SEWRPC/WDNR FLOOD-PRODUCING STORM RAINFALL DISTRIBUTION STUDY: PROCEDURES FOR ANALYSIS OF RAINFALL DATA

Summary: Rainfall time distributions were developed for three- through 48-hour rain storms recorded at selected gauges in the Region. Those distributions were plotted as percent of total rainfall (y-axis) versus percent of total time (x-axis). The data were used to develop a representative storm distribution in Southeastern Wisconsin.

Background: Hourly data from the following gauges and periods of record were analyzed to determine when storms occurred:

- MMSD/City of Milwaukee gauges **WS 1204** (3/1/1993 to 6/30/2004), **WS1205** (3/1/1995 to 6/30/2004), **WS1209** (8/5/1986 to 8/6/1986 and 9/9/1986 to 9/11/1986), **WS1210** (8/5/1986 to 8/6/1986 and 3/1/1993 to 6/30/2004), **WS1212** (3/1/1993 to 6/30/2004), **WS1218** (3/1/1993 to 6/30/2004), and **WS1219** (3/1/1993 to 6/30/2004)
- Hartford 2W (3/1/1983 to 4/1/2004)
- Kenosha Airport (11/1/1997 to 10/5/2004)
- General Mitchell International Airport (3/1/1986 to 5/31/2004)

The NWS cooperator gauge at Eagle (EAGLE2W) and the USGS gauge at Jackson Creek were also originally analyzed but were dropped from further consideration because each gauge appeared to be underrecording rainfall in comparison to the other gauges. The apparent underrecording resulted in very few storms meeting the depth threshold for consideration in the analysis.

Sliding rainfall totals were computed for three-, six, 12-, 24- and 48-hour periods over the total period of record for each gauge.

For each gauge, storms with recurrence intervals of 10- years or longer were initially selected for analysis. In order to obtain an adequate sample size, the thresholds were subsequently reduced to depths in the two- to five-year recurrence interval range as indicated below.

- 3-hour storm: 10-year depth=2.40”, final threshold depth=1.50”
- 6-hour storm 10-year depth=2.79”, final threshold depth=2.00”
- 12-hour storm 10-year depth=3.17”, final threshold depth=2.50”
- 24-hour storm 10-year depth=3.62”, final threshold depth=3.00”
- 48-hour storm 10-year depth=4.20”, final threshold depth=3.50”

The months of December, January, and February and large blocks of time with no rain were omitted from the analysis. Also storms from 5/16/1997 to 5/19/1997, from 4/21/1999 to 4/23/1999, 11/28/2001 to 11/30/2001 were deleted from gauge 1205 because similar rainfall were not reflected at other nearby rainfall gauges and/or recorded streamflows at USGS gages did not indicate the occurrence of large storms.

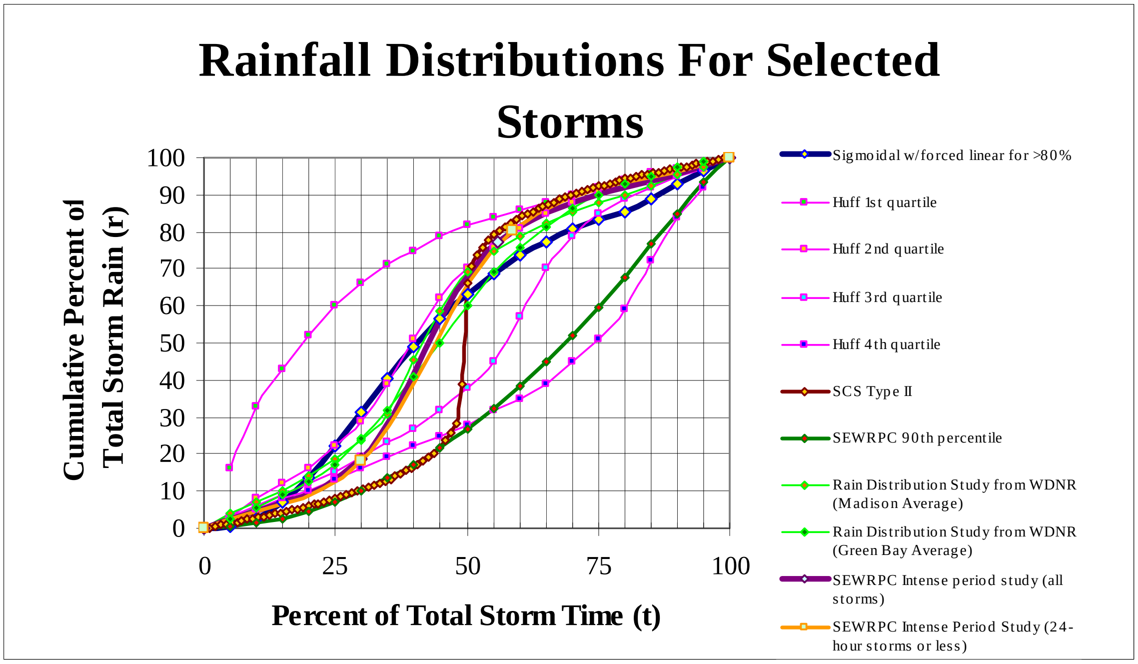
Analysis: The time and rainfall depths were converted to percent of total time (x-axis) and percent of total rainfall (y-axis) for each storm and plotted. After the storms were selected based on the minimum rainfall criteria as stated above, each event was reviewed graphically to determine what the true duration of the storm was. For example, a 6-hour time period with 2.2' of rain met the minimum criteria for a 6-hour storm. However, if rainfall only occurred over a 4-hour period, the storm was analyzed as a four-hour storm. As another example, if a 48-hour time period met the minimum depth criterion, the rainfall record was investigated to determine if it should be divided up into more storms of shorter lengths or if it should be considered as one long storm.

After all of the final storms and their durations were determined, all individual data points (percent period verses percent rainfall) were plotted and statistically analyzed to determine the best fit (average curve) for the data. Six different non-linear regression models were tested: sigmoidal, logistic, 6^{th} order polynomial, reciprocal exponential, exponential saturated, and hyperbolic. Based on the residual plots and the coefficient of multiple determination (R^2), the sigmoidal model, $r = 1/1 + 0.0950 * t^{-2.6047}$, where r is the percent rainfall and t is the percent time, was the best fit for the data. The sigmoidal curve had no asymptotic limit as it approached 100 percent of the total storm rainfall. Therefore, a linear approximation was used for greater than 80% of the total rainfall (see Figure 1).

The sigmoidal fit was compared to the Wisconsin Department of Natural Resources (WDNR) Green Bay and Madison Rain Distribution Studies curves, the Huff distribution (Huff, 1990), the SCS Type II curve (USDA, 1986), and the SEWRPC 90^{th} Percentile curve (Loucks and others, 2000).

Final Procedure: The sigmoidal curve did not show a portion of the storm with an intensity as high as the WDNR curves; therefore, another approach was considered. Under that approach, the beginning and end of the high intensity period for each individual storm was determined by inspection of the percent total storm depth versus percent total storm time plots. The percents of each total storm rainfall and total storm time corresponding to the high intensity period were calculated, as were the percents of rainfall and storm time for the periods before and after the high intensity period. The median and average percents of rainfall and storm time were calculated for the initial, intense, and final storm periods, producing four points of the total storm distribution (including the zero time, zero rainfall point) that were then used to define the representative curve for all the selected storms (Figure 1). Another similar curve was generated using only storms 24 hours or less in length.

Figure 1



Sources:

Huff, F.A., “Time Distributions of Heavy Rainstorms in Illinois,” Illinois State Water Survey, Champaign, Circular 173, 1990.

Loucks, E., Rodgers, C., Potter, K., and Hahn, M.G., “Rainfall Frequency in the Southeastern Wisconsin Region,” SEWRPC Technical Report Number 40, April 2000.

U.S. Department of Agriculture (1986). Soil Conservation Service (SCS, now known as the Natural Resources Conservation Service). TR-55, Urban Hydrology for Small Watersheds.