USEFULNESS OF SUPPLEMENTAL FIELD DATA IN MAPPING SEVERE RAINSTORMS OF SHORT DURATION

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INTRODUCTION

Severe rainstorms of short duration, defined as those lasting 48 hours or less and producing rainfall of 6 inches or more, are usually characterized by irregular rainfall patterns, steep rainfall gradients, and small core areas of very high rainfall. Information concerning such storms is desired by many scientists and engineers for application in various fields. The present U. S. Weather Bureau climatological raingage network in Illinois does not and cannot be expected to describe adequately the characteristics of individual storms. The spacing of official network gages is too sparse to secure sufficient detailed data.

Since 1947, whenever possible, the Illinois State Water Survey has attempted to obtain supplemental data on rainfall, mainly by field searches immediately following heavy rainfall. Field measurements are collected by canvassing the storm areas to find persons having raingages or well-exposed vessels of any type, such as buckets, jars, or cans, which would furnish measurements of the storm rainfall. These supplemental field surveys over the past ten years have provided a considerable amount of interesting and valuable information on severe rain rainstorms. Moreover, the accumulated field data are now of sufficient quantity to permit evaluation of their usefulness.

Obtaining detailed information on severe rainstorms is necessary for the purpose of determining the physical characteristics of storms so that the time and space distribution of the storm rainfall may be better defined. Specific factors of interest include maximum rainfall values, mean rainfall values, areal dimensions, pattern characteristics, duration, and intensity. This information is desired principally by hydrologists and meteorologists for application in the design of hydraulic structures for small drainage areas and in the study of rainfall physics, respectively.

METHODOLOGY OF EVALUATING USEFULNESS OF FIELD DATA

The usefulness of the field data collected on rainfall is evaluated mainly by comparing them with published Weather Bureau data. Obviously, the field data plus the Weather Bureau data should more accurately describe rainstorms than the Weather Bureau data alone, but the magnitude and significance of the differences between the two must be ascertained before any evaluation can be made.

During 1957 four extremely severe rainstorms occurred in Illinois and surrounding states. Information and maps of these four storms, an unusual number for one year, are presented herein to illustrate the de-

tail obtained from field survey data. The four storms in 1957 are among the heaviest on record in Illinois. Extensive field surveys to obtain rainfall data for detailed analysis were conducted by the State Water Survey on three of the four storms. For the one storm not surveyed detailed data in the region of heavy rainfall were obtained because at that time the State Water Survey in cooperation with Southern Illinois University maintained a dense network of raingages in the storm area.

In addition to the indication of usefulness as shown by rainfall maps, the results of all field data, collected on severe rainstorms occurring in Illinois during the 1948-57 period, have been summarized and statistically compared with Corps of Engineer data and Weather Bureau data through use of area-depth relationships.

Severe Rainstorms During 1957

The first of the four severe rainstorms in Illinois during 1957 lay in an east-west belt across Illinois along the northern edge of the Shawnee Hill region on May 21-23 (Fig. 1). The storm began on the afternoon of May 21, ended 39 hours later during the forenoon of May 23, and consisted of three separate rain periods. The first and most severe period began at 4:00 p.m. on May 21 and ended in the morning of May 22; the second occurred during the afternoon of May 22, while the third and final phase of the storm occurred the night of May 22-23. Although no field survey was accomplished, 60 raingages in a 400-square-mile network located near the core of the storm furnished considerable detail on the rainfall pattern. Data from these gages and from 68 Weather Bureau gages in southern Illinois provided 128 rainfall measurements of this storm in Illinois.

Rainfall exceeding 6 inches covered an area of 2576 square miles in Illinois, Indiana, and Missouri. The maximum amount recorded in this storm was 9.60 inches at the Weather Bureau station in Harrisburg, Illinois, whereas the peak amount from the network of raingages was 8.01 inches at a gage 6 miles east of Marion, Illinois. Although the raingage network did not furnish the highest rainfall value for this storm, it did influence the isohyetal pattern in the core of the storm.

On June 14-15 one of the more severe rainstorms of any duration to be recorded in the Middle West occurred in southwestern Illinois and eastern Missouri (Fig. 2). All of the rainfall in the core of the storm near Belleville fell within a 15-hour period beginning at 5:00 p.m. on June 14. A total of 302 rainfall observations were obtained for ascertaining the isohyetal pattern and 205 of these were collected by the field survey. Rainfall amounts exceeding 16 inches occurred in the center of the storm and rainfall in excess of 6 inches fell on more than 2000 square miles. The highest rainfall recorded for the storm by a Weather Bureau gage was 12.01 inches 11 miles northwest of Belleville. However, the maximum value discovered by the field survey was 16.54 inches, 6 miles west of Belleville, which exceeded the 24-hour maximum rainfall record for Illinois. Examination of the

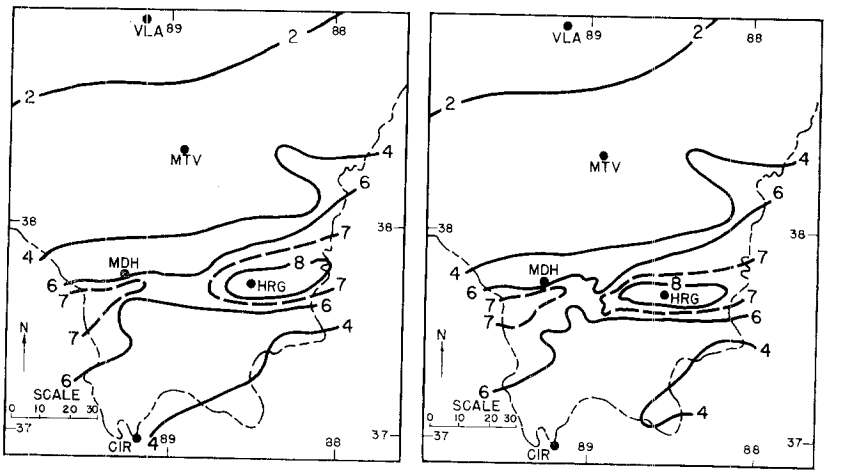


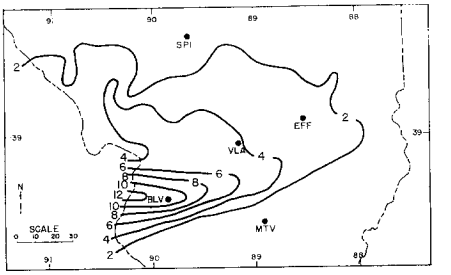
FIG. 1.—Isohyetal patterns for May 21-23, 1957.

storm rainfall maps (Figs. 2a, b) reveals that the Weather Bureau data (Fig. 2a) failed to describe adequately the core of the storm, although the overall patterns on both maps are quite similar.

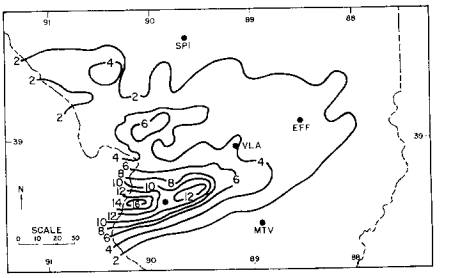
On June 27-28 the third major rainstorm in Illinois of 1957 occurred (Fig. 3); it also had an east-west orientation similar to those of the two previous storms. All of the rain in this storm occurred in less than 24 hours, while the major portion occurred within a 12-hour period beginning at 10:30 p.m. on June 27. More than 400 observations of rainfall were obtained in Illinois with 255 of these being collected by the field survey. The highest amount recorded by a Weather Bureau station was 10.82 inches at Paris. However, the highest value obtained by the field survey was 13.10 inches 7 miles west of Paris. Rainfall in excess of 6 inches fell over 3343 square miles in Illinois and Indiana. As shown in Figure 3, the field data plus Weather Bureau data (Fig. 3b) supplied considerably more detail of the rainfall pattern, which was quite irregular along the axis of the storm, than did the Weather Bureau data alone (Fig. 3a). In addition, the field data revealed a second core of more than 12 inches northwest of Effingham, which was not apparent from the Weather Bureau data.

On July 12-13 the final severe rainstorm during 1957 occurred in northeastern Illinois (Fig. 4), and was the third storm of the year to have rainfall in excess of 10 inches. This was the only storm of 1957 that did not have an east-west major axis. The north-south orientation exhibited by this storm is very unusual for these short-duration storms. An analysis of 59 severe short-duration storms which occurred in Illinois from 1915 to 1957 reveals that 84% had approximately east-west orientations while only 7% had approximately north-south orientations.

The field survey collected 211 ob-



a. Weather Bureau Data



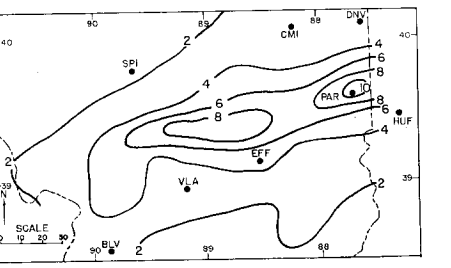
b. Field Data Plus Weather Bureau Data

FIG. 2.—Isohyetal patterns for June 14-15, 1957.

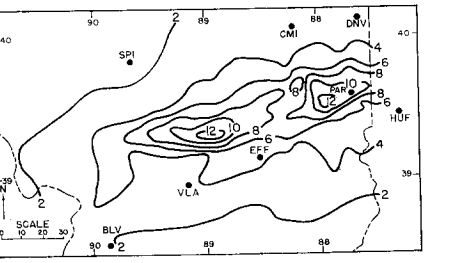
servations and, combined with those furnished by other organizations, provided a total of 454 measurements of rainfall from the storm. The Chicago office of the Weather Bureau also collected 75 measurements from volunteer observers in Cook County. In this storm, rainfall exceeding 6 inches covered an area of 1965 square miles in Illinois and Indiana. All the rainfall occurred during a 21-hour period beginning at noon on July 12. The maximum observed in this storm, 11.10 inches in Kankakee and near St. Anne, was noted by the field survey. The maximum recorded by a Weather Bureau station was 9.56 inches at Peotone. Comparison of maps (Fig. 4a and 4b) reveals that, as with other 1957 storms, considerable detail is added by the field survey data.

AREA-DEPTH RELATIONSHIPS FOR 1948-1957 SEVERE STORMS

The Illinois State Water Survey conducted field surveys of four severe rainstorms occurring in the nine years prior to 1957. Data from these storms and the four 1957 storms have been combined to provide more extensive data for statistical evaluation of the usefulness of field data on severe rainstorms. Since the physical characteristics of these storms, or similar future storms, materially affect the magnitude and characteristics of stream runoff in watersheds over which they may occur, hydrologists have devised a method for numerically describing rainstorms. This method is the area-depth relationship and can be expressed graphically as the number of square miles covered by vari-



a. Weather Bureau Data



b. Field Data Plus Weather Bureau Data

FIG. 3.—Isohyetal patterns for June 27-28, 1957.

ous average amounts of rainfall in a storm of a given duration.

Figure 5 shows 24-hour, area-depth envelope values, or a combination of the maximum observed area-depth values, obtained from the eight storms field-surveyed by the Illinois State Water Survey since 1947. An area-depth envelope curve for 24-hour storm duration which was developed from published data of the Corps of Engineers is also shown in Figure 5. These envelope values are based upon Corps of Engineers' studies of storms centered in Illinois during the 1910-46 period; their rainfall data were largely obtained from the Weather Bureau climatological network. The curve in Figure 5 based upon Corps of Engineers' data considerably underestimates the maximum area-depth values that are shown to be possible by the State Water Survey curve for areas of 100 to 7000 square miles.

A further illustration of the significant differences between the field data and the Weather Bureau data in the quantitative description of severe rainstorms is shown in Table 1. This table reveals the ratio of the area-depth values from the field survey to those derived from the climatological network data for the same eight storms during the 1948-57 period; in every instance the field survey values are larger. For instance, on the average for a 10-square-mile area, the area-depth value, as determined from the field survey rainfall map, is 1.2 times the value obtained from the Weather Bureau rainfall map, and the maximum ratio found in a single storm for ten square miles was 1.36. Figure 5 and Table 1 emphasize the inability of existing climatological raingage networks to define adequately the maximum area-depth relationships which occur in severe short-duration rainstorms.

The inadequacy of the climatological raingage network to describe these storms is a problem of gage density. The effect of raingage density on storm reports can be ascertained by comparing, for each decade during the past 40 years, the number of severe storms as determined by the number of Weather

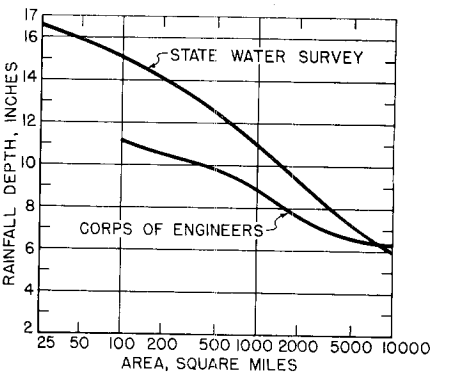


FIG. 5.—Area-depth envelope curves of 24-hour storms.

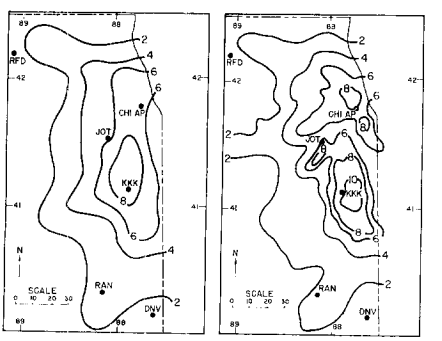


FIG. 4.—Isohyetal patterns for July 12-13, 1957.

TABLE 1.—Ratio of Area-Depth Values from Field Survey to Climatological Network.

Area, sq. miles	Ratio, av. max.
point	1.28 1.62
10	1.20 1.36
50	1.17 1.26
100	1.16 1.24
200	1.13 1.19
500	1.10 1.14
1000	1.08 1.13
2000	1.05 1.12

FIG. 1.—Isohyetal patterns for May 21-23, 1957.

Bureau raingages. During 1918-27 there were 10 severe storms as detected by approximately 90 gages, and in the following decade, 1928-37, 8 storms were discovered with roughly 100 gages in operation. The gage density in Illinois increased from 120 in 1938 to 161 in 1942, and to 240 gages by 1947; 12 storms were detected in the 1938-47 decade. The increase in storms with a rainfall of more than 6 inches prevailed during the 1948-57 decade with a total of 19, as reported by approximately 260 gages in operation. There is no method of directly proving that the 100% increase in the number of storms detected during the past 40 years can be attributed to the increase in gage density, but the increasing density is undoubtedly the principal cause. Data collected on the average physical dimensions of these storms indicate that it is quite possible that the 90 to 100 gages located in Illinois from 1918 to 1937 might not have detected the areas of 6 inches or more rainfall associated with many storms.

SUMMARY

For every severe rainstorm during the past 10 years, which was field surveyed, the maximum rainfall in the storm has been discovered by the field survey, and these values have averaged 28% higher than the maximum rainfall obtained at any Weather Bureau raingage in the storm area. Rainfall maps plotted from the field data plus the published climatological data have been found to furnish considerably more information on the storm pattern and rainfall gradients than the network data alone. The added map detail and information have provided average area-depth values ranging from 5% higher for 2000-square-mile areas to 20% higher for 10-square mile areas. Research on storms occurring prior to 1948 has substantiated findings of the past 10 years concerning the orientation of the severe rainstorms. More than 80% of the storms tend to orient their major axes in an approximate east-west position.

This evaluation of supplemental field data by comparison with Weather Bureau climatological data is not intended in any way as a criticism of that network which is effective for large-area storms, as well as being the bench marks against which supplemental data are evaluated. The differences have been shown only to reveal the usefulness of and the necessity for collecting additional rainfall data to describe severe short-duration rainstorms adequately.

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