8. GENERAL SUMMARY AND CONCLUSIONS

Major Climatic Fluctuations

The frequency distributions of heavy storm rainfall derived from two 40-year periods (1901-1940 and 1941-1980) were examined for climatic fluctuations. The results indicated a substantial change in the intensity of these storms between the two periods. In general, the 1941-1980 rainfall for given recurrence intervals was greater than the 1901-1940 rainfall over the northern and central portions of the state. However, it was slightly less in the southeastern and extreme southern parts of the state. The change was most pronounced in the northwest, northeast, and west southwest climatic sections (figure 7).

Furthermore, results suggest that hydrologic designs based on the 1901-1940 data for a given recurrence interval would have underestimated the rainfall intensity distribution during 1941-1980 over much of the state, particularly in northeastern Illinois.

Further investigation of the existence of a climatic trend was pursued through analyses of four independent 20-year periods during 1901-1980. Frequency distributions derived from the 20-year samples provided support for the results obtained from comparison of the two 40-year periods. That is, a general trend was indicated for an increase in the intensity of heavy rainfall events over a major portion of Illinois since the beginning of this century.

Although the intensity of heavy rainfall events increased substantially over much of the state during 1901-1980, the spatial (isohyetal) patterns remained stable with respect to the locations of major highs and lows found in the statewide distribution. This indicates that the observed changes were not associated with changes in macroscale storm tracks or other large-scale features of the precipitation climate. Rather, the frequency and intensity of heavy rain events appear to have been in an upward trend since the start of the twentieth century. These findings agree well with fluctuations in other relevant conditions, including thunderstorms, total seasonal precipitation, and cloud cover.

As a result of the foregoing analyses, it was concluded that an adjustment should be made to incorporate the observed trends in our updating of Illinois rainfall frequency relations. Several investigators have shown that climatic conditions in the near future are most highly related to what has happened in the immediate past. Findings also lead to the conclusion that rainfall frequency relations should be updated more frequently than has been done in the past. An updating every 10 years (decade) would be desirable, but updates should certainly be made at intervals of no greater than 20 years.

Frequency of Heavy Rainfall Events

Statewide Patterns

Frequency distributions were determined for rain periods ranging from 5 minutes to 10 days and for recurrence intervals varying from 2 months to 100 years. Analyses were based on carefully edited daily data for 61 Illinois stations in operation during the 1901-1983 period and on hourly data for 34 stations during 1948-1983. The state was divided into ten sections of approximately homogeneous precipitation climate with respect to the distribution of heavy rainstorm events. This division was based on assessment of the 83-year sample of heavy rainstorms and on consideration of pertinent meteorological and climatological factors.

The resulting statewide pattern shows differences in rainfall frequencies that agree well with physical causative factors, including the distribution of 1) weather fronts and low-pressure centers, 2) thunderstorms, and 3) topographic, lake (Lake Michigan), and urban influences.

Both sectional mean and point rainfall frequency distributions were derived after adjusting for the climatic trend found in the 83-year sample. *The sectional mean relationships are recommended for use.* This approach lessens the effects of natural and human-induced variability (undetected measurement and computational errors) between points in an area of approximately homogeneous precipitation climate. However, some users still prefer to work with point relationships, so these relationships have been included, along with selected isohyetal patterns derived from them.

The sectional relationships have been presented in two forms: in families of curves and in a table. The tabular values provide the best means of interpolating between storm periods or recurrence intervals not included in the presentation, and they can be read more accurately than the curves, which were produced from the table. Point rainfall frequency distributions have been presented in tabular form. Because some users prefer the findings to be presented in map form, isohyetal patterns for the state

have been presented for the most critical storm periods and recurrence intervals used by the hydrologic community. Caution in their use is urged.

Urban Effects

Past research has indicated increases in rainfall frequencies in Illinois in two major urban areas. Hence a special study was made of frequency distributions for the Chicago urban area and the surrounding six counties to update a 1976 Water Survey study. This area has experienced numerous problems related to flash floods in recent years.

More detailed rainfall analyses were possible than for the remainder of the state because of the existence of an urban network of 16 recording gages covering 430 square miles that provided useful data in the 1949-1974 period. These data were used in conjunction with the 1901-1983 record from NWS stations in the six-county area in the present study. Only slight adjustment of the 1976 findings was found necessary for the urban area, but substantial changes were required for the region west, southwest, and south of the city. Adjustments to the 1976 findings are presented in this report.

An urban-induced rainfall anomaly produced by the St. Louis urban environment extends northeast, east, and southeast of the city into Illinois. This rain enhancement is confined largely to St. Clair and Madison Counties in southwestern Illinois. An adjustment to the regional rainfall frequency distributions was derived for use in Madison County; no adjustment was found necessary for St. Clair County.

Variability within Climatic Sections

Within any particular climatic section, natural variability will produce variations between sampling points for any given recurrence interval and storm period. This variability will be substantial and will occur even when long periods of record are used in developing heavy rainfall frequency distributions. Two methods of assessing this variability were used in the present study.

The first method involved comparing the variation in rainfall amounts between the frequency distributions derived for individual stations within a climatic section and the sectional mean distribution. The variability measured by this method results primarily from sampling variations due to the random distribution of heavy storms in the climatic section within the sampling period. The effects resulting from undetected measurement and computational errors and from rare events nonrepresentative of the sampling period expectancies were minimized but not completely eliminated by this approach.

The second method involved a study of outlier storms, which are those storms producing amounts that greatly exceed the amounts expected to occur at a given location for a given rain duration within the sampling period used in developing frequency distributions of heavy rainstorms. They are often considered to be storms that might occur in sampling periods exceeding 100 years; that is, they are very unusual storms.

We defined outlier storms as those that exceeded three standard deviations about the sectional mean distribution at the 100-year recurrence interval, based on the dispersion calculations in the first method described above. We then identified outlier storms for rain periods of 24 hours to 10 days in each of the ten climatic sections.

On the basis of our definition, we identified nine, ten, eleven, seven, and four outlier storms for 1901-1983 for rain periods of 24 hours, 48 hours, 72 hours, 5 days, and 10 days, respectively. The maximum rainfall amounts in these storms ranged from 9.5 to 11.3 inches for 24-hour rain periods, 10.6 to 13.7 inches for 48-hour periods, 11.0 to 15.2 inches for 72-hour rain periods, 11.6 to 15.3 inches for 5-day rains, and 14.2 to 15.7 inches for 10-day rains. The foregoing occurrences comprise less than 0.25% of the approximately 5,000 station years of data in the Illinois sample (61 stations, 83 years of record at most stations).

These storms tend to occur most frequently in summer (June-August). The 24-hour outliers occurred most frequently in north and central Illinois, but the longer storms (48 hours to 10 days) were most common in the southern part of the state. In most of the longer storms, the major portion of the rainfall occurred within a period of 24 hours or less. These storms tended to occur in clusters rather than in any orderly fashion. Combining all occurrences for 24-hour to 10-day rain periods, 41% occurred in the 1951-1960 decade.

Seasonal Relations

Separation of frequency distributions according to season provides information useful to the design of some hydraulic systems and structures. Runoff characteristics vary between seasons as a result of a variety of factors such as vegetative cover, plant foliage, frozen soils, snow cover, soil saturation, and transpiration. In this Illinois study, seasonal fre-

quency distributions were derived for the four traditional climatic seasons: winter (December-February), spring (March-May), summer (June-August), and fall (September-November). Relations were developed for precipitation periods of 30 minutes to 10 days and recurrence intervals of 1 to 100 years. Both sectional and point rainfall distributions were derived from the 61-station sample for 1901-1983.

With respect to spatial distribution characteristics, the spring, summer, and fall isohyetal patterns are very similar to those derived from the total data sample (all seasons combined). During winter, a relatively strong precipitation gradient exists from southern to northern Illinois and eliminates some of the features common to the distributions for the other seasons.

The seasonal frequency distributions for the ten climatic sections were compared for storms having intensities equaling or exceeding the 2-year recurrence-interval value. In the northernmost areas (northwest, northeast, and west sections), these storms occurred predominantly in summer. The central area (central, eastern, and west southwestern sections) also had a strong contribution from summer storms.

The south-central area (east southeast, southwest, and southeast sections) had their heavy storms quite equally divided between spring, summer, and fall. Extreme southern Illinois (southern section) showed a maximum frequency in spring and moderate occurrences during spring, fall, and winter. The winter contribution was insignificant in northern Illinois and small in the central and south central parts of the state.

In general, the season having the most heavy storms changes from summer in the north to the transition seasons (spring and fall) across the central part of the state; in the extreme south, significant contributions are made by storms in all seasons. A primary force behind this distribution is the duration of the convective rainfall season, which is relatively short in extreme northern Illinois but nearly year-round in the extreme southern part of the state. Consequently, thunderstorms, which breed most of the heavy rainstorm events, are much more frequent in the south.