COMPOSITE LOG-TYPE III FREQUENCY-MAGNITUDE CURVE OF ANNUAL FLOODS

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CURVE OF ANNUAL FLOODS

By John R. Crippen (Hydrologist, Menlo Park, Calif.)

By coincidence, shortly after receiving the recent directive of the Water Resources Council (1967) that prescribed use of the log-Pearson Type III distribution in developing flood-frequency curves, the California District found it necessary to analyze the annual floods of Merced River at Happy Isles Bridge, in Yosemite National Park. We feel that this constitutes a severe test of the adaptability of the type III distributions, and we think Pearson came out a winner.

There are 51 years of data available from Happy Isles, covering the period 1916-66. The five highest annual floods are outstandingly greater than the remaining 46. All five of these "outliers" were caused by warm storms that originated in tropical regions and swept inland to the Sierra Nevada, bringing temperatures above the freezing point at altitudes of more than 9,000 feet and resulting in high flows that were made up principally of direct runoff, but that included some snowmelt runoff. All other annual peaks, with one exception, came from late April to early June, when precipitation is invariably negligible, and are almost entirely the result of snowmelt alone. They range from 1.0 to 3.8 thousand cfs. The exception is an annual peak of 3.7 thousand cfs caused by an unusually early storm in October 1946.

Although the altitude of the Happy Isles gage is about 4,000 feet, more than 90 percent of the basin lies above 7,000 feet and more than 50 percent lies above 9,000 feet; therefore, the usual winter storms coming from the north, with a freezing level of 3,000 to 6,000 feet, do not cause flooding. The occasional maverick storms coming from the south are another story. The high peak flows that have been mentioned when plotted in conjunction with the much lower snowmelt peaks to form a single family of annual peaks, present a rather ambiguous flood-frequency curve. The occurrence of warm winter storms causes enough water loss from the snowpack that snowmelt peaks during the following spring probably cannot always be considered independent events; however, there are snowmelt peaks each year although there are not always obvious winter storm peaks. We therefore seem to have two greatly different parent populations, that of storm peaks and that of snowmelt peaks, from either of which any annual peak may derive. Given enough additional decades, there may occur enough

-between situations to define a compound distribution at can perhaps be described by a single Pearson ype III curve; at present, using the methods that seem ractical for use, one curve cannot describe the enre panoply of events.

We have treated the data thus: We found (or esmated) the snowmelt peaks for the 6 years when orm peaks were higher and assumed the resulting l snowmelt events to be a sample of independent ems. We computed a type III distribution of the gs of the events (fig. 1). We estimated, from inpection of daily flows, the winter period peaks during he 45 years that lacked notable storm peaks, and these ogether with the six known storm peaks were used to efine a type III distribution of storm peaks (fig. 2, ee p. 30). Thus, we had estimates of each of the two istributions from which we assume annual peaks nay derive. Based on these two distributions, we then pplied the equation

$$P_3 = P_1 + P_2 - P_1P_2$$

o compute the combined distributions, shown in figure 3. (See p. 35.) The components of the equation are:

P_1 = Probability of exceedence of a given snowmelt peak during any single year;

P_2 = Similar probability, winter storm peak;

P_3 = Probability of exceedence of a given peak from either distribution during any single year.

(In effect the equation states that the annual peak may be either a snowmelt or a storm peak, but not both.)

For example, graphical inspection of the probabilities associated with a peak of 2,000 cfs indicates a probability of 0.760 that it will be exceeded by the snowmelt peak of any single year and a probability of 0.116 that it will be exceeded by a storm peak. P_3 therefore is 0.788, and the corresponding recurrence interval is 1/0.788, or 1.27 years. For peak discharges greater than about 4,000 cfs, the probabilities of both type peaks occurring during the same year (P_1P_2) becomes negligible, and for peak discharges of 5,000 cfs or greater the probability of snowmelt peaks can be considered zero, and P_3 is equal to P_2.

All the work that has been described could be done with no plotting, but the determination of exceedence probability of selected discharges is simpler using the snowmelt and storm curves, and we wish to compare the computed curves with the plot of the original data at their assigned frequencies.

Inspection of the final composite curve shows that the storm peaks have little effect on the magnitude of floods of less than 10 years recurrence interval while the magnitudes of floods of 20 years or longer in recurrence interval are determined almost solely by the distribution assigned to the storm peaks. It is unlikely that most hydrologists would empirically agree with the computed upper end of the frequency curve; however, there is little question but that each hydrologist would arrive at his own unique solution,

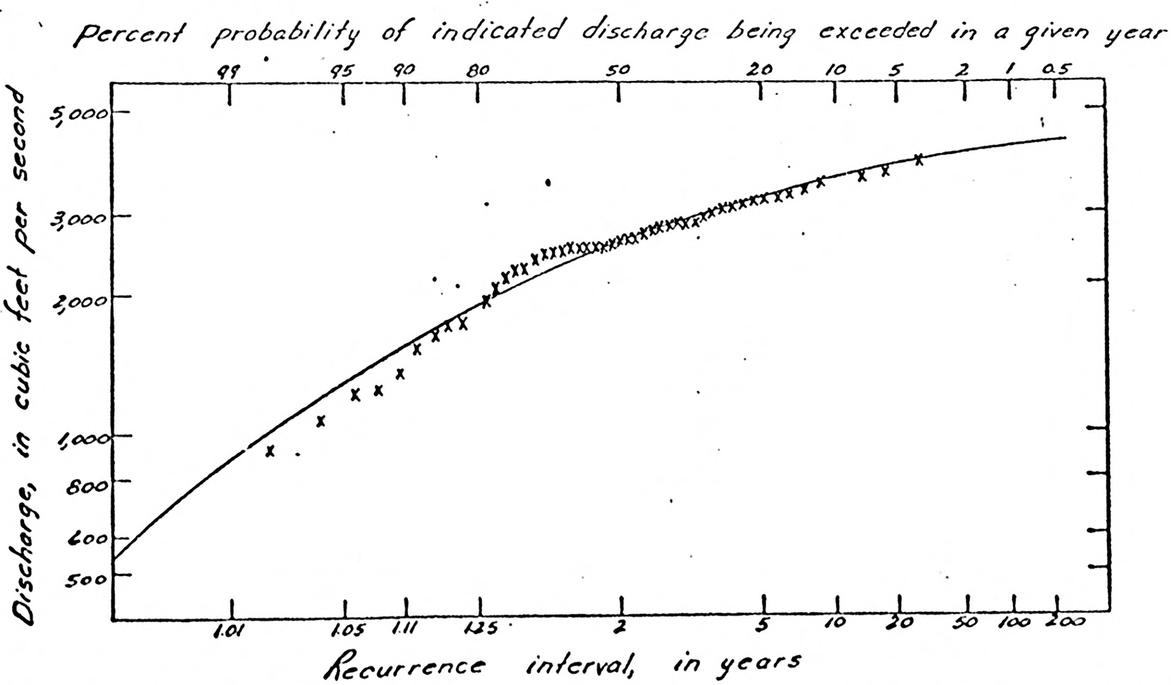

Figure 1.--Flood frequency-magnitude relation (snowmelt peaks), Merced River at Happy Isles Bridge, Yosemite, Calif.

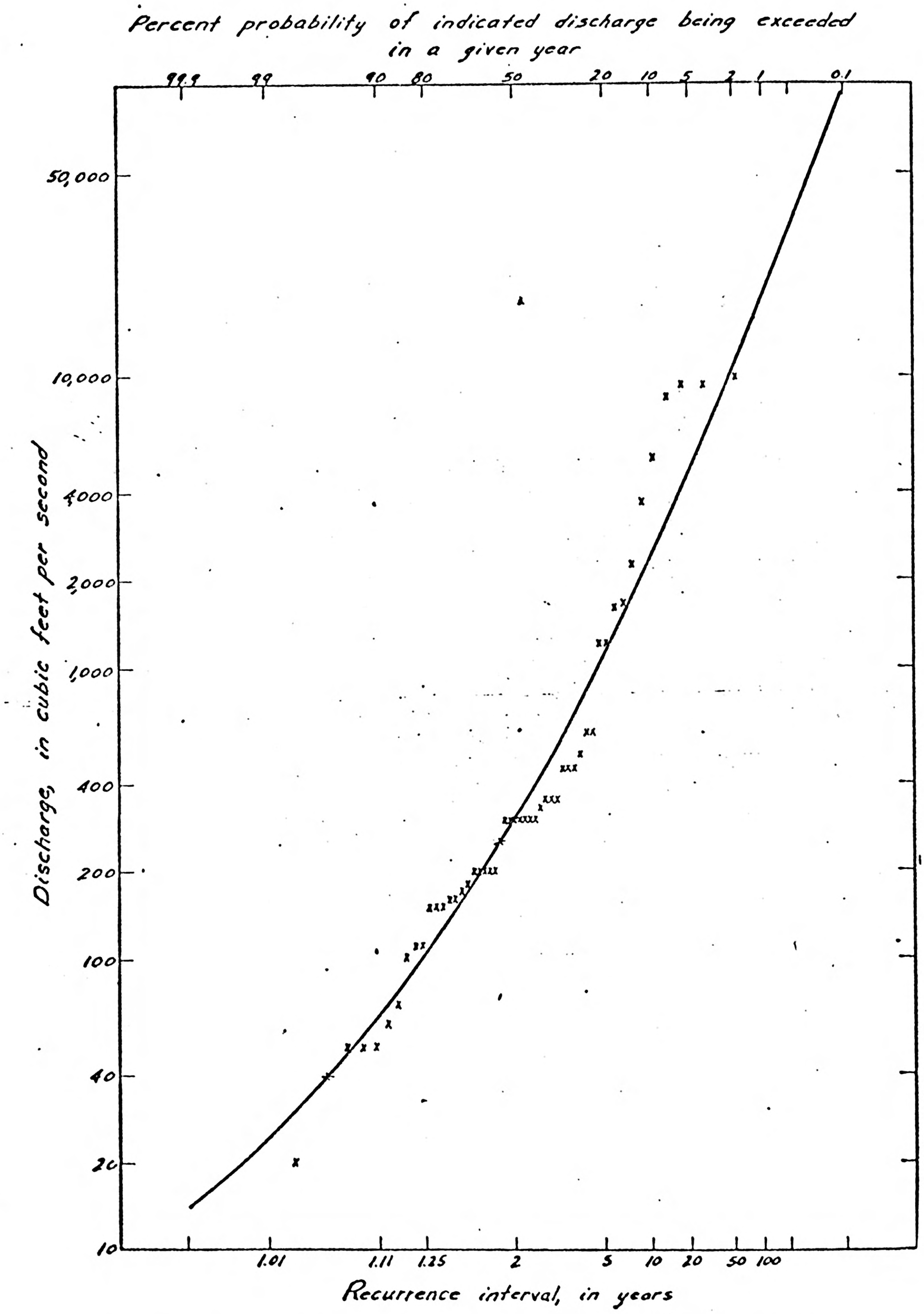

Figure 2.--Flood frequency-magnitude relation (storm peaks), Merced River at Happy Isles Bridge, Yosemite, Calif.

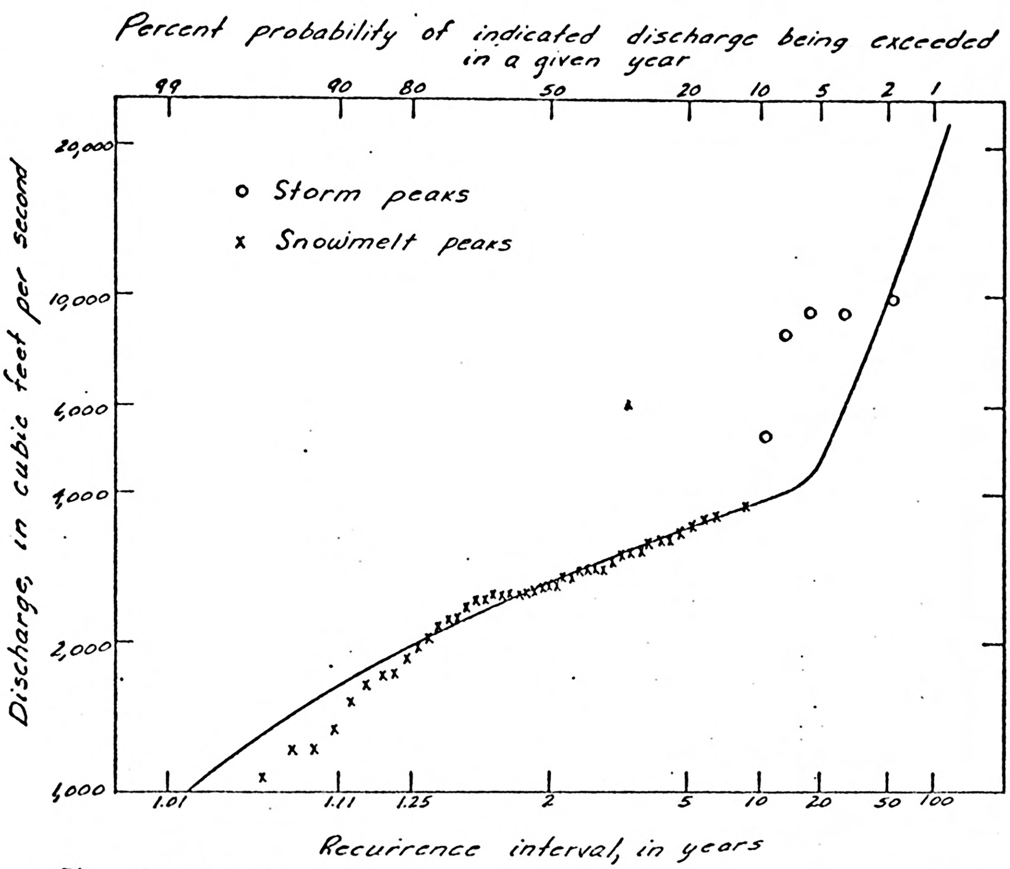

Figure 3.--Flood frequency-magnitude relation (composite curve), Merced River at Happy Isles Bridge, Yosemite, Calif.

different from that of all other hydrologists, and there is little question but that the computed curve may be just as valid an interpretation as any of the individual results would be. The upper end looks very steep when compared to the slope of the 2- to 10-year part of the curve, but that is likely a reflection of the suppression of peak flows during most years by storage (as snow) of the runoff that would otherwise result from the usual winter storms. Certainly the possibility of a 100-year flood peak of some 100 cfs per square mile from a 181 square mile basin is well within reason.

We feel that this application of the method prescribed by the Water Resources Council provides a resonable and reproducible solution for the interpretation of this difficult set of data.

Reference Cited

Water Resources Council, Hydrology Committee, 1967, A uniform technique for determining flood-flow frequencies: Water Rescources Council Bull. 15.

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DISCUSSION OF

COMPOSITE LOG-TYPE III FREQUENCY-MAGNITUDE CURVE OF ANNUAL FLOODS

By John R. Crippen (WRD Bulletin, April-June 1968, p. 32-35)

By Saul E. Rantz (Hydrologist, Menlo Park, Calif.)

Crippen has presented a method of combining the flood-frequency curves for two populations into a single composite flood-frequency curve. There can be little argument concerning the method he used once the individual curves are derived, but is it always desirable to compute a single composite relation whenever we have two flood populations? I believe the composite relation can be misleading to the user of the frequency curve for watersheds, such as the Merced River basin, that receive their runoff from the west slope of the Sierra Nevada or the Cascade Range.

As Crippen states, each year these areas experience a winter rain "flood" and a late-spring or early-summer snowmelt "flood." No significant storms occur in the summer. Generally, 4 to 6 months elapse between the two events in a given year, so that areas damaged by a winter rain flood may often, but not always, be rehabilitated in time to sustain full damage again by a summer snowmelt flood occurring in that same year. Crippen also points out that there is some interaction between a rain flood and the subsequent snowmelt flood in a given year, in that the major rain floods reduce the peak of the subsequent snowmelt floods by removing much of the snow that accumulated prior to the rains. However, to a greater degree, the rain floods and snowmelt floods are independent of each other, and it is not to be presumed that a severe rain flood will be followed by a light snowmelt flood. For example, the greatest snowmelt flood in the 51-year record for the Merced River occurred in the same year as the fourth greatest rain flood. The fifth greatest snowmelt flood, only 12 percent smaller than the greatest snowmelt flood, occurred in the same year as the greatest rain flood.

At this point we turn our attention to the use of a flood-frequency curve. The most important use of the curve is for computing mean annual monetary flood damage either in studies of the economics of flood-control measures or in the economic design of waterway structures. The computation is made by first converting discharge to stage and then converting stage to damage in dollars, thereby arriving at a frequency curve of monetary damage. Integration of the damage-frequency curve gives the mean annual flood damage. It should be borne in mind that damage varies not only with stage, but also with season. In urban areas of a basin a given stage will cause the same amount of damage, regardless of whether the stage resulted from a rain or snowmelt flood. However, in the agricultural areas of the basin, the damage caused by a snowmelt flood, which always occurs during the growing season, will be greater than that caused by a similar stage during a rain flood, which always occurs during the dormant season.

From the foregoing discussion it would seem that many basins in the Far Western States face a flood hazard twice every year. If we accept the premises that the winter and summer floods are largely independent of each other and that the monetary damages caused by each of the two floods in a given year are additive, then we should provide both a rain and a snowmelt flood-frequency curve. The user of the curves will compute mean annual damage from each curve and then add the two values to obtain total mean annual damage.

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