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# DESIGN RAINFALL CURVE

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*Abstract*
To design urban storm water infrastructures, hydrologists apply the SCS Type I and II 24-hr rainfall distribution curves to create various rainfall hyetographs by which storm runoff can be predicted accordingly. Although SCS Type I and II curves are recommended by the Natural Resources Conservation Service and have been widely adopted for many cosmopolitan areas in the United States, it is not enough understanding how these curves compare with the observed. In this study, a 57-year hourly rainfall data recorded in Denver, Colorado was analyzed and then compared with the SCS 24-hr rainfall curves. It is concluded that these SCS 24-hr Type I and II curves are not the statistically averaged, rather, they represent the worst time distribution to form a sever storm. Using the concept of enveloping curves, conservative rainfall distributions can be derived using the similar approach as revealed by the SCS 24-hr curves. This approach requires much less rainfall data than the statistical average.

*Key Words*: Rainfall Distribution, Runoff Prediction, SCS Type I, Type II.

## INTRODUCTION

For more than a century, the Natural Resources Conservation Service has continued working on the development of empirical formulas to improve the Soil Conservation (SCS) method for predicting storm runoff from design storm events. The SCS method (1973) presents the 24-hr Type I, IA, II, and IIA rainfall time distributions for runoff predictions. Technical Release 55 (TR-55) presents a unit graph approach to predict peak discharge according to a 24-hr synthetic storm (SCS 1986). For studies in Hawaii, Alaska, and the coastal side of the Sierra Nevada and Cascade mountain ranges, the Type I and IA curves are recommended for using TR-55. The Type II curve is applied to the remaining part of the United States, Puerto Rico, and the Virgin Islands. TR-55 only presents rainfall distribution maps for the United States. Therefore, applications of TR-55 elsewhere demand the development of the local synthetic storm distribution. It is a long existing question as to how these SCS rainfall curves represent the observed events. Comparisons between Type I and II SCS rainfall curves with the observed rainfall events can reveal some clues to assist the new formulation of localized synthetic rainfall time distributions.

In this study, the 57-year one-hr continuous rainfall data recorded in the Stapleton International Airport rain gage in the City of Denver, Colorado was analyzed using the dimensionless mass curve method. In this paper, 24 observed storm events are plotted to form a set of family curves and their enveloping curves. In comparison, the SCS Type I and II curves have a leading section that is parallel to the low enveloping curve, and a tail section that follows the high enveloping curve. Between these two sections is a sharp rise through the most intense duration of the event. This finding provides a guidance to derive a conservative design rainfall distribution in case of inadequate data.

## OBSERVED RAINFALL RECORD

Extensive efforts have been dedicated to the development of design storms, including thunderstorm and general storm. For instance, the U.S. Weather Bureau procedure (1961) suggested that depth-duration-frequency (DDF) curves be used to construct design storm rainfall curves. Huff (1967) presented a procedure to derive the distribution patterns based on the time quartile from observed heavy storms. Kerr, et al., (1974) presented a method of hyetograph construction for the State of Pennsylvania.

Dimensionless rainfall mass curve versus clock time was derived from historical rainfall data. The Bureau of Reclamation method (1977) was developed in two parts, one is for the United States east of the 105° meridian and the other is for areas west of the 105° meridian. NOAA Atlas 14 is an intensive documentation of 6-, 12-, 24- and 96-hr rainfall distributions of heavy storms for semi-arid southwest areas of the United States, Ohio River basin areas, Puerto Rico, and Hawaii. The temporal distributions are expressed in probabilistic terms as cumulative percentages of precipitation and duration at various percentiles (NOAA 2007).

The study of time distribution of rainfall requires historic data recorded as continuously as possible. The rain gage used in this study is located at 39.77° north latitude, 104.87° west longitude, and at elevation of 5286 ft. This rain gage has been operated at the Stapleton International Airport, Denver, Colorado for 57 years from August 1948 to January 2005. Using the minimum inter-event time of six hours (Guo and Urbonas, 1996), there were 253 storm events identified. The definition of a severe storm has to be established before usable information can be abstracted from the database. In this study, Denver's 1-hour 2-yr rainfall depth, or 1.0 inch, serves as the cutoff threshold to select severe storms (USWDCM 2001). Under this criterion, 25 out of 253 events were chosen to form the database for further rainfall distribution analysis.

**COMPARISON WITH SCS RAIN CURVES**

All the rainfall events were converted into their dimensionless mass curves, i.e. the cumulative precipitation depth and elapsed time are expressed as the percentages.
These 24 observed dimensionless mass rainfall curves are superimposed on one graph. Both axes in the graph are ranged between zero and 100%. As recommended, the mean curve is to fit through the central points representing the average cumulative rainfall depth percentage at each five percent time increment (Kerr, et al. 1974). Using the cut off limits such as 10% and 90%, the low and high envelop curves are defined for these observed rainfall curves.

Many studies have been conducted to verify how closely SCS Type I and II curves compare with the observed events (Reilly and Piechota, 2005). As shown in Figures 1, the center of the SCS 24-hr Type I rainfall curve is between 35% and 45% of its duration. A total of 40% of the event depth occurs within this 10% of duration. On the contrary, the SCS 24-hr Type II rainfall curve produces 60% of the event depth within 45% to 55% of its duration. As shown in Figure 1, the leading and tail sections of the Type I SCS curve are parallel to the low and high enveloping curves. A sharp rise connects the leading and tail sections. Similarly, Type II SCS curve is also formed with a sharp rise between the low and high enveloping curves.

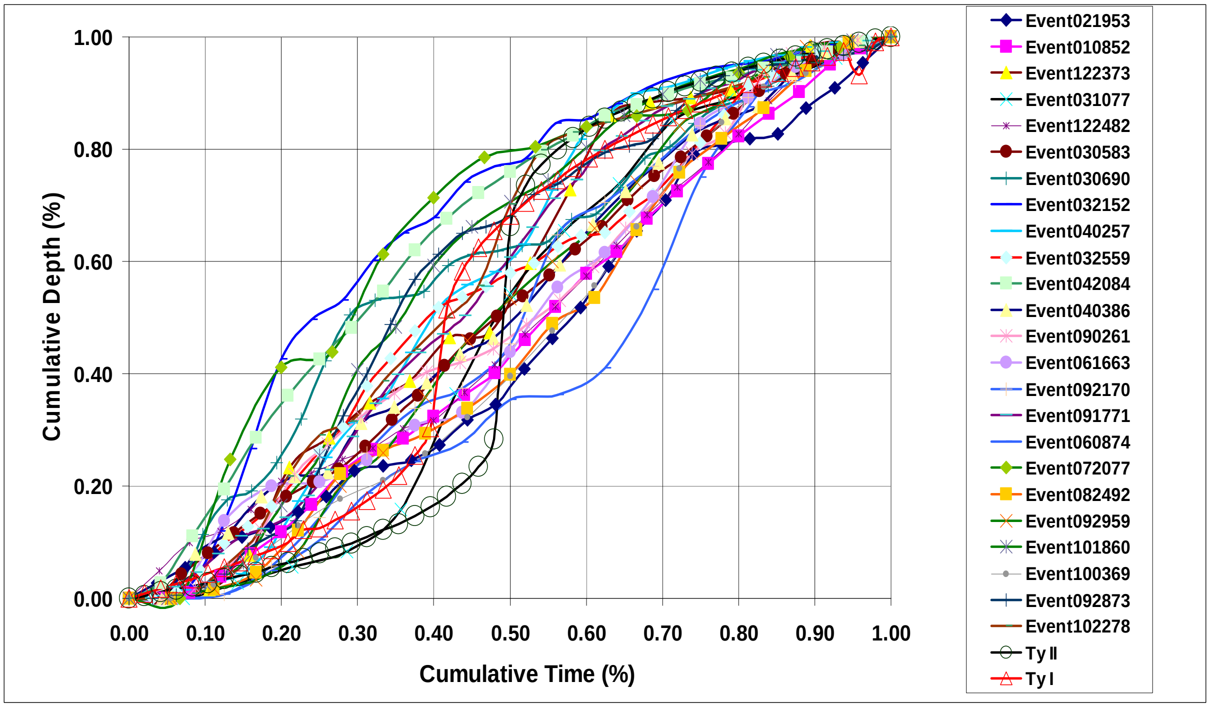


Figure 1 Comparison of Denver's Rainfall Events with SCS Type I and II Curves.

To apply TR-55 procedure outside of the United States, the local synthetic storm distribution needs to be developed. Often, rainfall data is inadequate. For instance, Figure 2 presents two severe storm events observed in Taiwan (Ushiyama 2001). It is a challenge to derive a design rainfall curve out of two events. As revealed in Figure 1, it is suggested that the conservative rainfall curve be constructed by the low and high enveloping curves, as shown in Figure 2, with a sharp rise from 40% to 50% of time interval.

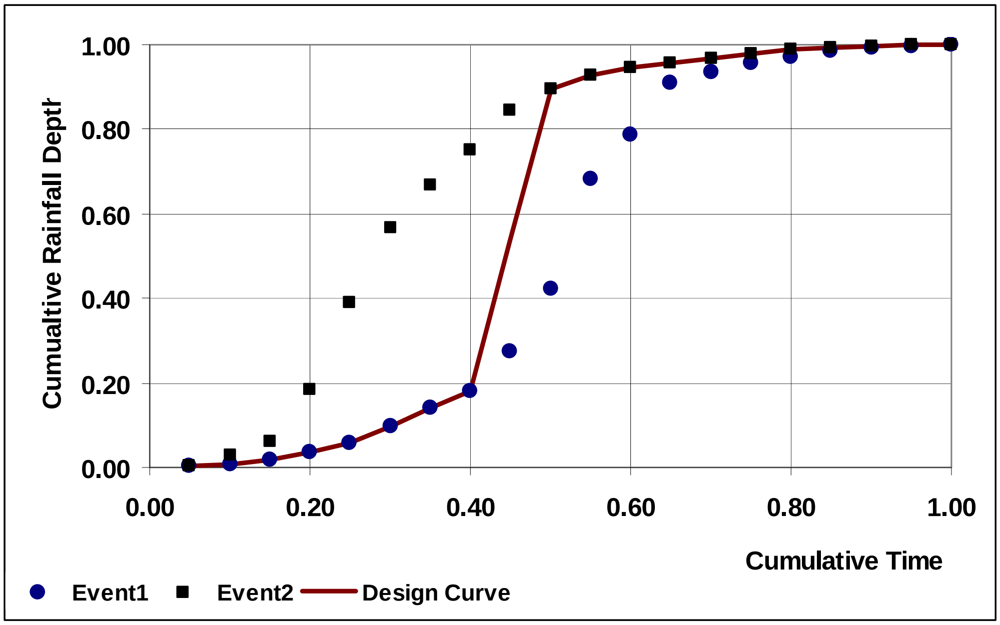


Figure 2 Conservative Approach for Design Rainfall Curve.

## CONCLUSION

The most outstanding characteristics of observed storms are their individual diversity. The analysis of 24 severe storms observed in Denver, Colorado shows that no relationship exists between time distribution characteristics and event duration. Therefore, the mass curve method is employed for the time-distribution analysis. The comparison with SCS 24-hr Type I and II curves suggests that the design rainfall curves be constructed using the low enveloping curve for the leading portion, the high enveloping curve for the tail portion, and a sharp rise in between.

With sufficient local rainfall data, the time distribution of both thunderstorms and general storms can be derived from the dimensionless mass curves. Under the circumstance that the local rainfall data is inadequate, the conservative approach discussed in this paper is to combine the low and high enveloping curves with a sharp rise through the rainfall center.

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