unit debris yields and that predicted by the regression equations) on a graph of Years-Since-100% Wildfire versus Fire Factor (Figure 2) or Years-Since-100% Wildfire versus drainage area (Figure 3) using log-log paper and graphically fitting a curve to the plotted data. A list of Fire Factors, flood dates, and watersheds for the selected locations is presented in Table E-1.

Table E-2 presents the debris basin data used in development of Equation 1. Tables E-3a through E-3k contain the survey date, percent of watershed burned, and the residual (from SPSS) listed by time since burn for the debris basins in Table E-2.

Tables E-4a through E-4g list the parameter values used in the development of Equations 2-5.

TABLE E-1: WATERSHEDS SUFFERING 100% WILDFIRE USED IN DEVELOPMENT OF FIRE FACTOR CURVES

Watershed		Drainage Area (mi^2)	Flood Date	Fire Factor
1	Big Dalton Dam	4.5	Nov 1960	6.00
2	Santa Anita Dam	10.8	Jan 1954	6.00
3	Santa Anita Dam	10.8	Jul 1954	5.80
4	Santa Anita Dam	10.8	Nov 1954	5.64
5	Santa Anita Dam	10.8	Jan 1956	4.98
6	Santa Anita Dam	10.8	Feb 1957	4.70
7	Santa Anita Dam	10.8	Apr 1958	4.49
8	Santa Anita Dam	10.8	Jan 1959	4.32
9	Santa Anita Dam	10.8	Feb 1962	3.79
10	Santa Anita Dam	10.8	Feb 1963	3.61
11	Santa Anita Dam	10.8	Apr 1965	3.18
12	Santa Anita Dam	10.8	Nov 1967	3.00
13	San Dimas Dam	16.2	Nov 1960	6.00
14	San Dimas Dam	16.2	Nov 1961	5.64
15	San Dimas Dam	16.2	Sep 1962	5.33
16	San Dimas Dam	16.2	Feb 1963	5.03
17	San Dimas Dam	16.2	Apr 1965	4.57
18	San Dimas Dam	16.2	Nov 1965	4.53
19	San Dimas Dam	16.2	Aug 1966	4.38
20	San Dimas Dam	16.2	Dec 1966	4.34
21	San Dimas Dam	16.2	Jan 1969	3.91
22	San Dimas Dam	16.2	Mar 1970	3.77
23	San Dimas Dam	16.2	Nov 1970	3.68
24	San Dimas Dam	16.2	Dec 1971	3.54
25	San Dimas Dam	16.2	Feb 1973	3.14
26	San Dimas Dam	16.2	Jan 1974	3.00

TABLE E-2: DEBRIS BASIN DATA USED IN DEVELOPMENT OF EQUATION 1

Debris Basin	Flood Date	Debris Yield	Precip	Relief Ratio	Drainage Area	Fire Factor
Aliso	Dec 1970	3.49	1.75	2.72	3.25	6.50
Aliso	Mar 1978	3.99	1.78	2.72	3.25	3.12
Aliso	Feb 1983	4.00	2.00	2.72	3.25	3.12
Auburn	Jan 1956	3.77	1.90	3.44	2.01	3.91
Auburn	Feb 1962	4.91	1.90	3.44	2.01	5.45
Auburn	Dec 1965	4.23	1.79	3.44	2.01	4.05
Auburn	Jan 1969	4.55	2.20	3.44	2.01	3.43
Auburn	Feb 1978	3.71	2.04	3.44	2.01	3.00
Auburn	Jan 1979	4.10	1.48	3.44	2.01	6.50
Auburn	Jan 1979	4.31	1.60	3.44	2.01	6.50
Auburn	Feb 1979	4.43	1.70	3.44	2.01	6.50
Auburn	Mar 1979	4.17	1.60	3.44	2.01	6.50
Auburn	Feb 1980	4.91	2.23	3.44	2.01	6.15
Auburn	Mar 1983	4.15	2.08	3.44	2.01	4.34
Bailey	Jan 1954	4.57	1.47	3.25	2.58	5.10
Bailey	Feb 1956	3.69	1.26	3.25	2.58	4.38
Bailey	Mar 1962	4.23	1.90	3.25	2.58	4.05
Bailey	Jan 1969	4.66	2.20	3.25	2.58	3.19
Bailey	Mar 1978	4.03	2.04	3.25	2.58	3.00
Bailey	Jan 1979	3.58	1.48	3.25	2.58	6.50
Bailey	Jan 1979	3.91	1.60	3.25	2.58	6.50
Bailey	Feb 1979	4.37	1.70	3.25	2.58	6.50
Bailey	Mar 1979	3.66	1.48	3.25	2.58	6.50
Bailey	Mar 1979	3.71	1.60	3.25	2.58	6.50

TABLE E-2: DEBRIS BASIN DATA USED IN DEVELOPMENT OF EQUATION 1

Debris Basin	Flood Date	Debris Yield	Precip	Relief Ratio	Drainage Area	Fire Factor
Bailey	Feb 1980	5.11	2.23	3.25	2.58	6.15
Bailey	Sep 1983	4.04	2.08	3.25	2.58	4.19
Beatty	Feb 1980	4.45	1.30	3.06	2.24	3.00
Big Briar	Feb 1980	3.86	2.11	3.43	1.11	3.00
Big Briar	Feb 1983	4.10	2.18	3.43	1.11	3.00
Big Dalton	Nov 1965	3.96	1.89	2.80	3.22	4.10
Big Dalton	Jan 1969	4.94	1.99	2.80	3.22	3.43
Big Dalton	Feb 1983	3.37	1.90	2.80	3.22	3.00
Blanchard	Jan 1969	4.29	1.93	3.10	2.51	3.00
Blanchard	Mar 1976	3.81	1.34	3.10	2.51	6.15
Blanchard	Feb 1978	4.55	2.25	3.10	2.51	5.17
Bluegum	Jan 1969	3.75	1.93	3.09	2.08	3.13
Bluegum	Feb 1969	4.08	1.90	3.09	2.08	3.13
Bluegum	Feb 1976	4.41	2.34	3.09	2.08	6.50
Bluegum	Feb 1978	4.76	2.25	3.09	2.08	5.30
Bluegum	Mar 1978	4.63	2.00	3.09	2.08	5.28
Brace	Mar 1983	4.08	2.04	3.16	2.27	5.35
Bradbury	Jan 1956	3.98	1.95	3.11	2.64	3.80
Bradbury	Dec 1965	4.01	1.85	3.11	2.64	3.72
Bradbury	Jan 1969	4.76	2.16	3.11	2.64	3.00
Bradbury	Feb 1969	4.66	1.98	3.11	2.64	3.00
Bradbury	Mar 1978	4.08	2.04	3.11	2.64	3.00
Bradbury	Feb 1980	4.40	2.18	3.11	2.64	3.00
Bradbury	Feb 1983	4.17	2.00	3.11	2.64	5.43

TABLE E-2: DEBRIS BASIN DATA
USED IN DEVELOPMENT OF EQUATION 1

Debris Basin	Flood Date	Debris Yield	Precip	Relief Ratio	Drainage Area	Fire Factor
Brand	Dec 1965	4.24	1.72	3.17	2.82	5.92
Brand	Jan 1966	3.34	1.89	3.17	2.82	4.40
Brand	Jan 1969	4.42	1.91	3.17	2.82	4.25
Brand	Feb 1969	4.09	1.61	3.17	2.82	4.22
Brand	Mar 1978	4.71	1.85	3.17	2.82	3.00
Brand	Feb 1980	4.34	2.04	3.17	2.82	3.00
Brand	Mar 1983	4.03	2.00	3.17	2.82	3.12
Carriage House	Feb 1979	4.43	1.78	3.36	1.28	6.50
Carriage House	Feb 1980	4.95	2.23	3.36	1.28	6.15
Carter	Jan 1956	4.06	1.90	3.41	1.89	3.00
Carter	Dec 1961	4.48	1.66	3.41	1.89	6.15
Carter	Feb 1962	4.80	1.90	3.41	1.89	6.15
Carter	Jan 1969	4.24	2.20	3.41	1.89	3.59
Carter	Feb 1969	3.66	1.84	3.41	1.89	3.27
Carter	Mar 1978	3.54	2.04	3.41	1.89	3.00
Carter	Feb 1979	4.26	1.70	3.41	1.89	6.50
Carter	Mar 1979	3.34	1.48	3.41	1.89	6.50
Carter	Mar 1979	3.73	1.60	3.41	1.89	6.50
Carter	Feb 1980	4.86	2.23	3.41	1.89	6.15
Carter	Mar 1983	3.75	2.08	3.41	1.89	4.34
Cassara	Feb 1978	4.69	2.08	2.93	2.13	4.27
Cassara	Feb 1983	4.14	2.00	2.93	2.13	3.34
Chamberlain	Mar 1975	3.89	1.79	3.04	1.41	3.00
Childs	Sep 1965	4.42	1.90	3.22	2.30	6.05

TABLE E-2: DEBRIS BASIN DATA USED IN DEVELOPMENT OF EQUATION 1

Debris Basin	Flood Date	Debris Yield	Precip	Relief Ratio	Drainage Area	Fire Factor
Childs	Jan 1969	4.08	1.91	3.22	2.30	4.25
Childs	Feb 1969	3.76	1.61	3.22	2.30	4.22
Childs	Mar 1978	4.14	1.85	3.22	2.30	3.06
Childs	Feb 1980	3.89	2.04	3.22	2.30	3.00
Childs	Feb 1981	4.51	1.78	3.22	2.30	5.80
Childs	Feb 1983	3.86	2.08	3.22	2.30	4.99
Cloud Creek	Mar 1976	4.52	2.34	3.44	1.11	6.50
Cloud Creek	May 1977	3.16	1.70	3.44	1.11	5.82
Cloud Creek	Feb 1978	4.67	2.26	3.44	1.11	5.49
Cloud Creek	Mar 1978	4.65	2.00	3.44	1.11	5.41
Cloud Creek	Feb 1980	4.03	2.11	3.44	1.11	4.39
Cloud Creek	Feb 1983	4.35	2.18	3.44	1.11	3.64
Cloudcraft	Dec 1973	3.94	1.81	3.21	2.13	6.50
Cloudcraft	Mar 1978	3.49	1.90	3.21	2.13	4.34
Cloudcraft	Feb 1980	4.04	2.08	3.21	2.13	3.86
Cooks	Jan 1954	3.59	1.78	3.10	2.57	3.00
Cooks	Nov 1965	4.04	2.07	3.10	2.57	3.15
Cooks	Jan 1969	4.17	2.01	3.10	2.57	3.00
Cooks	Feb 1978	4.64	2.26	3.10	2.57	5.49
Cooks	Feb 1980	4.44	2.11	3.10	2.57	4.42
Cooks	Feb 1983	4.43	2.18	3.10	2.57	3.66
Deer	Dec 1965	4.35	1.72	3.11	2.58	5.57
Deer	Jan 1969	4.71	1.91	3.11	2.58	4.10
Deer	Feb 1969	4.37	1.61	3.11	2.58	4.07

TABLE E-2: DEBRIS BASIN DATA USED IN DEVELOPMENT OF EQUATION 1

Debris Basin	Flood Date	Debris Yield	Precip	Relief Ratio	Drainage Area	Fire Factor
Deer	Mar 1978	4.58	1.85	3.11	2.58	3.00
Deer	Feb 1980	4.05	3.04	3.11	2.58	3.00
Dunsmuir	Mar 1938	4.97	2.11	3.17	2.73	4.30
Dunsmuir	Feb 1978	4.72	2.26	3.17	2.73	5.49
Dunsmuir	Mar 1978	4.67	2.00	3.17	2.73	5.41
Elmwood	Jun 1965	4.59	1.90	3.27	2.30	6.27
Elmwood	Jan 1969	3.92	1.91	3.27	2.30	4.23
Elmwood	Mar 1978	4.07	1.85	3.27	2.30	3.00
Elmwood	Feb 1980	4.23	2.04	3.27	2.30	3.00
Elmwood	Jan 1981	4.58	1.78	3.27	2.30	6.50
Emerald East	Jan 1969	3.70	1.73	2.49	2.01	3.47
Emerald East	Feb 1969	3.71	1.62	2.49	2.01	3.45
Emerald East	Mar 1978	3.88	2.26	2.49	2.01	3.00
Emerald East	Feb 1980	3.65	1.95	2.49	2.01	3.00
Englewild	Jan 1969	5.05	2.11	3.14	2.41	6.50
Englewild	Feb 1969	4.58	1.93	3.14	2.41	6.48
Englewild	Mar 1978	3.45	1.78	3.14	2.41	3.24
Englewild	Feb 1980	4.49	2.18	3.14	2.41	3.00
Fairoaks	Nov 1965	4.20	1.92	2.50	2.13	3.00
Fairoaks	Jan 1969	4.63	2.04	2.50	2.13	3.00
Fairoaks	Feb 1980	3.19	1.48	2.50	2.13	3.00
Fairoaks	Feb 1983	3.51	2.00	2.50	2.13	3.00
Fern	Jan 1954	3.19	1.68	3.13	2.30	3.00
Fern	Jan 1956	3.12	1.85	3.13	2.30	3.00

TABLE E-2: DEBRIS BASIN DATA USED IN DEVELOPMENT OF EQUATION 1

Debris Basin	Flood Date	Debris Yield	Precip	Relief Ratio	Drainage Area	Fire Factor
Fern	Jul 1963	4.35	1.95	3.13	2.30	4.40
Fern	Nov 1965	4.55	1.92	3.13	2.30	3.80
Fern	Feb 1969	4.69	1.00	3.13	2.30	3.36
Fern	Mar 1978	4.16	2.08	3.13	2.30	3.00
Fern	Feb 1980	3.85	1.48	3.13	2.30	3.00
Fern	Feb 1983	3.93	2.00	3.13	2.30	3.00
Fieldbrook	Mar 1978	3.15	1.78	3.03	2.35	3.62
Fieldbrook	Sep 1983	3.11	1.80	3.03	2.35	3.00
Golf Course	Dec 1974	3.44	1.79	2.78	2.31	3.00
Golf Course	May 1977	3.41	1.60	2.78	2.31	3.00
Gordon	Feb 1980	3.55	2.18	3.06	2.06	3.00
Gordon	Feb 1983	2.19	1.90	3.06	2.06	3.00
Gould	Nov 1965	4.45	1.83	2.88	2.48	3.46
Gould	Feb 1969	4.37	1.84	2.88	2.48	3.14
Gould	Feb 1980	4.26	2.11	2.88	2.48	3.00
Gould	Feb 1983	4.02	2.18	2.88	2.48	3.00
Haines	Feb 1969	4.31	1.93	3.04	2.99	3.00
Halls	Mar 1938	5.12	2.05	3.07	2.70	4.04
Halls	Jan 1954	3.59	1.78	3.07	2.70	3.00
Halls	Jan 1956	3.67	1.85	3.07	2.70	3.00
Halls	Nov 1965	3.81	1.83	3.07	2.70	3.19
Halls	Feb 1969	4.81	1.84	3.07	2.70	3.05
Halls	May 1977	4.11	1.70	3.07	2.70	3.00
Halls	Feb 1978	4.57	2.23	3.07	2.70	3.00

TABLE E-2: DEBRIS BASIN DATA USED IN DEVELOPMENT OF EQUATION 1

Debris Basin	Flood Date	Debris Yield	Precip	Relief Ratio	Drainage Area	Fire Factor
Halls	Feb 1980	4.42	2.11	3.07	2.70	3.00
Halls	Feb 1983	4.44	2.18	3.07	2.70	3.00
Harrow	Jan 1969	5.09	2.16	3.24	2.44	6.50
Harrow	Feb 1969	4.40	1.76	3.24	2.44	6.48
Harrow	Mar 1978	3.71	1.78	3.24	2.44	3.20
Harrow	Mar 1983	3.88	2.18	3.24	2.44	3.00
Hay	Mar 1938	4.96	2.05	3.27	2.11	4.32
Hay	Jun 1963	3.88	1.89	3.27	2.11	4.84
Hay	Nov 1965	4.04	1.83	3.27	2.11	4.01
Hay	Jan 1969	4.38	1.97	3.27	2.11	3.35
Hay	Feb 1969	3.64	1.76	3.27	2.11	3.00
Hay	Mar 1978	4.34	2.23	3.27	2.11	3.00
Hay	Feb 1980	3.89	2.11	3.27	2.11	3.00
Hay	Feb 1983	3.83	2.18	3.27	2.11	3.00
Hillcrest	Nov 1965	3.80	1.72	3.24	2.35	5.92
Hillcrest	Jan 1969	4.36	1.91	3.24	2.35	4.25
Hillcrest	Feb 1980	3.58	2.04	3.24	2.35	3.00
Hillcrest	Feb 1983	2.78	2.00	3.24	2.35	3.00
Hook East	Jan 1969	5.15	2.16	3.32	2.06	6.50
Hook East	Feb 1969	4.92	1.76	3.32	2.06	6.48
Hook East	Mar 1978	4.08	1.78	3.32	2.06	3.23
Hook East	Feb 1980	4.12	2.18	3.32	2.06	3.00
Hook West	Feb 1980	4.33	2.18	3.23	2.04	3.00
Jasmine	Mar 1980	4.02	1.48	2.82	1.81	3.00

TABLE E-2: DEBRIS BASIN DATA USED IN DEVELOPMENT OF EQUATION 1

Debris Basin	Flood Date	Debris Yield	Precip	Relief Ratio	Drainage Area	Fire Factor
Jasmine	Mar 1983	4.03	1.70	2.82	1.81	3.22
Kinneloa East	Dec 1965	4.05	2.04	3.37	2.11	3.00
Kinneloa West	Jan 1969	4.83	2.09	3.37	2.11	6.50
Kinneloa West	Feb 1978	3.82	1.78	3.37	2.11	3.25
Kinneloa West	Jan 1969	4.94	2.09	3.40	2.11	6.50
Kinneloa West	Feb 1969	4.48	1.90	3.40	2.11	6.50
Kinneloa West	Feb 1976	4.52	1.74	3.40	2.11	3.62
Kinneloa West	Feb 1978	3.85	1.78	3.40	2.11	3.25
Kinneloa West	Mar 1978	4.07	2.00	3.40	2.11	3.24
Kinneloa West	Feb 1980	4.23	2.23	3.40	2.11	3.00
Kinneloa West	Feb 1983	4.36	2.08	3.40	2.11	3.00
Lannan	Jan 1956	3.76	1.90	3.33	2.20	5.49
Lannan	Jan 1969	4.13	2.04	3.33	2.20	3.00
Lannan	Feb 1980	4.56	2.23	3.33	2.20	3.33
Lannan	Feb 1983	3.61	2.08	3.33	2.20	3.15
Las Flores	Feb 1962	4.74	1.90	3.24	2.46	5.59
Las Flores	Dec 1965	4.39	1.92	3.24	2.46	4.48
Las Flores	Jan 1969	4.55	2.04	3.24	2.46	3.68
Las Flores	Feb 1980	4.48	1.48	3.24	2.46	3.00
Las Flores	Feb 1983	4.23	2.00	3.24	2.46	3.00
La Tuna	Jan 1956	3.50	1.70	2.66	3.53	3.00
La Tuna	Nov 1965	3.70	1.70	2.66	3.53	3.15
La Tuna	Jan 1969	3.86	1.70	2.66	3.53	3.00
La Tuna	Feb 1983	4.08	2.04	2.66	3.53	4.42

TABLE E-2: DEBRIS BASIN DATA USED IN DEVELOPMENT OF EQUATION 1

Debris Basin	Flood Date	Debris Yield	Precip	Relief Ratio	Drainage Area	Fire Factor
Laurel Ridge	Dec 1978	4.29	2.00	3.02	1.28	3.47
Limekiln	Nov 1965	4.06	2.24	2.66	3.37	3.73
Limekiln	Jan 1969	3.61	1.72	2.66	3.37	3.31
Limekiln	Feb 1969	3.76	1.71	2.66	3.37	3.30
Limekiln	Dec 1970	3.52	1.75	2.66	3.37	5.98
Limekiln	Mar 1983	3.81	2.00	2.66	3.37	3.79
Lincoln	Nov 1965	4.09	1.92	2.88	2.43	3.00
Lincoln	Jan 1969	4.56	2.04	2.88	2.43	3.53
Lincoln	Feb 1978	3.48	1.78	2.88	2.43	3.00
Lincoln	Mar 1978	3.90	2.32	2.88	2.43	3.00
Lincoln	Feb 1980	3.75	1.48	2.88	2.43	3.00
Lincoln	Feb 1983	3.37	2.00	2.88	2.43	3.00
Linda Vista	Jun 1977	2.50	1.60	2.93	2.37	3.00
Linda Vista	Feb 1978	3.65	1.85	2.93	2.37	3.00
Little Dalton	Mar 1962	4.75	1.81	2.76	3.33	5.60
Little Dalton	Nov 1965	4.16	1.89	2.76	3.33	3.98
Little Dalton	Jan 1969	4.88	1.97	2.76	3.33	3.28
Little Dalton	Feb 1978	3.58	1.85	2.76	3.33	3.00
Little Dalton	Feb 1983	3.36	1.90	2.76	3.33	3.00
Maddock	Feb 1969	4.50	2.16	3.28	2.24	3.00
Maddock	Feb 1969	4.10	1.98	3.28	2.24	3.00
Maddock	Mar 1978	3.23	2.04	3.28	2.24	3.00
Maddock	Feb 1980	4.34	2.18	3.28	2.24	3.00
Maddock	Feb 1983	3.03	2.00	3.28	2.24	5.49

TABLE E-2: DEBRIS BASIN DATA USED IN DEVELOPMENT OF EQUATION 1

Debris Basin	Flood Date	Debris Yield	Precip	Relief Ratio	Drainage Area	Fire Factor
May #1	Nov 1965	4.03	2.03	3.20	2.66	3.00
May #1	Nov 1966	3.88	2.19	3.20	2.66	6.50
May #1	Dec 1966	4.88	1.78	3.20	2.66	6.50
May #1	Feb 1969	3.88	1.66	3.20	2.66	5.41
May #1	Feb 1976	4.46	1.60	3.20	2.66	3.29
May #1	Feb 1978	3.82	1.53	3.20	2.66	3.00
May #1	Mar 1978	3.58	1.70	3.20	2.66	3.00
May #1	Feb 1980	3.51	2.00	3.20	2.66	3.00
May #1	Mar 1983	4.19	2.11	3.20	2.66	3.00
May #2	Nov 1965	3.97	2.03	3.04	1.76	3.00
May #2	Jan 1969	4.50	1.79	3.04	1.76	5.55
May #2	Feb 1976	4.58	1.60	3.04	1.76	3.29
May #2	Feb 1980	3.79	2.00	3.04	1.76	3.00
May #2	Feb 1983	4.32	2.11	3.04	1.76	3.00
Morgan	Jan 1969	4.21	1.97	3.16	2.58	3.43
Morgan	Feb 1969	3.73	1.99	3.16	2.58	3.40
Morgan	Mar 1978	3.85	2.00	3.16	2.58	3.00
Morgan	Feb 1983	3.40	1.90	3.16	2.58	6.00
Mull	Feb 1980	3.85	2.18	3.10	1.98	3.00
Mullally	May 1977	3.36	1.70	3.17	2.34	4.22
Mullally	Feb 1978	4.46	2.23	3.17	2.34	4.00
Mullally	Feb 1980	3.97	2.11	3.17	2.34	3.57
Mullally	Feb 1983	4.37	2.18	3.17	2.34	3.27
Pickens	Mar 1938	4.91	2.05	3.01	2.99	4.26

TABLE E-2: DEBRIS BASIN DATA
USED IN DEVELOPMENT OF EQUATION 1

Debris Basin	Flood Date	Debris Yield	Precip	Relief Ratio	Drainage Area	Fire Factor
Pickens	Jan 1954	3.46	1.73	3.01	2.99	3.00
Pickens	Jan 1956	3.48	1.85	3.01	2.99	3.00
Pickens	Nov 1965	4.47	1.83	3.01	2.99	3.88
Pickens	Jan 1969	4.37	2.01	3.01	2.99	3.34
Pinelawn	Dec 1974	3.89	1.78	3.37	1.11	3.00
Pinelawn	Feb 1976	4.73	2.34	3.37	1.11	6.50
Pinelawn	May 1977	4.78	1.70	3.37	1.11	6.05
Pinelawn	Feb 1978	4.56	2.23	3.37	1.11	5.49
Pinelawn	Feb 1980	4.67	2.11	3.37	1.11	4.42
Pinelawn	Mar 1983	4.38	2.18	3.37	1.11	3.65
Rubio	Nov 1965	3.95	1.92	3.17	2.91	3.20
Rubio	Jan 1969	4.58	2.04	3.17	2.91	3.00
Rubio	Feb 1969	3.77	1.46	3.17	2.91	3.00
Rubio	Mar 1978	3.73	2.08	3.17	2.91	3.00
Rubio	Feb 1980	4.72	1.48	3.17	2.91	6.50
Rubio	Feb 1983	4.09	2.00	3.17	2.91	4.74
Ruby	Nov 1965	3.98	1.81	2.94	2.25	3.00
Ruby	Jan 1969	4.33	1.41	2.94	2.25	3.00
Ruby	Feb 1980	4.07	2.18	2.94	2.25	3.00
Santa Anita	Jan 1965	4.23	1.54	3.00	3.04	3.00
Santa Anita	Jan 1969	4.86	2.04	3.00	3.04	3.00
Santa Anita	Feb 1980	4.09	2.23	3.00	3.04	3.00
Santa Anita	Feb 1983	4.29	3.08	3.00	3.04	3.00
Sawpit	Jan 1956	3.54	1.95	3.08	3.25	4.38

TABLE E-2: DEBRIS BASIN DATA USED IN DEVELOPMENT OF EQUATION 1

Debris Basin	Flood Date	Debris Yield	Precip	Relief Ratio	Drainage Area	Fire Factor
Sawpit	Nov 1965	4.11	1.81	3.08	3.25	3.28
Sawpit	Jan 1969	4.85	2.16	3.08	3.25	3.00
Sawpit	Feb 1983	4.08	2.00	3.08	3.25	3.85
Schoolhouse	Jun 1963	4.89	1.72	3.08	2.25	6.50
Schoolhouse	Nov 1965	4.12	2.11	3.08	2.25	4.85
Schoolhouse	Jan 1969	3.76	1.74	3.08	2.25	3.64
Schoolhouse	Mar 1978	3.75	1.68	3.08	2.25	3.00
Schwartz	Feb 1978	4.36	2.08	2.87	2.23	5.49
Schwartz	Feb 1983	4.46	2.00	2.87	2.23	3.67
Shields	Mar 1938	5.09	2.11	3.42	1.28	4.38
Shields	Jan 1956	3.30	1.88	3.42	1.28	3.00
Shields	Nov 1965	4.03	2.07	3.42	1.28	4.05
Shields	Jan 1966	4.38	2.02	3.42	1.28	4.04
Shields	Jan 1969	3.82	1.93	3.42	1.28	3.52
Shields	Feb 1969	3.76	1.90	3.42	1.28	3.50
Shields	Feb 1976	4.36	2.34	3.42	1.28	6.50
Shields	Feb 1978	4.82	2.26	3.42	1.28	5.49
Sierra Madre Dam	Jan 1954	4.38	1.88	3.07	3.18	6.50
Sierra Madre Dam	Jan 1956	3.14	1.90	3.07	3.18	5.49
Sierra Madre Dam	Jan 1965	2.86	1.46	3.07	3.18	3.00
Sierra Madre Dam	Jan 1969	4.57	1.81	3.07	3.18	3.00
Sierra Madre Dam	Feb 1978	3.93	2.04	3.07	3.18	3.09
Sierra Madre Villa	Mar 1962	4.91	1.63	3.15	2.97	4.75
Sierra Madre Villa	Feb 1969	4.84	1.84	3.15	2.97	3.32

**TABLE E-2: DEBRIS BASIN DATA
USED IN DEVELOPMENT OF EQUATION 1**

Debris Basin	Flood Date	Debris Yield	Precip	Relief Ratio	Drainage Area	Fire Factor
Snover	Mar 1938	4.96	2.05	3.12	2.13	3.91
Snover	Jan 1969	4.57	2.03	3.12	2.13	3.00
Snover	Feb 1969	4.05	1.91	3.12	2.13	3.00
Snover	Mar 1978	4.86	2.23	3.12	2.13	3.12
Snover	Feb 1980	4.25	2.11	3.12	2.13	3.07
Snowdrop	Feb 1980	3.87	1.48	2.71	1.95	3.00
Snowdrop	Mar 1983	3.62	1.70	2.71	1.95	3.00
Starfall	Dec 1974	4.13	1.78	3.33	1.92	3.00
Starfall	Feb 1976	4.30	2.34	3.33	1.92	6.50
Starfall	May 1977	3.16	1.70	3.33	1.92	6.05
Starfall	Feb 1978	4.83	2.26	3.33	1.92	5.49
Starfall	Feb 1980	4.62	2.11	3.33	1.92	4.38
Starfall	Feb 1983	3.88	2.18	3.33	1.92	3.66
Stetson	Feb 1978	3.72	1.68	3.07	2.27	3.00
Sturtevant	Jan 1969	3.64	2.04	3.28	1.28	3.00
Sturtevant	Feb 1978	3.94	2.00	3.28	1.28	4.36
Sturtevant	Feb 1980	3.67	2.23	3.28	1.28	3.79
Sturtevant	Feb 1983	2.85	2.08	3.28	1.28	3.37
Sullivan	Feb 1983	3.85	2.13	2.52	3.18	3.82
Sunnyside	Feb 1983	3.22	2.08	3.40	1.11	4.39
Sunset	Nov 1965	4.00	1.72	3.21	2.45	5.92
Sunset	Jan 1969	3.91	1.91	3.21	2.45	3.98
Sunset	Dec 1974	2.90	1.95	3.21	2.45	3.00
Sunset	Feb 1980	4.48	2.04	3.21	2.45	3.00

TABLE E-2: DEBRIS BASIN DATA
USED IN DEVELOPMENT OF EQUATION 1

Debris Basin	Flood Date	Debris Yield	Precip	Relief Ratio	Drainage Area	Fire Factor
Sunset	Feb 1983	4.11	3.00	3.21	2.45	3.00
Turnbull	Oct 1968	3.99	1.72	2.75	2.80	6.50
Turnbull	Jan 1969	3.98	1.65	2.75	2.80	6.15
Turnbull	Feb 1969	3.81	1.66	2.75	2.80	3.67
Turnbull	Mar 1978	3.45	3.00	2.75	2.80	3.00
Turnbull	Feb 1983	3.51	1.90	2.75	2.80	3.00
Turnbull	Aug 1983	2.95	1.48	2.75	2.80	3.00
Ward	Nov 1965	3.75	2.07	3.23	1.89	3.30
Ward	Jan 1969	4.02	1.93	3.23	1.89	3.00
Ward	Feb 1969	4.28	1.90	3.23	1.89	3.00
Ward	Feb 1976	3.72	2.34	3.23	1.89	6.50
Ward	Feb 1978	4.82	2.26	3.23	1.89	5.49
Ward	Mar 1978	4.91	2.00	3.23	1.89	5.41
Ward	Feb 1980	4.59	2.11	3.23	1.89	4.42
Ward	Mar 1983	4.69	2.18	3.23	1.89	3.65
West Ravine	Mar 1938	5.17	2.43	3.18	2.20	5.32
West Ravine	Jan 1956	3.73	1.85	3.18	2.20	3.00
West Ravine	Jan 1966	4.58	1.95	3.18	2.20	3.19
West Ravine	Jan 1969	4.83	1.97	3.18	2.20	3.09
West Ravine	Mar 1983	3.76	1.85	3.18	2.20	3.00
Wildwood	Jan 1969	4.09	1.81	2.67	2.62	3.09
Wildwood	Feb 1978	4.36	1.90	2.67	2.62	3.31
Wildwood	Feb 1980	4.07	2.00	2.67	2.62	3.14
Wildwood	Feb 1983	3.90	2.00	2.67	2.62	3.00

TABLE E-2: DEBRIS BASIN DATA USED IN DEVELOPMENT OF EQUATION 1

Debris Basin	Flood Date	Debris Yield	Precip	Relief Ratio	Drainage Area	Fire Factor
Wilson	Nov 1965	3.77	2.03	2.98	3.22	4.20
Wilson	Dec 1974	4.25	1.51	2.98	3.22	3.18
Wilson	Feb 1980	3.31	2.00	2.98	3.22	3.00
Wilson	Feb 1983	3.78	2.11	2.98	3.22	3.00
Winery	Jan 1969	4.66	1.97	3.16	2.06	3.34
Winery	Feb 1969	3.97	1.76	3.16	2.06	3.33
Winery	Mar 1978	4.44	2.23	3.16	2.06	3.00
Winery	Feb 1980	4.05	2.11	3.16	2.06	3.00
Winery	Mar 1983	3.88	2.18	3.16	2.06	3.00
Zachau	Feb 1969	4.52	1.93	3.17	2.35	3.00
Zachau	Feb 1976	4.72	2.34	3.17	2.35	6.50
Zachau	Feb 1978	4.91	2.26	3.17	2.35	5.49
Zachau	Mar 1978	4.86	2.00	3.17	2.35	5.41

TABLE E-3a: WATERSHEDS <1 YEAR SINCE BURN

Watershed	Survey Date	% Burn	Time Since Burn	Residual
Auburn	Feb 1962	70	3 Months	0.517
Auburn	Jan 1979	100	3 Months	-0.144
Auburn	Jan 1979	100	3 Months	-0.012
Auburn	Feb 1979	100	4 Months	0.042
Auburn	Mar 1979	100	5 Months	-0.152
Bailey	Jan 1954	60	? Months	0.514
Bailey	Mar 1962	30	6 Months	0.018
Bailey	Jan 1979	100	3 Months	-0.650
Bailey	Jan 1979	100	3 Months	-0.398
Bailey	Feb 1979	100	4 Months	-0.004
Bailey	Mar 1979	100	5 Months	-0.570
Bailey	Mar 1979	100	5 Months	-0.598
Blanchard	Mar 1976	90	4 Months	-0.181
Bluegum	Feb 1976	100	3 Months	-0.192
Carriage House	Feb 1979	100	4 Months	0.172
Carter	Dec 1961	90	2 Months	0.201
Carter	Feb 1962	90	4 Months	0.364
Carter	Feb 1979	100	4 Months	-0.087
Carter	Mar 1979	100	5 Months	-0.863
Carter	Mar 1979	100	5 Months	-0.552
Childs	Feb 1981	80	3 Months	0.237
Cold Creek	Jan 1976	100	4 Months	-0.122
Cold Creek	Jan 1973	100	2 Months	-0.399
Elmwood	Jan 1981	100	2 Months	0.193

TABLE E-3a: WATERSHEDS <1 YEAR SINCE BURN

Watershed	Survey Date	% Burn	Time Since Burn	Residual
Emerald East	Jan 1969	15	5 Months	0.244
Emerald East	Mar 1969	15	7 Months	0.328
Englewild	Jan 1969	100	5 Months	0.507
Englewild	Mar 1969	100	7 Months	0.158
Fern	Jul 1963	40	7 Months	0.189
Harrow	Jan 1969	100	5 Months	0.447
Harrow	Mar 1969	100	7 Months	0.021
Hay	Jun 1963	10	7 Months	-0.346
Hook East	Jan 1969	100	5 Months	0.527
Hook East	Mar 1969	100	7 Months	0.561
Kinneloa East	Jan 1969	100	5 Months	0.212
Kinneloa West	Jan 1969	100	5 Months	0.304
Kinneloa West	Mar 1969	100	7 Months	-0.032
Las Flores	Feb 1963	74	2 Months	0.372
Limekiln	Dec 1970	85	3 Months	-0.602
Lincoln	Jan 1969	15	6 Months	0.576
Little Dalton	Jan 1969	5	6 Months	0.882
May #1	Nov 1966	100	0 Months	-0.798
May #1	Dec 1966	100	1 Month	0.471
Pickens	Nov 1965	25	3 Months	0.399
Pinelawn	Feb 1976	100	3 Months	0.131
Rubio	Feb 1980	100	5 Months	0.480
Schoolhouse	Jun 1963	100	10 Months	0.669
Shields	Nov 1965	30	3 Months	-0.162

TABLE E-3a: WATERSHEDS <1 YEAR SINCE BURN

Watershed	Survey Date	% Burn	Time Since Burn	Residual
Shields	Jan 1966	30	5 Months	0.222
Shields	Feb 1976	100	3 Months	-0.301
Sierra Madre Dam	Jan 1954	100	3 Months	-0.109
Sierra Madre Dam	Mar 1962	50	5 Months	0.782
Starfall	Feb 1976	100	3 Months	-0.422
Ward	Feb 1976	100	3 Months	-0.934
Zachau	Feb 1976	100	3 Months	0.019

TABLE E-3b: WATERSHEDS 1-2 YEARS SINCE BURN

Watershed	Survey Date	% Burn	Time Since Burn	Residual
Auburn	Feb 1980	100	1 Year 4 Months	0.218
Bailey	Feb 1980	100	1 Year 4 Months	0.432
Brand	Dec 1965	100	1 Year 8 Months	-0.071
Brand	Jan 1966	100	1 Year 9 Months	-0.901
Carriage House	Feb 1980	100	1 Year 4 Months	0.440
Carter	Feb 1980	100	1 Year 4 Months	0.208
Childs	Sep 1965	100	1 Year 6 Months	0.039
Cold Creek	May 1977	100	1 Year 10 Months	-0.983
Deer	Dec 1965	90	1 Year 9 Months	0.161
Elmwood	Jun 1965	100	1 Year 3 Months	0.152
Hillcrest	Nov 1965	100	1 Year 8 Months	-0.469
La Tuna	Mar 1983	5	1 Year 8 Months	-0.08
Limekiln	Mar 1962	25	1 Year 8 Months	-0.114
Limekiln	Feb 1983	25	1 Year 4 Months	-0.214
Little Dalton	Mar 1962	89	1 Year 8 Months	0.579
Morgan	Feb 1983	100	1 Year 7 Months	-0.989
Mullally	May 1977	40	1 Year 6 Months	-0.648
Pinelawn	May 1977	100	1 Year 6 Months	0.653
Starfall	May 1977	100	1 Year 6 Months	-1.090
Sunset	Nov 1965	100	1 Year 8 Months	-0.269
Turnbull	Oct 1968	100	1 Year 0 Months	-0.127
Turnbull	Feb 1969	100	1 Year 4 Months	-0.049
Turnbull	Mar 1969	100	1 Year 5 Months	0.071

TABLE E-3c: WATERSHEDS 2-3 YEARS SINCE BURN

Watershed	Survey Date	% Burn	Time Since Burn	Residual
Aliso	Mar 1978	5	2 Years 6 Months	0.175
Auburn	Jan 1956	30	3 Years 6 Months	-0.439
Bailey	Feb 1956	60	2 Years 6 Months	-0.143
Blanchard	Feb 1978	90	2 Years 4 Months	0.081
Bluegum	Feb 1978	100	2 Years 6 Months	0.360
Bluegum	Mar 1978	100	2 Years 6 Months	0.396
Brace	Mar 1983	100	2 Years 5 Months	-0.266
Bradbury	Jan 1956	40	3 Years 0 Months	-0.159
Bradbury	Feb 1983	100	2 Years 4 Months	-0.196
Brand	Mar 1983	5	2 Years 6 Months	-0.130
Cassara	Feb 1978	51	2 Years 3 Months	0.615
Childs	Feb 1983	80	2 Years 3 Months	-0.512
Cold Creek	Feb 1978	100	2 Years 3 Months	0.201
Cold Creek	Mar 1978	100	2 Years 4 Months	0.36
Cooks	Feb 1978	100	2 Years 3 Months	0.116
Dunsmuir	Feb 1978	100	2 Years 3 Months	0.123
Dunsmuir	Mar 1978	100	2 Years 4 Months	0.253
Fern	Nov 1965	40	2 Years 11 Months	0.481
Jasmine	Mar 1983	10	2 Years 8 Months	0.455
Lannan	Jan 1956	100	2 Years 3 Months	-0.604
Las Flores	Dec 1965	74	3 Years 0 Months	0.142
La Tuna	Feb 1983	57	2 Years 3 Months	-0.074
Maddock	Feb 1983	100	2 Years 3 Months	-1.380
May #1	Mar 1969	100	2 Years 4 Months	0.000

TABLE E-3c: WATERSHEDS 2-3 YEARS SINCE BURN

Watershed	Survey Date	% Burn	Time Since Burn	Residual
May #2	Jan 1969	100	2 Years 2 Months	0.461
Mullally	Feb 1978	40	2 Years 3 Months	0.132
Pinelawn	Feb 1978	100	2 Years 3 Months	0.154
Rowley	Feb 1978	75	2 Years 3 Months	0.437
Rubio	Nov 1965	10	2 Years 11 Months	-0.184
Sawpit	Jan 1956	60	2 Years 1 Month	-0.760
Sawpit	Feb 1983	34	2 Years 3 Months	-0.190
Schwartz	Feb 1978	100	2 Years 3 Months	0.158
Shields	Feb 1978	100	2 Years 3 Months	0.332
Sierra Madre Dam	Jan 1956	100	2 Years 3 Months	-1.240
Sierra Madre Dam	Feb 1978	4	2 Years 5 Months	-0.256
Snover	Mar 1978	5	2 Years 4 Months	0.706
Starfall	Feb 1978	100	2 Years 3 Months	0.281
Sturtevant	Feb 1978	58	2 Years 5 Months	-0.156
Ward	Feb 1978	100	2 Years 3 Months	0.339
Ward	Mar 1978	100	2 Years 4 Months	0.608
West Ravine	Mar 1978	100	2 Years 5 Months	0.573
Zachau	Feb 1978	100	2 Years 3 Months	0.382
Zachau	Mar 1978	100	2 Years 4 Months	0.512

TABLE E-3d: WATERSHEDS 3-4 YEARS SINCE BURN

Watershed	Survey Date	% Burn	Time Since Burn	Residual
Auburn	Dec 1965	70	4 Years 0 Months	0.076
Hay	Nov 1965	10	3 Years 0 Months	-0.048
Pickens	Jan 1969	25	3 Years 5 Months	0.246
Rubio	Feb 1983	100	3 Years 5 Months	-0.280
Schoolhouse	Nov 1965	100	3 Years 3 Months	-0.159
Shields	Feb 1969	30	3 Years 6 Months	-0.217
Shields	Mar 1969	30	3 Years 7 Months	-0.255
West Ravine	Jan 1966	10	3 Years 3 Months	0.551
Wilson	Nov 1965	65	3 Years 3 Months	-0.494

TABLE E-3e: WATERSHEDS 4-5 YEARS SINCE BURN

Watershed	Survey Date	% Burn	Time Since Burn	Residual
Auburn	Mar 1983	100	4 Years 6 Months	-0.228
Bailey	Sep 1983	100	5 Years 0 Months	-0.306
Bluegum	Jan 1969	10	4 Years 6 Months	-0.181
Bluegum	Feb 1969	10	4 Years 8 Months	0.169
Brand	Jan 1969	100	4 Years 10 Months	0.184
Brand	Feb 1969	100	4 Years 11 Months	0.054
Carter	Mar 1983	100	4 Years 6 Months	-0.588
Childs	Jan 1969	100	4 Years 10 Months	-0.093
Childs	Feb 1969	100	4 Years 11 Months	-0.213
Cold Creek	Feb 1980	100	4 Years 4 Months	-0.210
Cold Creek	Mar 1978	100	4 Years 5 Months	-0.650
Cooks	Feb 1980	100	4 Years 3 Months	0.142
Deer	Jan 1969	90	4 Years 10 Months	0.573
Deer	Mar 1969	90	5 Years 0 Months	0.432
Dunsmuir	Mar 1938	94	4 Years 4 Months	0.614
Elmwood	Jan 1969	100	4 Years 10 Months	-0.281
Halls	Mar 1938	76	4 Years 4 Months	0.901
Hay	Mar 1938	96	4 Years 4 Months	0.691
Hillcrest	Jan 1969	100	4 Years 10 Months	0.166
Lannan	Feb 1980	24	4 Years 5 Months	0.238
La Tuna	Jan 1969	5	4 Years 10 Months	0.098
Limekiln	Jan 1969	25	4 Years 10 Months	-0.173
Limekiln	Mar 1969	25	5 Years 0 Months	-0.016
Mullally	Feb 1980	40	4 Years 3 Months	-0.228

TABLE E-3e: WATERSHEDS 4-5 YEARS SINCE BURN

Watershed	Survey Date	% Burn	Time Since Burn	Residual
Pickens	Mar 1938	91	4 Years 4 Months	0.649
Pinelawn	Feb 1980	100	4 Years 3 Months	0.470
Shields	Mar 1938	100	4 Years 4 Months	0.833
Snover	Feb 1980	5	4 Years 2 Months	0.181
Starfall	Mar 1980	100	4 Years 4 Months	0.302
Sturtevant	Feb 1980	58	4 Years 5 Months	-0.508
Sullivan	Mar 1983	60	4 Years 5 Months	-0.141
Sunnyside	Feb 1983	100	4 Years 4 Months	-0.975
Ward	Feb 1980	100	4 Years 3 Months	0.335

TABLE E-3f: WATERSHEDS 5-6 YEARS SINCE BURN

Watershed	Survey Date	% Burn	Time Since Burn	Residual
Big Dalton	Nov 1965	100	5 Years 4 Months	-0.088
Golf Course	Dec 1974	10	5 Years 1 Month	-0.234
Halls	Nov 1965	20	6 Years 0 Months	-0.163
Little Dalton	Nov 1965	89	5 Years 4 Months	0.131
Snover	Nov 1939	97	6 Years 0 Months	0.830
Sunset	Jan 1969	100	5 Years 10 Months	-0.251

TABLE E-3g: WATERSHEDS 6-7 YEARS SINCE BURN

Watershed	Survey Date	% Burn	Time Since Burn	Residual
Bradbury	Dec 1965	100	7 Years 0 Months	-0.054
Cold Croft	Feb 1980	100	6 Years 4 Months	-0.160
Fern	Feb 1969	40	6 Years 2 Months	1.270
Gould	Nov 1965	50	6 Years 1 Month	0.602
Hay	Jan 1969	10	6 Years 2 Months	0.279
Las Flores	Jan 1969	74	6 Years 1 Month	0.319
Rubio	Jan 1969	10	6 Years 1 Month	0.392
Rubio	Mar 1969	10	6 Years 3 Months	-0.039
West Ravine	Feb 1969	10	6 Years 4 Months	0.800
Winery	Jan 1969	40	6 Years 4 Months	0.638
Winery	Mar 1969	40	6 Years 5 Months	0.086

TABLE E-3h: WATERSHEDS 7-8 YEARS SINCE BURN

Watershed	Survey Date	% Burn	Time Since Burn	Residual
Aliso	Feb 1983	5	7 Years 6 Months	0.041
Auburn	Jan 1969	70	7 Years 6 Months	0.202
Bailey	Jan 1969	30	7 Years 6 Months	0.355
Carter	Jan 1969	90	7 Years 3 Months	-0.086
Carter	Feb 1969	90	7 Years 4 Months	-0.393
Cassara	Feb 1983	51	7 Years 3 Months	0.338
Childs	Mar 1978	10	7 Years 6 Months	0.149
Cold Creek	Feb 1983	100	7 Years 4 Months	0.154
Cooks	Feb 1983	100	7 Years 3 Months	0.177
Fieldbrook	Mar 1978	100	7 Years 6 Months	-0.753
Golf Course	May 1977	10	7 Years 6 Months	-0.139
Kinneloa West	Feb 1976	100	7 Years 6 Months	0.457
Lannan	Feb 1983	24	7 Years 5 Months	-0.592
Mullally	Feb 1983	40	7 Years 3 Months	0.162
Pinelawn	Mar 1983	100	7 Years 4 Months	0.226
Sawpit	Nov 1965	40	7 Years 1 Month	0.033
Schoolhouse	Jan 1969	100	7 Years 5 Months	-0.133
Schwartz	Feb 1983	100	7 Years 3 Months	0.528
Sierra Madre Dam	Mar 1969	50	7 Years 5 Months	0.746
Starfall	Feb 1983	100	7 Years 3 Months	-0.398
Sturtevant	Feb 1983	58	7 Years 5 Months	-1.180
Ward	Mar 1983	100	7 Years 4 Months	0.481
Wildwood	Mar 1978	50	7 Years 6 Months	0.589

TABLE E-3i: WATERSHEDS 8-9 YEARS SINCE BURN

Watershed	Survey Date	% Burn	Time Since Burn	Residual
Big Dalton	Jan 1969	100	8 Years 6 Months	0.906
La Tuna	Jan 1956	10	8 Years 6 Months	-0.262
Laurel Ridge	Dec 1978	100	8 Years 3 Months	0.462
Morgan	Jan 1969	100	8 Years 6 Months	0.083
Morgan	Mar 1969	100	8 Years 8 Months	-0.407
Wilson	Dec 1974	35	8 Years 1 Month	0.448

TABLE E-3j: WATERSHEDS 9-10 YEARS SINCE BURN

Watershed	Survey Date	% Burn	Time Since Burn	Residual
Childs	Feb 1980	10	9 Years 6 Months	-0.218
Cooks	Nov 1965	50	9 Years 2 Months	-0.800
Emerald East	Mar 1978	15	9 Years 7 Months	0.134
Englewild	Mar 1978	100	9 Years 7 Months	-0.487
Gould	Feb 1969	50	9 Years 4 Months	0.554
Halls	Feb 1969	20	10 Years 0 Months	0.847
Harrow	Feb 1969	100	9 Years 7 Months	-0.290
Hook East	Mar 1978	100	9 Years 7 Months	0.096
Kinneloa East	Feb 1978	100	9 Years 6 Months	-0.206
Kinneloa West	Feb 1978	100	9 Years 6 Months	-0.195
Kinneloa West	Mar 1978	100	9 Years 7 Months	-0.118
Lincoln	Feb 1978	15	9 Years 7 Months	-0.271
Lincoln	Mar 1978	15	9 Years 8 Months	-0.204
Little Dalton	Feb 1978	5	9 Years 7 Months	-0.306
May #1	Feb 1976	100	9 Years 3 Months	0.552
May #2	Feb 1976	100	9 Years 3 Months	0.935
Ward	Nov 1965	100	9 Years 1 Month	-0.345
Wildwood	Jan 1969	50	9 Years 10 Months	0.404
Wildwood	Feb 1980	50	9 Years 5 Months	0.254

TABLE E-3k: WATERSHEDS >10 YEARS SINCE BURN

Watershed	Survey Date	Residual	Watershed	Survey Date	Residual
Auburn	Feb 1978	-0.482	Lincoln	Nov 1965	0.248
Bailey	Mar 1978	-0.148	Lincoln	Feb 1980	0.195
Beatty	Feb 1980	0.936	Lincoln	Feb 1983	-0.525
Big Briar	Feb 1980	-0.208	Linda Vista	Jun 1977	-1.150
Big Briar	Feb 1983	-0.013	Linda Vista	Feb 1978	-0.167
Big Dalton	Feb 1983	-0.554	Little Dalton	Feb 1983	-0.559
Blanchard	Jan 1969	0.290	Maddock	Feb 1969	0.287
Bradbury	Jan 1969	0.580	Maddock	Mar 1969	0.005
Bradbury	Feb 1969	0.597	Maddock	Mar 1978	-0.904
Bradbury	Mar 1978	-0.022	Maddock	Feb 1980	0.114
Bradbury	Feb 1980	0.207	May #1	Nov 1965	-0.125
Brand	Mar 1978	0.662	May #1	Feb 1978	-0.008
Brand	Feb 1980	0.168	May #1	Mar 1978	-0.359
Carter	Jan 1956	0.000	May #1	Feb 1980	-0.625
Carter	Mar 1978	-0.611	May #1	Mar 1983	-0.017
Chamberlain	Mar 1975	0.219	May #2	Nov 1965	0.078
Cooks	Jan 1954	-0.323	May #2	Feb 1980	-0.082
Cooks	Jan 1969	0.107	May #2	Feb 1983	0.376
Deer	Mar 1978	0.613	Morgan	Mar 1978	-0.246
Deer	Feb 1980	-0.695	Mull	Feb 1980	-0.217
Elmwood	Mar 1978	0.055	Pickens	Jan 1954	-0.441
Elmwood	Feb 1980	0.091	Pickens	Jan 1956	-0.499
Emerald East	Apr 1980	0.106	Pinelawn	Dec 1974	0.075
Englewild	Feb 1980	0.320	Rubio	Mar 1978	-0.484

TABLE E-3k: WATERSHEDS >10 YEARS SINCE BURN

Watershed	Survey Date	Residual	Watershed	Survey Date	Residual
Fair Oaks	Nov 1965	0.648	Ruby	Nov 1965	0.205
Fair Oaks	Jan 1969	0.999	Ruby	Jan 1969	0.817
Fair Oaks	Feb 1980	-0.074	Ruby	Feb 1980	0.053
Fair Oaks	Feb 1983	-0.094	Santa Anita	Jan 1965	0.450
Fern	Jan 1954	-0.627	Santa Anita	Jan 1969	0.754
Fern	Jan 1956	-0.808	Santa Anita	Feb 1980	-0.141
Fern	Mar 1978	0.082	Santa Anita	Feb 1983	-0.496
Fern	Feb 1980	0.164	Sawpit	Jan 1969	0.577
Fern	Feb 1983	-0.096	Schoolhouse	Apr 1978	-0.027
Fieldbrook	Sep 1983	-0.732	Shields	Jan 1956	-0.642
Gordon	Feb 1980	-0.507	Sierra Madre Dam	Jan 1965	-0.936
Gordon	Feb 1983	-1.680	Sierra Madre Dam	Jan 1969	0.545
Gould	Feb 1980	0.284	Snover	Jan 1969	0.561
Gould	Feb 1983	-0.002	Snover	Mar 1969	0.120
Haines	Feb 1969	0.260	Snowdrop	Mar 1980	0.508
Halls	Jan 1954	-0.328	Snowdrop	Mar 1983	0.114
Halls	Jan 1956	-0.294	Starfall	Dec 1974	0.193
Halls	May 1977	0.244	Stetson	Apr 1978	-0.054
Halls	Feb 1978	0.358	Sturtevant	Jan 1969	-0.320
Halls	Feb 1980	0.286	Sunset	Dec 1974	-1.170
Halls	Feb 1983	0.261	Sunset	Feb 1980	0.351
Harrow	Mar 1980	-0.358	Sunset	Feb 1983	-0.647
Hay	Mar 1978	0.111	Turnbull	Mar 1978	-1.090
Hay	Feb 1980	-0.260	Turnbull	Mar 1983	-0.306

TABLE E-3k: WATERSHEDS >10 YEARS SINCE BURN

Watershed	Survey Date	Residual	Watershed	Survey Date	Residual
Hillcrest	Feb 1980	-0.550	Ward	Feb 1969	0.052
Hillcrest	Feb 1983	-1.320	Ward	Mar 1969	0.332
Hook East	Feb 1980	-0.098	West Ravine	Jan 1956	-0.211
Hook West	Feb 1980	0.171	West Ravine	Mar 1983	-0.181
Jasmine	Mar 1980	0.615	Wildwood	Feb 1983	0.101
Kinneloa East	Dec 1965	-0.117	Wilson	Feb 1980	-0.791
Kinneloa West	Feb 1980	-0.079	Wilson	Feb 1983	-0.392
Kinneloa West	Feb 1983	0.149	Winery	Mar 1978	0.289
Lannan	Jan 1969	-0.028	Winery	Feb 1980	-0.023
Las Flores	Feb 1980	0.696	Winery	Mar 1983	-0.239
Las Flores	Feb 1983	0.000	Zachau	Mar 1969	0.506

TABLE E 4a: DATA USED IN DEVELOPMENT OF EQUATIONS 2 TO 5
BIG TUJUNGA DAM

Date of Flood	Debris Yield	Peak Discharge	Relief Ratio	Drainage Area	Fire Factor
Jan 1933	2.57	0.79	288.4	82.0	3.17
Jan 1934	3.24	1.47	288.4	82.0	3.10
Dec 1934	2.65	0.89	288.4	82.0	3.10
Jan 1935	2.55	0.78	288.4	82.0	3.09
Apr 1935	2.71	0.94	288.4	82.0	3.09
Feb 1936	2.33	0.58	288.4	82.0	3.08
Dec 1936	2.41	0.64	288.4	82.0	3.38
Feb 1937	3.09	1.32	288.4	82.0	3.32
Mar 1937	2.92	1.15	288.4	82.0	3.31
Mar 1938	4.37	2.60	288.4	82.0	3.28
Jan 1943	3.87	2.34	288.4	82.0	3.13
Feb 1944	3.52	1.76	288.4	82.0	3.12
Nov 1944	2.80	1.35	288.4	82.0	3.11
Mar 1946	2.89	1.45	288.4	82.0	3.09
Nov 1946	2.76	1.31	288.4	82.0	3.08
Jan 1952	2.84	1.39	288.4	82.0	3.00
Jan 1954	2.44	0.78	288.4	82.0	3.00
Jan 1956	2.50	0.85	288.4	82.0	3.00
Apr 1958	3.19	1.54	288.4	82.0	3.00
Feb 1962	3.42	1.79	288.4	82.0	3.20
Dec 1965	3.68	2.12	288.4	82.0	3.38
Dec 1966	3.23	1.50	288.4	82.0	3.33
Jan 1967	2.52	0.78	288.4	82.0	3.29

TABLE E 4a: DATA USED IN DEVELOPMENT OF EQUATIONS 2 TO 5
BIG TUJUNGA DAM

Date of Flood	Debris Yield	Peak Discharge	Relief Ratio	Drainage Area	Fire Factor
Mar 1967	2.52	0.78	288.4	82.0	3.28
Apr-May 1967	2.52	0.78	288.4	82.0	3.28
Nov 1967	2.67	0.95	288.4	82.0	3.27
Jan 1969	4.11	2.38	288.4	82.0	3.24
Nov 1970	3.52	1.68	288.4	82.0	3.21
Dec 1971	2.52	0.75	288.4	82.0	3.19
Feb 1973	3.72	1.89	288.4	82.0	3.12
Jan 1974	2.52	0.83	288.4	82.0	3.08
Mar 1975	2.52	0.58	288.4	82.0	3.65
Feb 1976	3.12	1.23	288.4	82.0	3.55
Jan 1977	2.82	1.03	288.4	82.0	3.49
Feb 1978	4.18	2.35	288.4	82.0	3.39
Feb 1980	4.32	2.20	288.4	82.0	3.32

TABLE E 4b: DATA USED IN DEVELOPMENT OF EQUATIONS 2 TO 5
COGSWELL DAM

Date of Flood	Debris Yield	Peak Discharge	Relief Ratio	Drainage Area	Fire Factor
Feb 1936	2.89	0.95	426.6	39.2	3.22
Dec 1936	3.01	1.06	426.6	39.2	3.16
Feb 1937	3.45	1.50	426.6	39.2	3.11
Mar 1937	3.15	1.19	426.6	39.2	3.10
Mar 1938	4.75	2.80	426.6	39.2	3.00
Jan 1943	4.23	2.58	426.6	39.2	3.00
Nov 1946	3.56	1.77	426.6	39.2	3.00
Feb 1958	3.35	1.78	426.6	39.2	3.42
Apr 1958	3.54	1.98	426.6	39.2	3.41
Jan 1959	3.26	1.65	426.6	39.2	3.38
Feb 1962	3.86	2.25	426.6	39.2	3.26
Feb 1963	3.01	1.41	426.6	39.2	3.23
Nov 1965	3.97	2.37	426.6	39.2	3.15
Dec 1966	3.67	2.07	426.6	39.2	3.10
Jan 1969	4.20	2.60	426.6	39.2	3.06
Jan 1974	2.87	1.35	426.6	39.2	3.00
Mar 1975	2.46	1.04	426.6	39.2	3.00
Feb 1976	2.87	1.32	426.6	39.2	3.00
Jan 1977	2.39	1.03	426.6	39.2	3.00
Feb 1978	3.98	2.46	426.6	39.2	3.00
Jan 1979	2.46	0.94	426.6	39.2	3.00
Feb 1980	3.77	2.19	426.6	39.2	3.00

TABLE E 4c: DATA USED IN DEVELOPMENT OF EQUATIONS 2 TO 5
DEVIL'S GATE DAM

Date of Flood	Debris Yield	Peak Discharge	Relief Ratio	Drainage Area	Fire Factor
Oct 1934	3.82	1.61	331.1	31.9	3.75
Feb 1936	3.59	1.47	331.1	31.9	3.92
Feb 1937	3.54	1.43	331.1	31.9	3.81
Mar 1938	4.65	2.53	331.1	31.9	3.71
Jan 1943	4.19	2.39	331.1	31.9	3.37
Jan 1952	4.13	1.92	331.1	31.9	3.13
Nov 1960	4.03	1.60	331.1	31.9	4.38
Feb 1962	4.19	1.76	331.1	31.9	4.36
Feb 1963	3.87	1.61	331.1	31.9	4.20
Nov 1965	4.33	2.07	331.1	31.9	3.96
Dec 1966	3.63	1.83	331.1	31.9	3.86
Nov 1967	3.42	1.61	331.1	31.9	3.74
Jan 1969	4.28	2.47	331.1	31.9	3.60
Feb 1969	4.07	2.26	331.1	31.9	3.59
Mar 1970	3.33	1.22	331.1	31.9	3.51
Dec 1970	3.85	1.74	331.1	31.9	3.40
Dec 1971	3.24	1.13	331.1	31.9	3.25
Jan 1974	3.50	1.54	331.1	31.9	3.15
Mar 1976	3.40	1.44	331.1	31.9	3.26
Jan 1977	3.22	1.27	331.1	31.9	3.23

**TABLE E 4d: DATA USED IN DEVELOPMENT OF EQUATIONS 2 TO 5
PACOIMA DAM**

Date of Flood	Debris Yield	Peak Discharge	Relief Ratio	Drainage Area	Fire Factor
Feb 1936	2.96	0.94	223.9	28.2	3.18
Feb 1937	3.28	1.26	223.9	28.2	3.16
Mar 1938	4.49	2.47	223.9	28.2	3.14
Jan 1940	3.71	1.52	223.9	28.2	3.11
Mar 1941	3.65	1.46	223.9	28.2	3.10
Jan 1943	3.79	1.97	223.9	28.2	3.07
Feb 1944	3.62	1.80	223.9	28.2	3.06
Feb 1945	3.01	1.24	223.9	28.2	3.03
Mar 1946	3.08	1.30	223.9	28.2	3.00
Jan 1952	3.43	1.66	223.9	28.2	3.00
Jan 1954	2.76	0.98	223.9	28.2	3.00
Jan 1956	3.29	0.80	223.9	28.2	3.00
Apr 1958	4.12	1.62	223.9	28.2	3.23
Feb 1962	3.84	1.46	223.9	28.2	3.28
Nov 1965	3.87	1.85	223.9	28.2	3.19
Dec 1966	3.70	1.69	223.9	28.2	3.16
Jan 1969	4.24	2.22	223.9	28.2	3.24
Feb 1973	3.92	1.77	223.9	28.2	3.11
Jan 1977	2.84	0.88	223.9	28.2	4.67
Feb 1978	4.14	2.20	223.9	28.2	4.45
Mar 1979	3.01	1.03	223.9	28.2	4.26
Feb 1980	3.76	1.77	223.9	28.2	4.14

TABLE E 4e: DATA USED IN DEVELOPMENT OF EQUATIONS 2 TO 5
SAN DIMAS GATE DAM

Date of Flood	Debris Yield	Peak Discharge	Relief Ratio	Drainage Area	Fire Factor
Feb 1936	2.78	1.00	501.2	16.2	3.00
Feb 1937	3.08	1.25	501.2	16.2	3.00
Mar 1938	4.30	2.48	501.2	16.2	3.00
Jan 1943	3.87	2.02	501.2	16.2	3.00
Jan 1956	3.32	1.35	501.2	16.2	3.00
Apr 1958	3.63	1.67	501.2	16.2	3.00
Jan 1959	3.00	1.07	501.2	16.2	3.00
Nov 1960	3.70	1.39	501.2	16.2	6.00
Nov 1961	4.29	2.19	501.2	16.2	5.63
1962	3.76	1.67	501.2	16.2	5.33
Feb 1963	3.66	1.43	501.2	16.2	5.02
Apr 1965	3.38	1.16	501.2	16.2	4.54
Nov 1965	4.03	1.80	501.2	16.2	4.50
Aug 1966	4.10	1.97	501.2	16.2	4.40
Dec 1966	4.02	2.03	501.2	16.2	4.35
Jan 1969	4.45	2.35	501.2	16.2	3.91
Mar 1970	3.00	0.85	501.2	16.2	3.76
Nov 1970	3.04	0.89	501.2	16.2	3.70
Dec 1971	2.48	0.68	501.2	16.2	3.58
Feb 1973	3.38	1.63	501.2	16.2	3.15
Jan 1974	2.84	1.06	501.2	16.2	3.00
Mar 1975	2.30	0.62	501.2	16.2	3.00
Sep 1976	3.20	1.44	501.2	16.2	4.05
Jan 1977	2.90	1.21	501.2	16.2	3.93
Feb 1978	4.17	2.02	501.2	16.2	3.81
Feb 1980	3.98	2.20	501.2	16.2	3.62

TABLE E 4f: DATA USED IN DEVELOPMENT OF EQUATIONS 2 TO 5
SAN GABRIEL DAM

Date of Flood	Debris Yield	Peak Discharge	Relief Ratio	Drainage Area	Fire Factor
Mar 1938	4.71	2.74	436.5	161.60	3.05
Feb 1941	3.67	1.55	436.5	161.60	3.00
Dec 1941	3.44	1.32	436.5	161.60	3.00
Jan 1943	4.30	2.45	436.5	161.60	3.00
Dec 1945	3.50	1.55	436.5	161.60	3.00
Nov 1946	3.55	1.60	436.5	161.60	3.00
Jan 1952	3.40	1.57	436.5	161.60	3.00
Nov 1952	2.34	0.52	436.5	161.60	3.00
Jan 1954	3.10	1.26	436.5	161.60	3.00
Jan 1956	2.54	1.14	436.5	161.60	3.00
Jan 1957	2.65	1.24	436.5	161.60	3.00
Apr 1958	3.03	1.63	436.5	161.60	3.58
Jan 1959	3.31	1.28	436.5	161.60	3.53
Nov 1960	2.62	0.59	436.5	161.60	3.91
Feb 1962	3.85	1.93	436.5	161.60	3.72
Feb. 1963	3.20	1.17	436.5	161.60	3.66
Apr 1965	2.84	0.82	436.5	161.60	3.52
Dec 1965	4.24	2.22	436.5	161.60	3.47
Jan 1966	4.03	1.90	436.5	161.60	3.46
Dec 1966	4.13	1.88	436.5	161.60	3.43
Nov 1967	2.97	1.00	436.5	161.60	3.40
Jan 1969	4.41	2.43	436.5	161.60	3.47
Feb 1969	4.30	2.43	436.5	161.60	3.45
Jan 1974	3.12	1.05	436.5	161.60	3.21
Mar 1975	2.51	0.73	436.5	161.60	3.57
Sep 1976	3.11	1.00	436.5	161.60	3.53
Jan. 1977	2.81	0.84	436.5	161.60	3.48
Feb 1978	4.19	2.17	436.5	161.60	3.44
Mar 1979	2.73	0.90	436.5	161.60	3.38
Feb 1980	4.00	2.20	436.5	161.60	3.33

TABLE E 4g: DATA USED IN DEVELOPMENT OF EQUATIONS 2 TO 5
SANTA ANITA DAM

Date of Flood	Debris Yield	Peak Discharge	Relief Ratio	Drainage Area	Fire Factor
Feb 1936	3.29	1.33	871.0	10.8	3.02
Feb 1937	3.43	1.46	871.0	10.8	3.01
Mar 1938	4.64	2.68	871.0	10.8	3.00
Jan 1943	4.30	2.46	871.0	10.8	3.00
Feb 1944	3.62	1.88	871.0	10.8	3.00
Dec 1949	2.87	1.03	871.0	10.8	3.00
Jan 1952	3.69	1.89	871.0	10.8	3.00
Dec 1952	2.95	1.15	871.0	10.8	3.00
Jan 1954	4.31	2.06	871.0	10.8	6.00
Jul 1954	4.13	1.54	871.0	10.8	5.80
Nov 1954	3.80	1.21	871.0	10.8	5.64
Jan 1956	3.78	1.72	871.0	10.8	4.98
Feb 1957	2.78	1.05	871.0	10.8	4.70
Apr 1958	3.52	1.76	871.0	10.8	4.49
Jan 1959	3.22	1.76	871.0	10.8	4.32
Feb 1962	3.61	2.13	871.0	10.8	3.79
Feb 1963	3.32	1.53	871.0	10.8	3.62
Apr 1965	2.87	1.08	871.0	10.8	3.22
Dec 1965	4.04	2.25	871.0	10.8	3.18
Dec 1966	3.80	2.15	871.0	10.8	3.10
Nov 1967	2.87	1.18	871.0	10.8	3.00
Jan 1969	4.61	2.71	871.0	10.8	3.26
Nov 1970	3.38	1.80	871.0	10.8	3.23
Dec 1971	2.48	0.96	871.0	10.8	3.20
Feb 1973	3.67	2.10	871.0	10.8	3.15
Jan 1974	3.02	1.41	871.0	10.8	3.13
Mar 1975	2.35	0.70	871.0	10.8	3.11
Mar 1976	2.65	0.97	871.0	10.8	3.09
Jan 1977	2.87	1.27	871.0	10.8	3.08
Feb 1978	3.85	2.24	871.0	10.8	3.06
Feb 1980	3.65	2.05	871.0	10.8	3.02