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Two Record Rainstorms during August 2002 in the Midwest

by
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Illinois State Water Survey
A Division of the Illinois Department of Natural Resources

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Abstract

Two August 2002 rainstorms, one centered in Illinois and Indiana on August 18-19, and one in Iowa, Illinois, and Wisconsin on August 21-22, created record-setting point rainfalls of >10 inches and >12 inches, respectively. Return intervals of both storms' heavy rain amounts for 3-, 6-, and 12- hour durations exceeded once in 100-year values. Storm characteristics were similar to those of 36 past rainstorms during 1951-2001 that also were investigated in comparable detail. The similarities included the fact that most of the rain fell over 8 hours at night, storm areas were oriented west-east, and the region with >2 inches covered more than 9,000 square miles. Synoptically, conditions were similar to those of most past rainstorms: the storms developed south of an west-east-oriented front, precipitable water values were exceptionally high, >1.7 inches, and the frontal position and low-level jet stream proximity led to training of thunderstorms along the same path.

However, the August 2002 rainstorms were different than past rainstorms in that the two storm events occurred just 2.5 days apart and in relatively adjacent areas. No other major past storms had occurred in such close time proximity. Both storms occurred where the prior 2.5-month rainfall was much below normal, creating much below normal soil moisture and droughtlike conditions for crops. All 36 previous major assessed rainstorms occurred after prolonged periods of average to much above average rainfall. This pre-storm difference in moisture conditions greatly affected the storms' impacts, and both August storms produced small economic losses compared to those of comparable prior storms. A much greater percentage of total storm rainfall infiltrated the soil, resulting in less runoff. High early peak flows in rivers where the heaviest rain fell quickly returned to normal levels within 10-22 days. Flooding, mostly near river courses, quickly dissipated, and flood losses were minimal. The major economic impact of the two August storms related to the added soil moisture and, in turn, the positive effects on soybean crops. Soybeans were in the pod-filling stage and shy of soil moisture when the storms occurred, and the rain-filled soils led to increased yields valued at $51 million in Illinois and Iowa.

Contents

Acknowledgments

This study was conducted as part of the research program of the Midwestern Regional Climate Center, funded by the National Oceanic and Atmospheric Administration (NOAA). However, the views expressed herein are those of the authors and do not represent those of NOAA or any of its sub-entities. Linda Hascall assisted with the preparation of certain figures and formatted the report in final form, and Eva Kingston carefully edited the text. Several county Extension agents in Illinois helped by providing storm rainfall amounts for farms after the two storms and names of farmers with raingages. Brian Jewitt, Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign, kindly provided surface analyses and some upper air data. Radar images and wind profiler maps were obtained from on-line image archive of the Warm Season Precipitation Episodes Project of the U.S. Weather Bureau Program, the NOAA Radar Operations Center, and National Center for Atmospheric Research (http://locust.mmm.ucar.edu). Lenny Walther, Cartography Laboratory, Northern Illinois University, prepared the watershed maps. Kenneth Kunkel and James Angel provided useful scientific reviews of the text and made valuable suggestions.

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Introduction

Between August 18 and 22, 2002, the central portion of the Midwest experienced two severe rainstorms, each producing more than 10 inches of rain in 8 hours, amounts in excess of the 100-year return period values. Assessment of such major rainstorms that cause serious impacts has been an ongoing activity of the Midwestern Regional Climate Center (MRCC) since its inception in 1987. These events are an important feature of the region's climate, and the MRCC receives numerous inquiries about the dimensions and impacts of such intense rainstorms from policymakers, hydrologists, agricultural interests, and other weather-sensitive sectors throughout the Midwest. They typically want information about storm dimensions, damage assessments relevant to relief needs, and the storm's hydroclimatic rating.

Prior MRCC storm assessments include the major rains leading to the record 1993 Midwestern floods. Rainfall amounts and their hydroclimatic significance (Kunkel, 1996), and the resulting impacts (Changnon, 1996), were studied extensively. Study of a severe rainstorm that struck Wisconsin, Illinois, and Indiana in July 1996 defined rain amounts, their hydroclimatic significance (Changnon and Kunkel, 1999), and their impacts (Changnon, 1999). Floods cause more damages in the Midwest (Iowa, Illinois, and Missouri) than elsewhere in the nation, and the climatic and societal factors underlying this situation also have been assessed (Changnon et al., 2001). Documenting such severe storms is a high priority of the MRCC.

Every Illinois storm since 1950 that produced 10 inches or more rainfall in 1- to 2-day periods, many initially detected and reported by farmers and the news media, has undergone intensive study involving field surveys to gather spatial rainfall and damage data essential to defining storm dimensions and characteristics. A study of 10 such storms and their various characteristics (size, shape, duration, etc.) was used to develop an initial statistical model of such storms (Huff and Changnon, 1964).

Assessment of subsequent storms was based on a sample of 26 intense events between 1950 and 1979. These storms underwent extensive analysis to define shapes, orientations, durations, area-depth relationships, and the frequency of area mean rainfall amounts for 6- to 48-hour periods (Huff, 1979). They typically produced rainfall amounts of 2 inches or more over 10,000 square miles, peak rain amounts of 10 inches or more, rain that began at 1900 Central Daylight Time (CDT) and lasted 8-10 hours, a pattern oriented west-southwest and east-northeast, and length-to-width ratios of 3.8 to 1. All storms occurred over areas that had experienced average to above average rainfall in preceding months, and the antecedent rainfall in the 10 days before 65 percent of the storms was more than 2.8 centimeters (cm) above average (Huff, 1979). All the storms produced extensive flash-flooding, major damages in urban areas, severe crop losses, and light to moderate soil erosion.

Intensive field measurement and study of subsequent rainstorms, including those with the 1993 flood (Kunkel, 1996), in 1996 (Changnon and Kunkel, 1999), and in 2001 (Changnon and Westcott, 2002), added to the wealth of storm information. Characteristics of these 10 recent storms all fit Huff’s 1979 storm model, suggesting that Midwestern intense short-duration rainstorms had been adequately defined.

The two severe rainstorms in the central Midwest during mid-August 2002 have been extensively investigated for three major reasons:

1) To define the rain amounts and their hydroclimatic significance.
2) To define the meteorological conditions that caused these two storms only 2.5 days apart after a prolonged dry period.
3) To measure storm impacts.

The two storms were found to have many characteristics similar to those of other severe Midwestern rainstorms studied over the past 50 years (Huff, 1993). Prior storm studies began in 1951, as part of the hydrometeorological research program of the Illinois State Water Survey (ISWS). Extensive studies of 26 severe rainstorms, each causing 10 or more inches of rain in 12 hours or less, led to a model of how such storms formed and their characteristics (Huff and Changnon, 1964; Huff, 1978).

Both storms in August 2002 began in the early evening and ended by noon on the following day; peak amounts in each storm exceeded 10 inches. The heaviest rainfall occurred at night, a common feature of severe rainstorms (Huff, 1979). The storms resulted from a series of major convective cells that developed and moved west-east along approximately the same path, leading to heavy rain totals. These characteristics are also common in most previous rainstorms assessed (Huff and Angel, 1989). However, the occurrence of two severe rainstorms close in time is unusual. They occurred within 2.5 days of each other, a condition not found in studies of storms occurring in Illinois and adjacent states since 1950.

The first storm began in the late evening of August 18 in western Illinois, between 2100 and 2200 CDT. Heavy rainfall developed as the convective cells moved eastward, with rains beginning from 0200 CDT to 0400 CDT on August 19 in east-central Illinois where the heaviest rainfall occurred. The rain at most points lasted 5-8 hours. The storm moved eastward across central Indiana, reaching the Indianapolis area by 0700 CDT on August 19. The system’s rainfall ended as it reached the Indiana-Ohio border at 1100 CDT.

The second August rainstorm began in east-central Iowa at 1900 CDT on August 21. Large rain cells had developed by the time the storm reached Dubuque at 2000 CDT. The massive cells moved eastward, with rain beginning at 2200 CDT at Rockford, Illinois. The heaviest rains fell between Dubuque and Rockford, with totals exceeding 12 inches. By midnight the storm had reached Chicago’s northern suburbs and then dissipated over Lake Michigan. Most point rainfall durations were 7-11 hours. Other moderately heavy rains occurred later on August 22-23 in southern Iowa and central Illinois, producing 1- to 3-inch amounts.

The ensuing text has three major parts: a detailed description of the storm rainfall, including its hydroclimatic rating; a meteorological analysis of the conditions that created the storms; and a definition of the impacts resulting from the heavy storms.

Rainfall Conditions

Data

Data that allowed definition of the rainfall patterns came from several sources, including the first-order stations and cooperative substations operated by the National Weather Service (NWS). Other data came from dense networks of recording raingages operated by the ISWS. One network in central Illinois had rainfall from the August 18-19 storm, and another in northeastern Illinois had rainfall from the August 21-22 storm. Data also were obtained from raingages in the Illinois Climate Network. Data from these networks and from the NWS first-order stations were hourly amounts. Numerous county Extension agents assisted by providing storm totals collected from farmers with gages and names of farmers with gages who were contacted later. Storm totals also were obtained from the NWS cooperative substations. Storm rainfall maps based on radar estimates developed by the NWS were obtained from the NWS. Streamflow data came from the U.S. Geological Survey. Soil moisture data came from the ISWS Illinois Climate Network, and crop yield data from the Illinois Farm Bureau.

August 18-19, 2002

Total storm rainfall produced on August 18-19, 2002, is shown (Figure 1). The storm-typical elongated west-east shape deposited the heaviest rainfall midway along the storm core. Rains exceeding 1 inch fell over 34,000 square miles, and area-depth values are shown (Table 1). Storm rain totals, as defined by NWS radar measurements, are shown (Figure 2). Much of the area of heavy rainfall (>2 inches) had experienced much below normal rainfall since early June.

Rain cells that formed this storm initiated rainfall at 2100 CDT near Peoria, Illinois, and the east-moving rain system reached Urbana, Illinois, by 0345 CDT. The core of the storm (Figure 1) straddled the Illinois-Indiana boundary. Measurements from three farms in northern Vermilion County (Illinois) were 10-10.5 inches. The storm began dissipating in central Indiana, with rain beginning at Indianapolis at 0700 CDT and ending there by 1100 CDT.

At locations where storm totals equaled or exceeded 3 inches, point rain durations were 5-6 hours. These 6-hour 3-inch rainfall values rate as once in 10-year values (Huff and Angel, 1992).

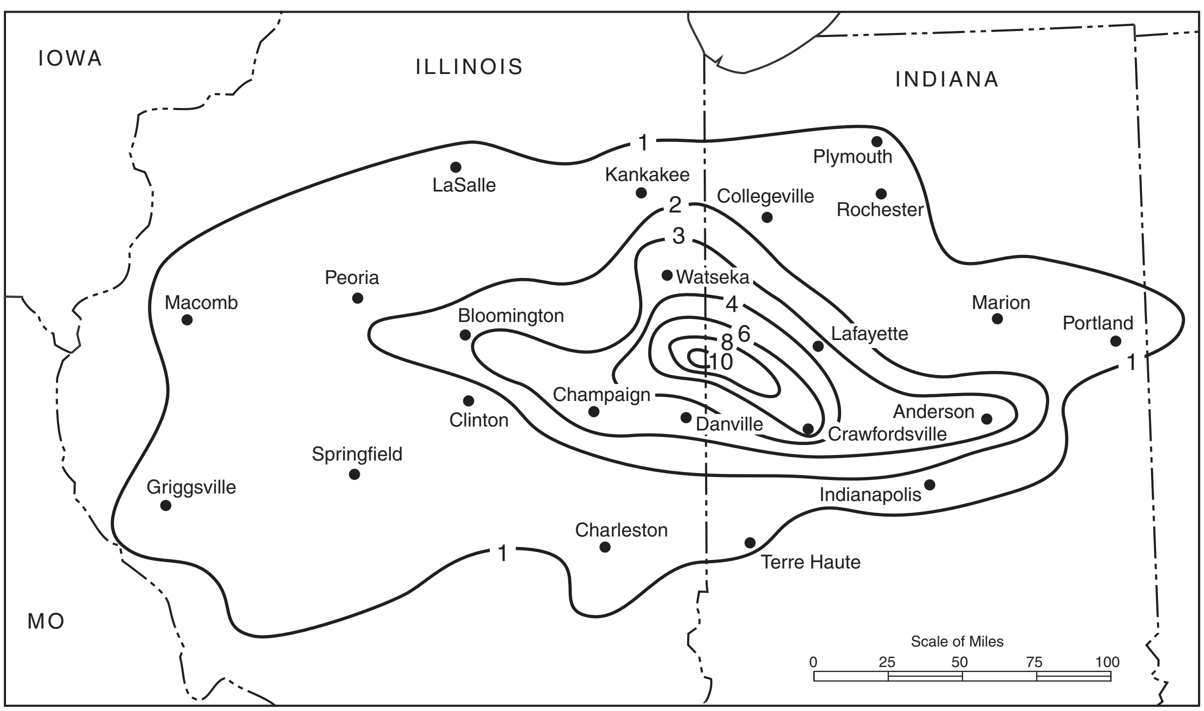

Figure 1. Total rainfall (inches) associated with the rainstorm on August 18-19, 2002.

Table 1. Area-depth Values for the Two August 2002 Rainstorms

	Area, mi²	
Rain amount, inches	*August 18-19 storm*	*August 21-22 storm*
2 or more	9100	10410
3 or more	7505	8225
4 or more	3100	6110
5 or more	2350	4260
6 or more	1500	3385
7 or more	980	2115
8 or more	650	990
9 or more	415	655
10 or more	65	280
11 or more	0	108
12 or more	0	67

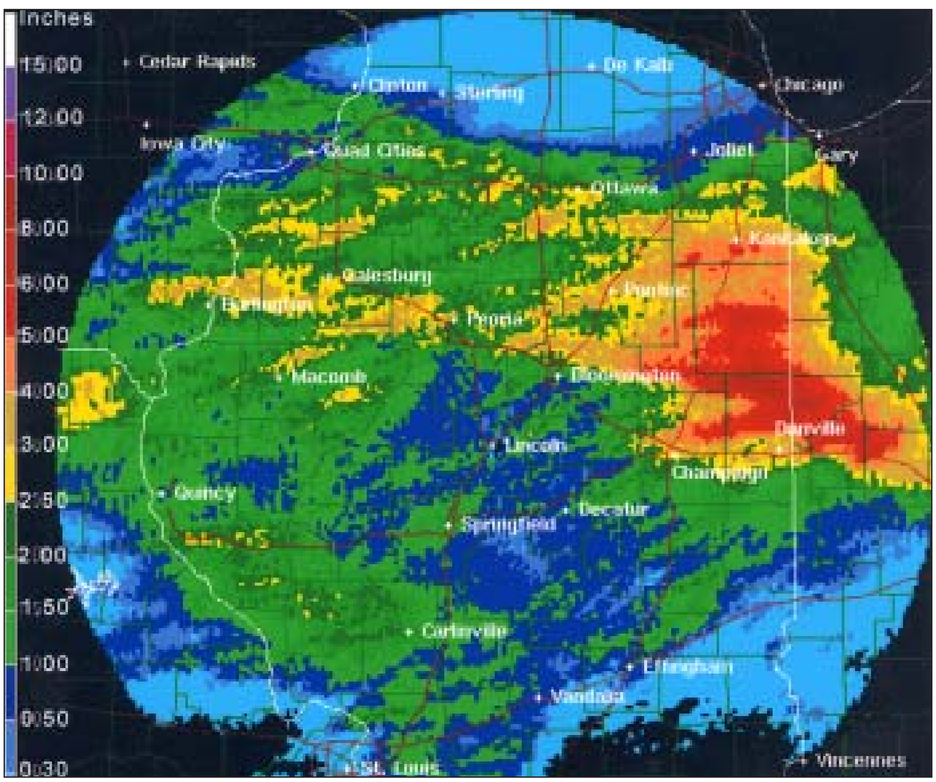

Figure 2. Rainfall pattern from 2013 CDT, August 18, to 0757 CDT, August 19, based on estimates using NWS radar data.

The 6-hour 4-inch values (Figure 1) rate as once in 25-year values; those of 4.5 inches or more rate as once in 50-year values; and those of 5 inches or more are once in 100-year values. Hence, the 2,350-square-mile area with >5 inches of rain (Table 1) experienced 100-year or greater return values.

Moderately heavy rains, defined as 2 inches or more, fell in an area that had experienced much below normal rainfall since early June. The storm area received only 3.5-4.5 inches of rain in the 2-month period from mid-June to mid-August. These amounts were 3.5-4 inches below normal. The dryness preceding the storm affected the hydrologic distribution of the storm's heavy rainfall (see "Impacts").

August 21-22, 2002

The total rainfall for the August 21-22, 2002, nocturnal rainstorm is depicted (Figure 3). Amounts exceeded 12 inches over a small area between Galena and Freeport, Illinois, and a long swath of more than 5 inches extended from Iowa to Lake Michigan. The cells that led to this record storm developed near Delaware, Iowa, around 1900 CDT, and then moved rapidly eastward, reaching Dubuque, Iowa, by 2000 CDT, and 9.14 inches fell in the ensuing 11 hours, primarily between 2100 CDT and 0400 CDT.

Intensification of the storm continued into northwestern Illinois with amounts exceeding 12 inches. The storm produced 6.82 inches in Rockford from 2200 CDT until 0800 CDT. The swath of 6 inches or more extended eastward to northwestern Chicago. Rainfall began at O'Hare Airport at 0000 CDT on August 22, and ended by 0930 CDT, producing 4.41 inches of rain. Figure 4, which is based on NWS radar data, defines the storm track across northwestern Illinois, southern Wisconsin, and southern Lake Michigan where the rains ended.

Storm rainfall totals based on data from the Cook County Raingage Network (Figure 5) define a narrow track of heavy rain, with the area experiencing >5 inches before the storm exited into the lake. The southern portion of the network got no rain. Most point rain durations in the network with amounts of 2-5 inches were 7 hours or less.

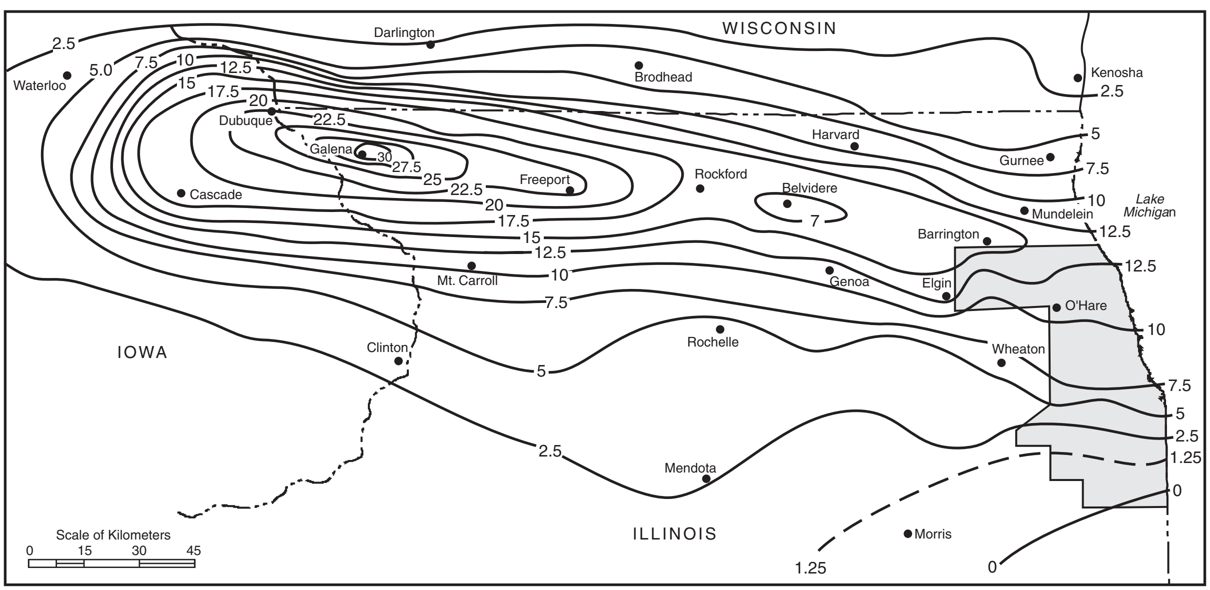

Figure 3. Total rainfall (inches) associated with the rainstorm on August 21-22, 2002.

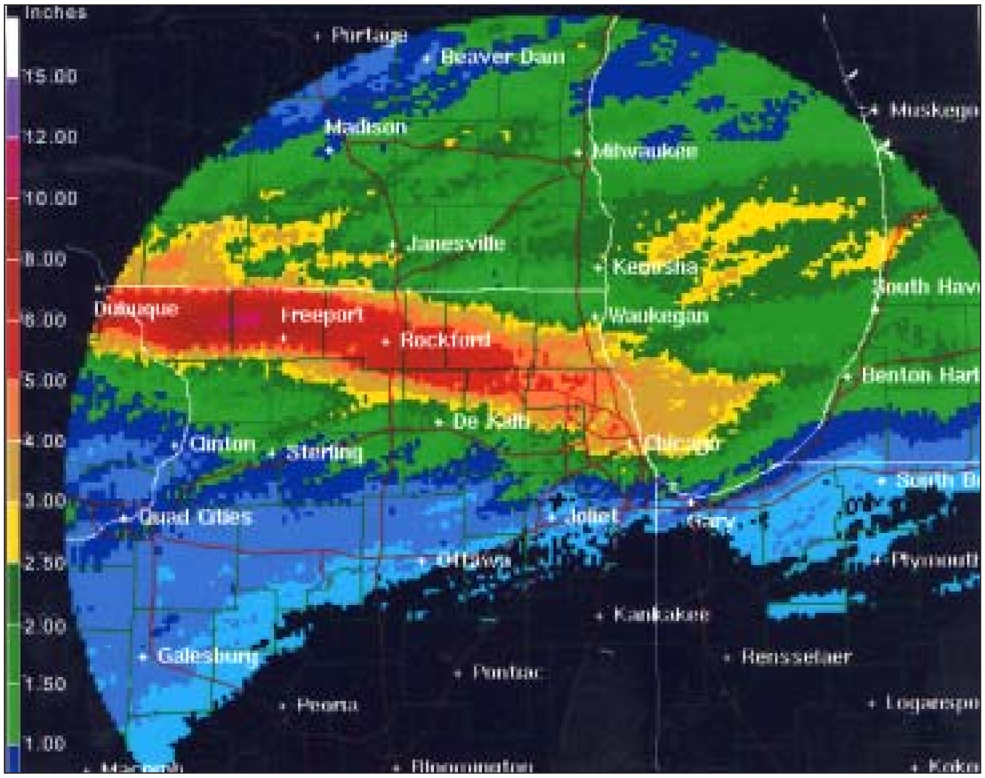

Figure 4. Rainfall pattern from 1508 CDT, August 21, to 0827 CDT, August 22, 2002, based on estimates using NWS radar data.

Figure 6 provides the rainfall pattern for August 21-23, 2002. Rains began re-developing in central Iowa near midnight on August 22-23 when the main rainstorm was moving over Chicago. This second rain system moved east-southeast, reaching Peoria by 1200 CDT on August 23. This system produced more than 3 inches of rain in west-central Illinois and in east-central Illinois where the August 18-19 storm had occurred. Rains also occurred in Wisconsin north of the main storm track during the morning and afternoon of August 22.

Inspection of Table 1 shows the area-depth values associated with the rainstorm of August 21-22. Areas for a given depth were generally larger than for the August 18-19 storm. Because most of the heavy rain on August 21-22 fell in 6 hours, the storm was rated on 6-hour and 12-hour durations (Huff and Angel, 1992). The heaviest 6-hour amounts included the 3,300-square-mile area of greater than 6 inches shown in Figure 3. This area had once in a 100-year rain amounts for 6-hour durations.

Assessment of the storm rainfall based on durations of 12 hours, which embraced all point durations, reveals areas of greater than 3.5 inches, which rated as once in 5-year amounts. Areas with 4 or more inches (Table 1) rated as once in 10-year values; values of 5 inches rated as once in 25-year events; values of 5.5 inches or more rated as once in 50-year values; and values in excess of 6.5 inches are amounts expected at least once in a 100-year period. More than 2,600 square miles had rains at the once in 100-year level for 12-hour durations.

This severe rainstorm also occurred in an area that had deficient rainfall in the two months preceding the storm. Amounts during that period were 30-50 percent below normal, a situation influencing the impacts of the storm.

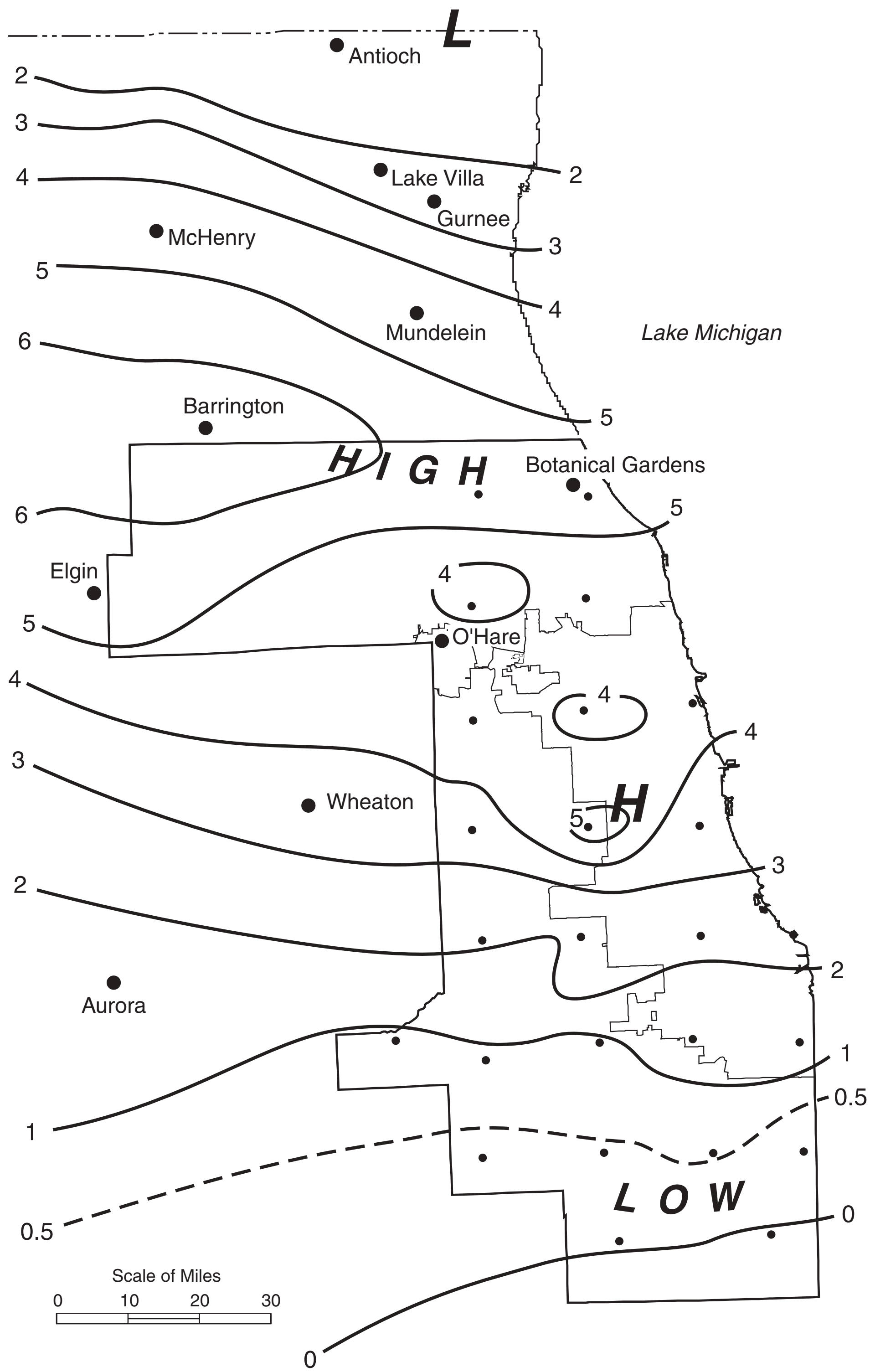

Figure 5. Rainfall pattern (inches) for the Chicago area, August 21-22, 2002, based on data from the Cook County Raingage Network.

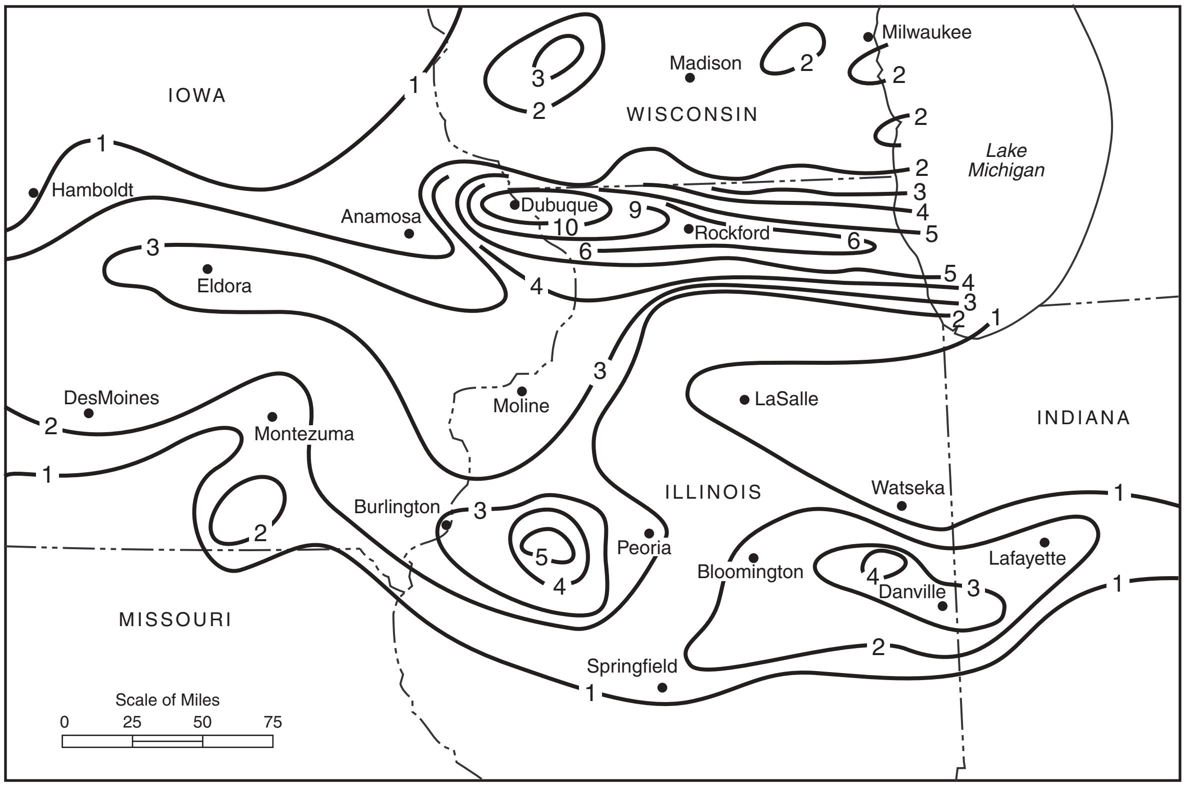

Figure 6. Rainfall pattern (inches) across Iowa, Wisconsin, Illinois, and Indiana, August 21-23, 2002.

Both August 2002 rainstorms occurred at the end of dry growing seasons. Review of pre-storm conditions for the 36 heavy prior rainstorms in the Midwest that had undergone extensive study revealed that the earlier storms occurred in areas that had experienced either normal or above normal rainfall in the preceding 2-3 months. Thus, the August 2002 storms were anomalous in occurring in areas with on-going dry periods.

Weather conditions across Illinois and surrounding states prior to the two August storms are important to understand the localized dryness in the storm areas. The spring of 2002 was cool and extremely wet, rated as fourth wettest in the Midwest since 1898. Midwest temperatures in June were 2-3.5°F above normal, and precipitation was 0.5-1 inch above normal, but 0.7 inch below normal in the Illinois areas where the two storms occurred. July temperatures were 3-4°F above normal, and precipitation was below normal across Illinois and Iowa, being 2 inches below normal where the northern storm would occur and 1.3 inches below normal where the central Illinois storm would occur. Dry conditions, an inch below normal, continued the first two weeks of August in the two storm areas, a result of natural variability typical of convective rainfall. Thus, the two storms occurred at localized sites with quite dry conditions for 2.5 previous months, whereas precipitation in other surrounding areas was normal to above. Warm-dry pre-storm conditions led to excessive evapotranspiration that created low soil moisture. This pre-storm situation was anomalous because the 36 prior storms since 1950 had occurred over areas that experienced average to much above average antecedent rainfall. This difference in pre-storm conditions had a profound effect on the types of impacts caused by the August 2002 storms.

A second anomalous situation involving the two August storms was the closeness of their occurrence in time. None of the prior 36 storms since 1950 were associated with a second storm within 2.5 days. The closest temporal events were two storms in June 1957 that occurred 12 days apart.

Meteorological Conditions

Synoptic Weather Conditions Associated with the August 18-19 Rainstorm

Development of the nocturnal thunderstorms producing the heavy rain on August 18-19, 2002, was related to the development of a strong low-level nocturnal jet south of a stationary front in the Midwest. Very moist air pumped northward by this jet converged with the strong frontal boundary, resulting in the rapid development and persistence of heavy thunderstorms. These thunderstorms continued to develop along the quasi-stationary boundary until the 500-millibar (mb) short wave and associated surface wave moved northeast, and the low-level winds began to weaken and veer to a more westerly direction.

At 1900 CDT on August 18, a stationary front bisected Illinois from western Kansas to near St. Joseph, Missouri, to near Quincy, Illinois, to just north of Champaign, Illinois, then north of Indianapolis, Indiana (Figure 7). South of the front, temperatures were in the 80s and 90s. The temperature gradient across the front was nearly 30°F in eastern Kansas and Nebraska (Figure 8a). Dewpoints were generally in the upper 60s and lower 70s south of the front (Figure 8b).

The cold front had moved through Illinois on August 17, 2002, almost as far south as the Ohio River before returning northward the next day. The 500-mb winds (Figure 9) over the Midwest were generally parallel to the surface front, an indication that the front would remain stationary. A strong 500-mb short wave from western North Dakota into southeastern Wyoming was reflected on the surface as a surface wave in western Kansas between Russell and Garden City. At lower levels, wind profiler data indicated a small 30-35 knot jet at 500 meters (m) over northern Oklahoma and northern Kansas, and a narrow 25-30 knot southerly jet from northwestern Texas into southeastern Kansas (Figure 10). At the 850-mb level, a 25-30 knot jet extended from western Oklahoma east-northeastward into western Illinois (Figure 11). Very strong surface moisture convergence [81 grams/kilogram/second (g/kg/s)] had developed on the nose of the jet in eastern Kansas and western Missouri (Figure 12). At the time there was no precipitation in eastern Kansas or western Missouri, and only scattered precipitation in western Kansas was associated with the surface wave (Figure 13). Precipitable water values calculated from the 1900 CDT soundings approached 2 inches along the front and southward (Figure 14).

By 2200 CDT, showers and thunderstorms were developing in southern Iowa (Figure 15), coinciding with the strengthening of the low-level jet (LLJ) to 35 knots. The LLJ also was becoming broader and more well-defined, concentrating the surface moisture convergence along a long axis from central Kansas through northern Missouri and into central Illinois. This pattern has been shown to increase the likelihood for training convection (Junker et al., 1999). Another area of precipitation was just beginning to develop near Burlington, Iowa.

By 2300 CDT, two distinct bands of thunderstorms had formed. One extended from south-central Iowa to the Quad Cities and another from near Burlington, Iowa, to Peoria, Illinois (Figure 16).

By 0100 CDT on August 19, the thunderstorms were producing heavy rain from near Bloomington, Illinois, east through Ford and Iroquois Counties in Illinois (Figure 17). Animation

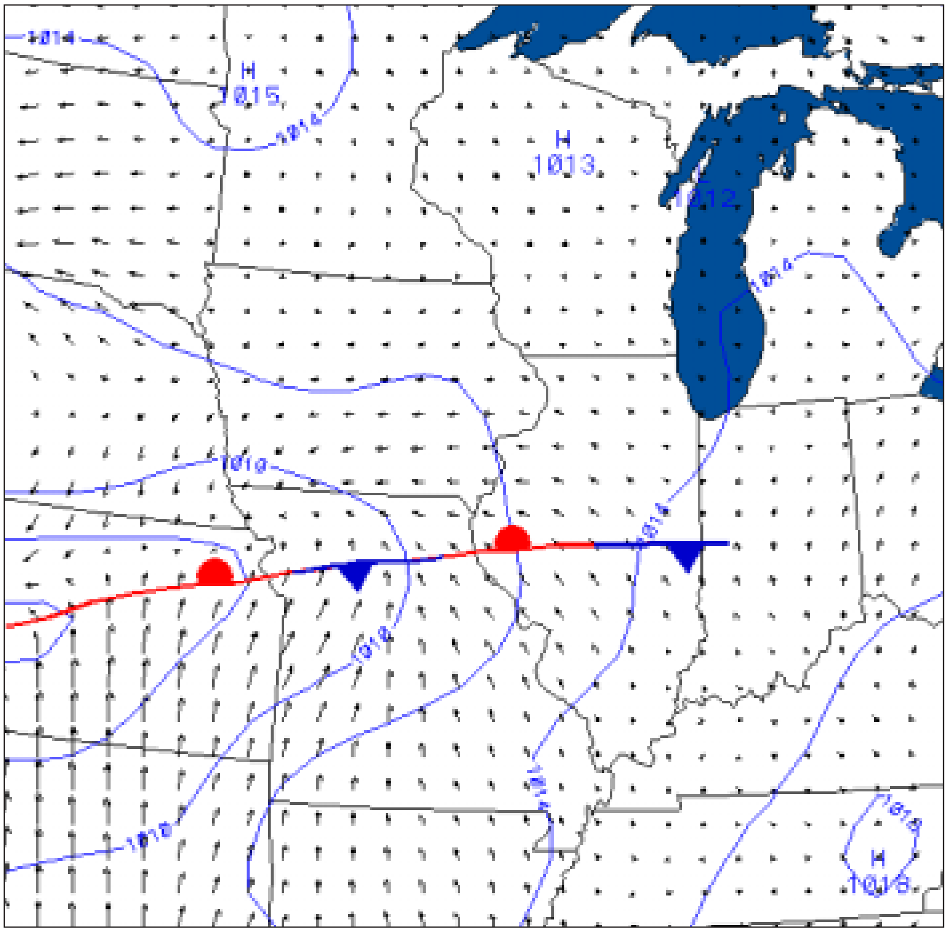

Figure 7. Surface winds and pressure at 1900 CDT, August 18, 2002.

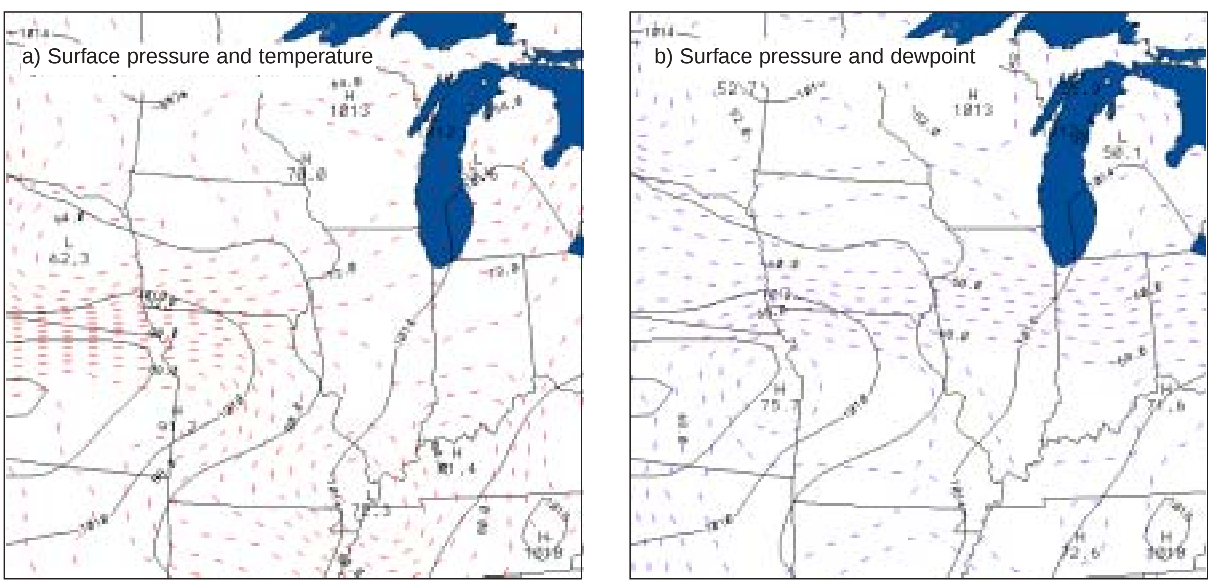

Figure 8. August 18, 2002: a) surface pressure and isotherms at 1900 CDT, and b) surface dewpoint temperatures and pressure analysis at 1900 CDT.

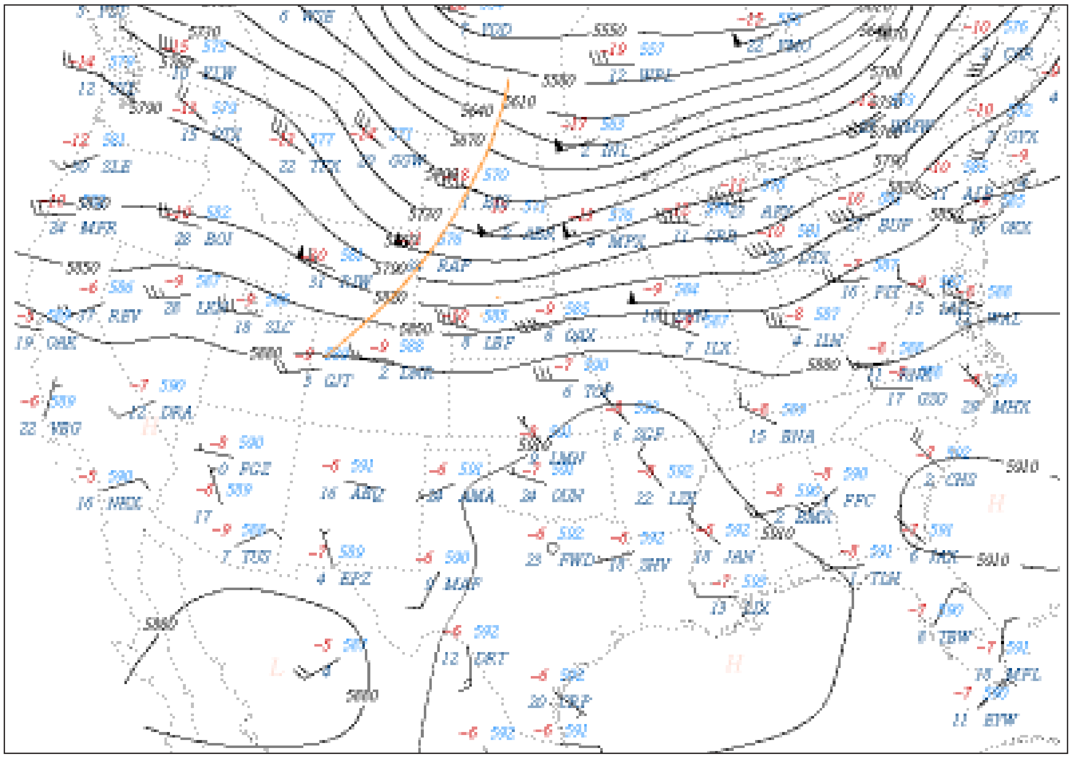

Figure 9. The 500-mb analysis at 1900 CDT, August 18, 2002.

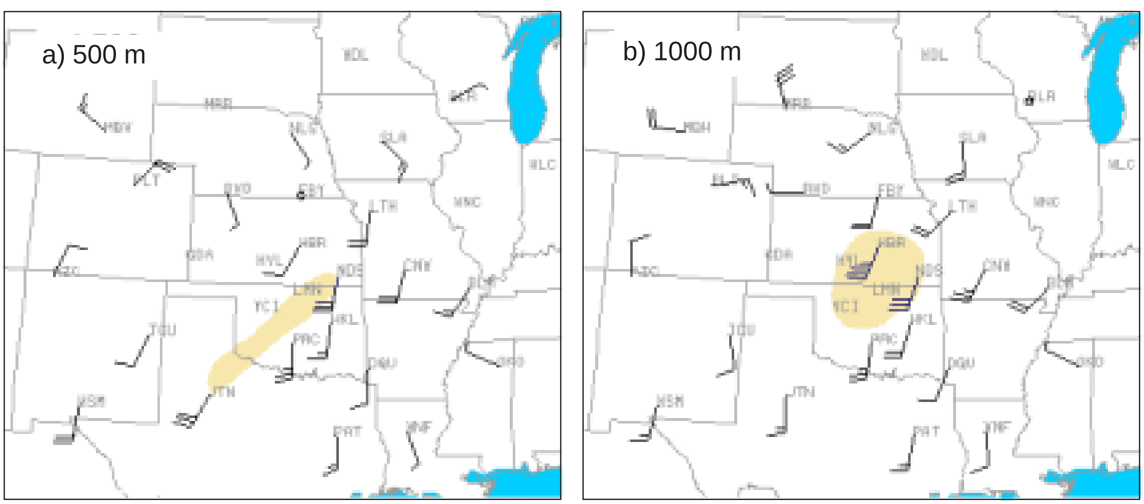

Figure 10. Analysis of wind profiler data at 1900 CDT, August 18, 2002:
a) 500 meters (m), and b) 1000 m. Shading denotes winds of 30 knots or greater.

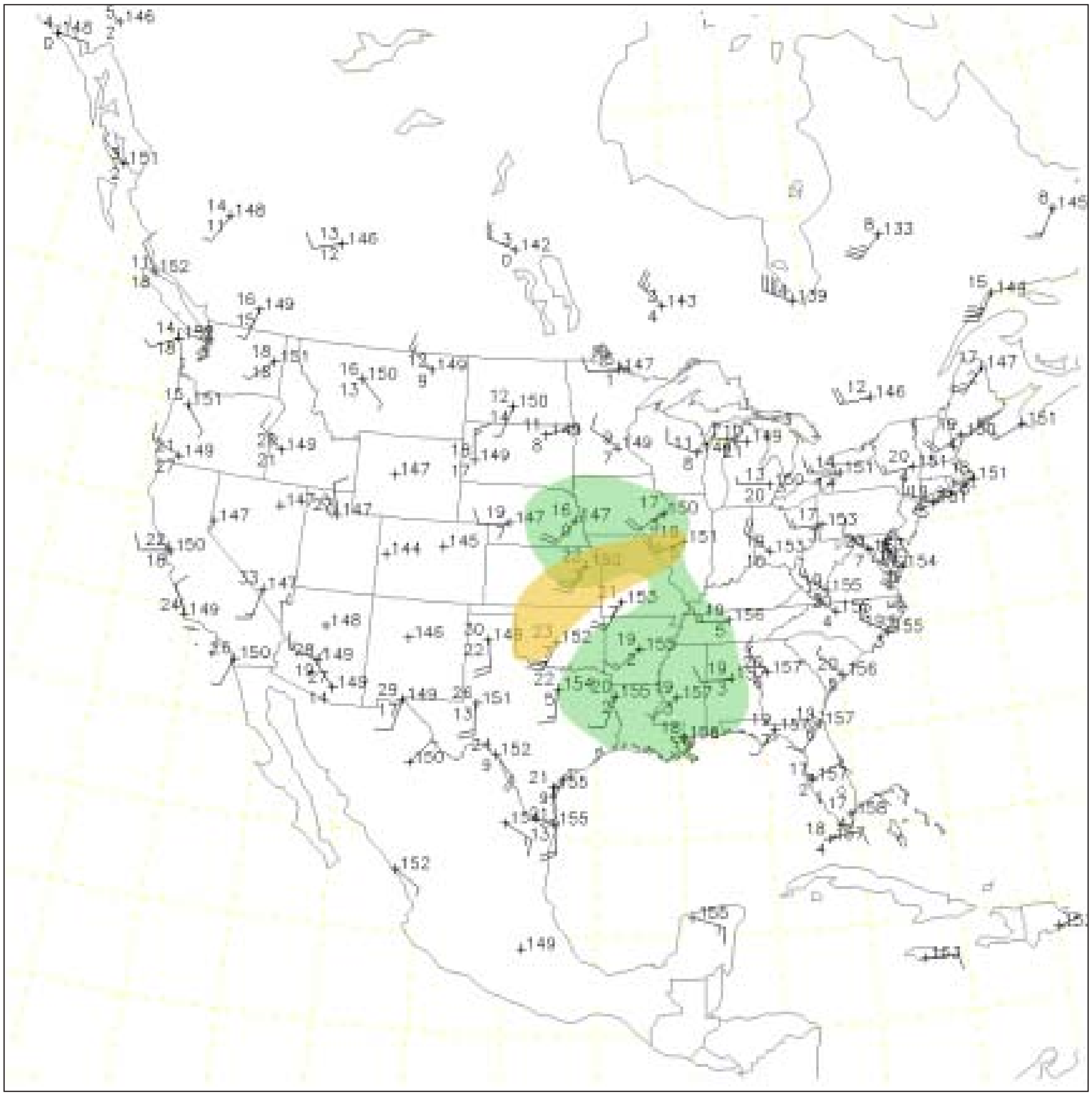

Figure 11. The 850-mb analysis at 1900 CDT, August 18, 2002.
Green shading depicts dew point depressions of 5°C or less.

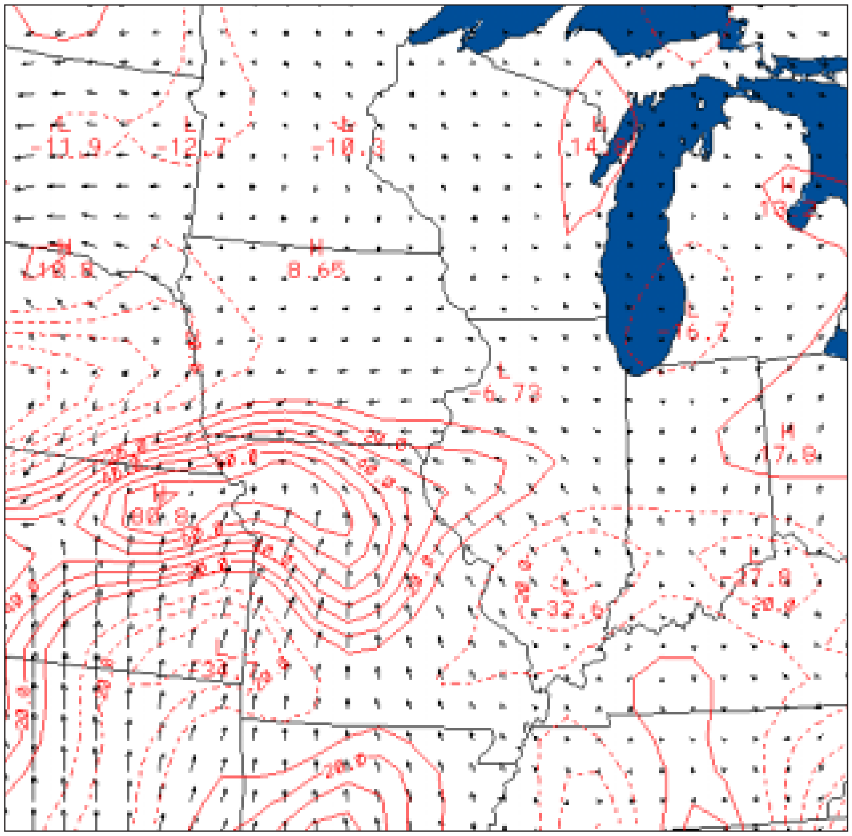

Figure 12. Surface moisture convergence (g/kg/s) at 1900 CDT, August 18, 2002.

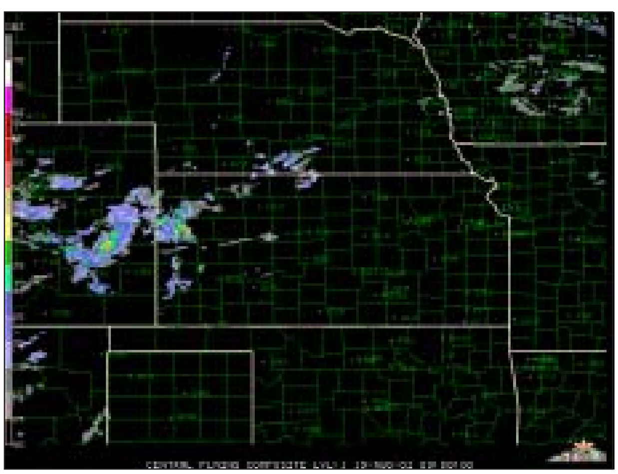

Figure 13. Composite reflectivity radar image at 1900 CDT, August 18, 2002.

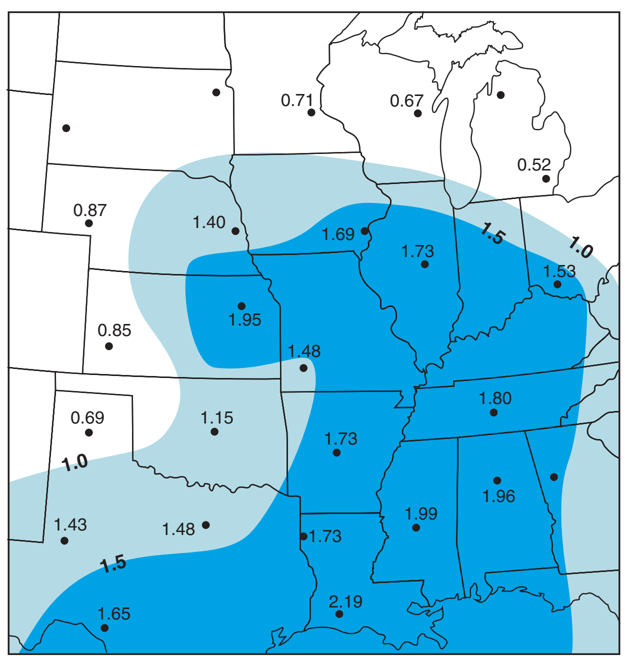

Figure 14. Precipitable water (inches) calculated from soundings at 1900 CDT, August 18, 2002.

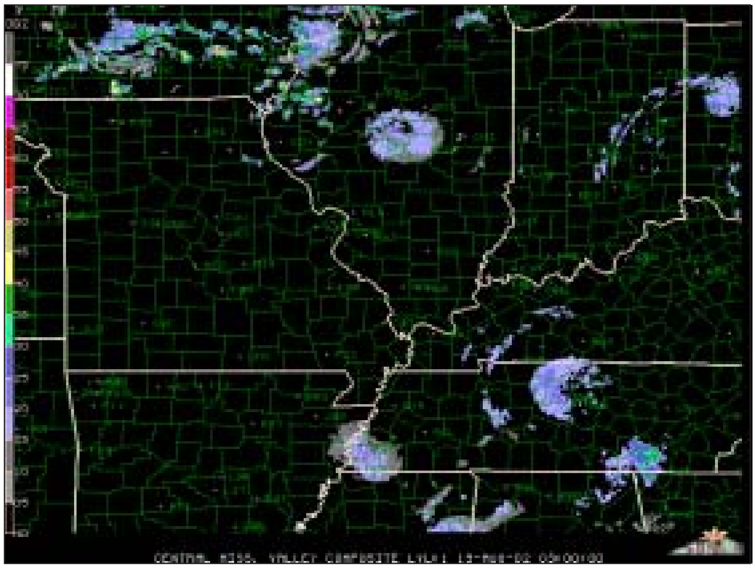

Figure 15. Composite reflectivity radar image at 2200 CDT, August 18, 2002.

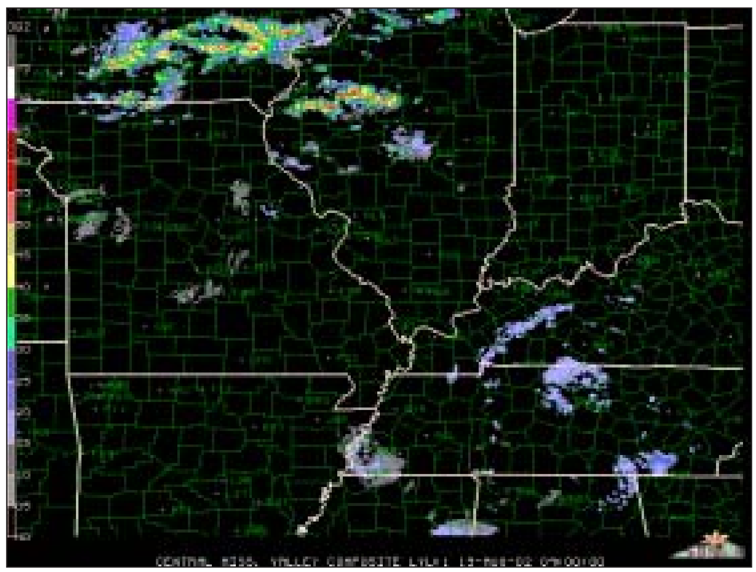

Figure 16. Composite reflectivity radar image at 2300 CDT, August 18, 2002.

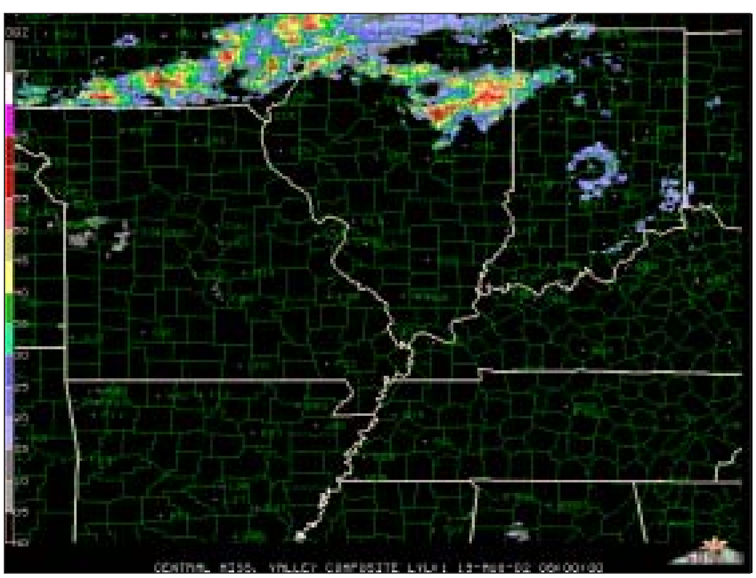

Figure 17. Composite reflectivity radar image at 0100 CDT, August 19, 2002.

of the radar images indicated that the thunderstorms over eastern Illinois/western Indiana were developing separately from the line of storms to the north.

The LLJ had increased to 35-40 knots at 500 m and at 1000 m, and surface moisture convergence was concentrated from eastern Kansas across northern Missouri into western Illinois (Figure 18). The line of storms exhibited a distinct wave configuration, with the "crest" of the wave just east of the Quad Cities in Illinois at 0200 CDT on August 19 (Figure 19). This coincided well with the surface analysis at that time, which placed a wave on the front just east-northeast of Quincy, Illinois (Figure 20). The line of thunderstorms from southern Iowa through northwestern Illinois was on the cold side of the front. A solid line of strong thunderstorms had developed in the warm, moist air south of the front and ahead of the surface wave from near Bloomington, Illinois, through southern Ford, northern Champaign, and northern Vermilion Counties in Illinois, and eastward through Warren and Fountain Counties in western Indiana. The sequence of radar images shows that heavy thunderstorms continued to "train" over eastern Illinois and western Indiana until 0500 CDT, when the line of storms began to move to the southeast and weaken (Figure 21). This weakening of the storms coincided with the veering of the LLJ from a south-southwesterly to westerly direction (Figure 22) and the movement of the surface frontal wave from western to northeastern Illinois. At 0500 CDT the strongest surface moisture convergence had shifted south and was oriented east-west from near St. Louis to near Terre Haute, Indiana.

By 0700 CDT on August 19, the leading edge of the rain had progressed to a line from St. Louis, Missouri, to Terre Haute and Indianapolis, Indiana, and the heaviest storms were in western Illinois and in central Indiana (Figure 23). The front extended from near Quincy, Illinois, to Chicago, and a weak wave was located on the front over southern Lake Michigan. At this time, showers and thunderstorms covered most of the northern two thirds of Illinois and the northern half of Indiana.

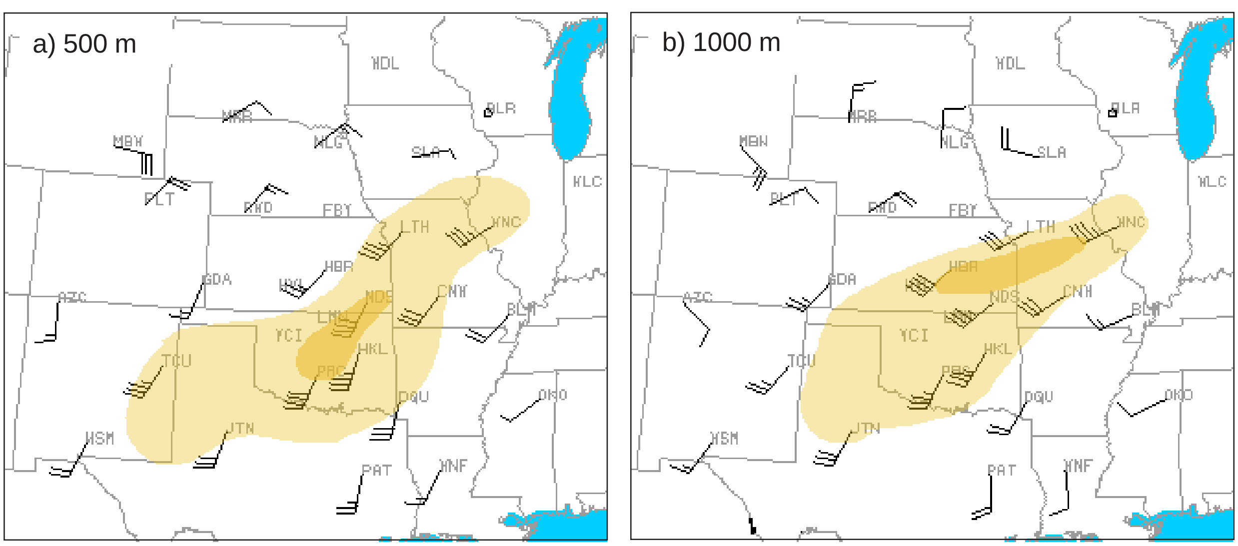

Figure 18. Analysis of wind profiler data at 0100 CDT, August 19, 2002: a) 500 m and b) 1000 m. Light shading denotes winds of 30 knots or higher, and darker shading denotes winds of 40 knots or higher.

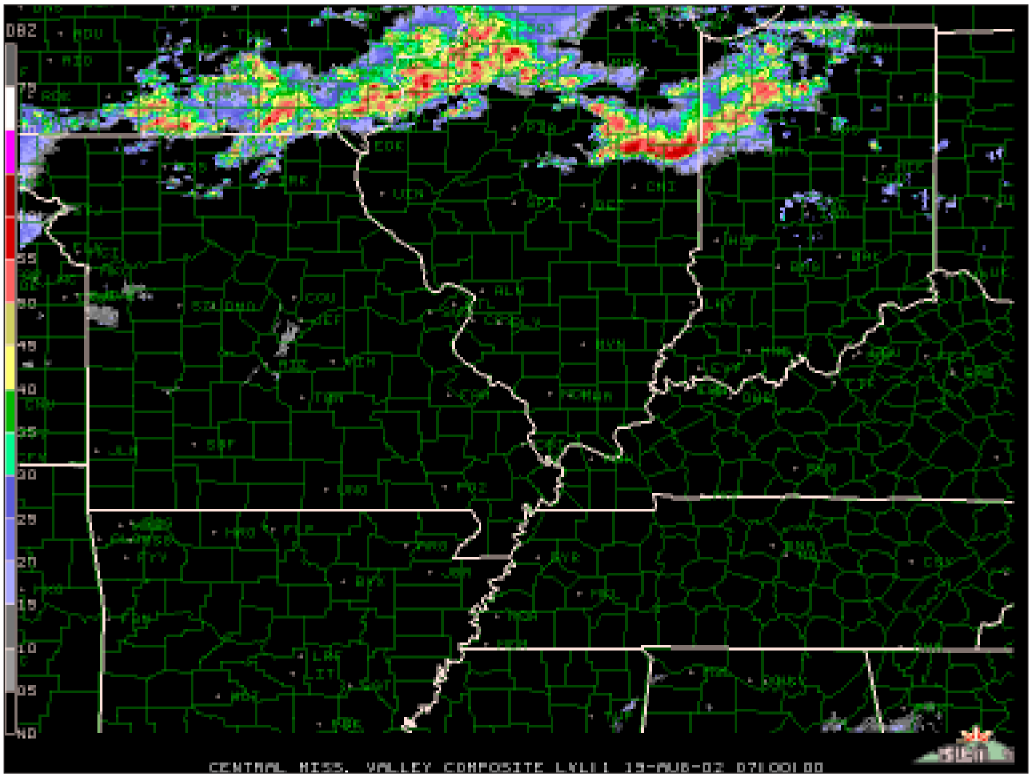

Figure 19. Composite reflectivity radar image for 0200 CDT, August 19, 2002.

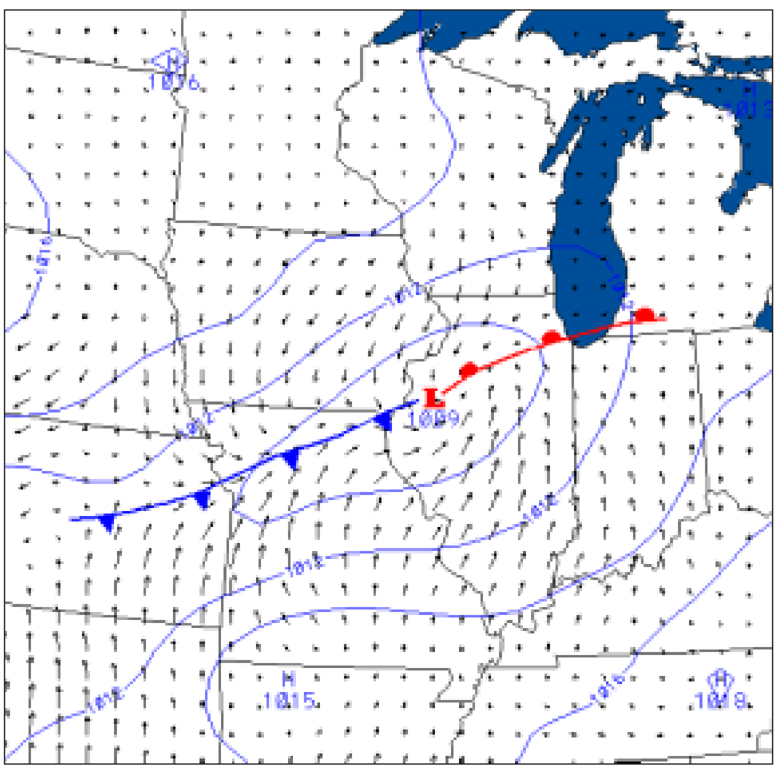

Figure 20. Surface analysis at 0200 CDT, August 19, 2002.

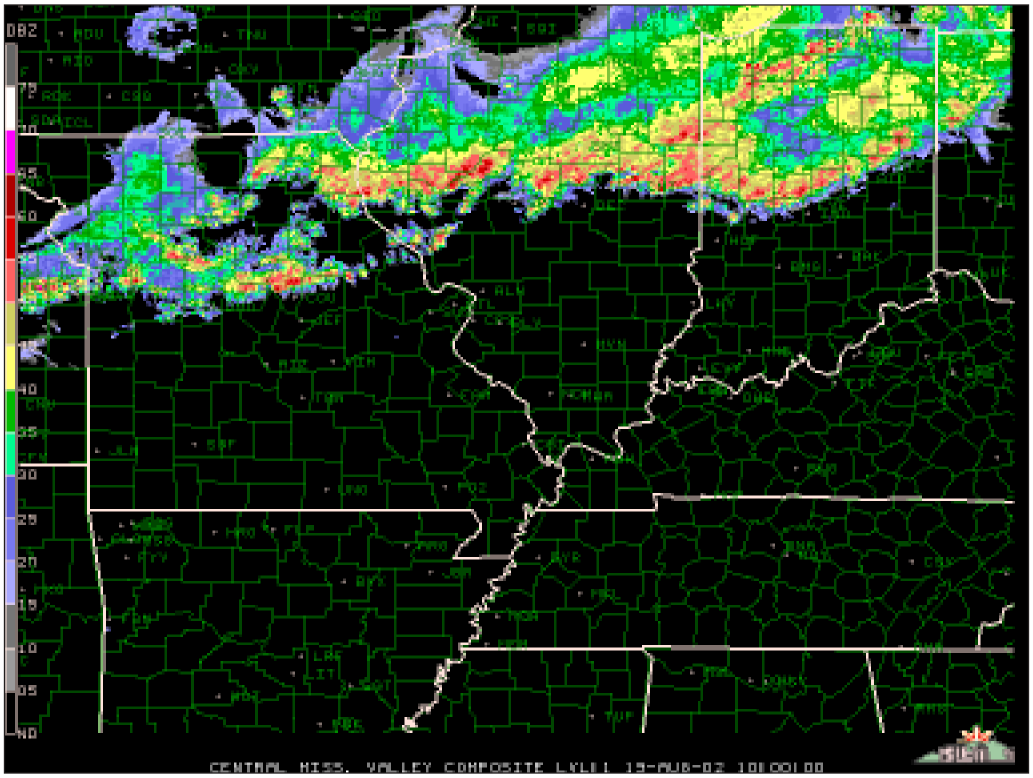

Figure 21. Composite reflectivity radar image at 0500 CDT, August 19, 2002.

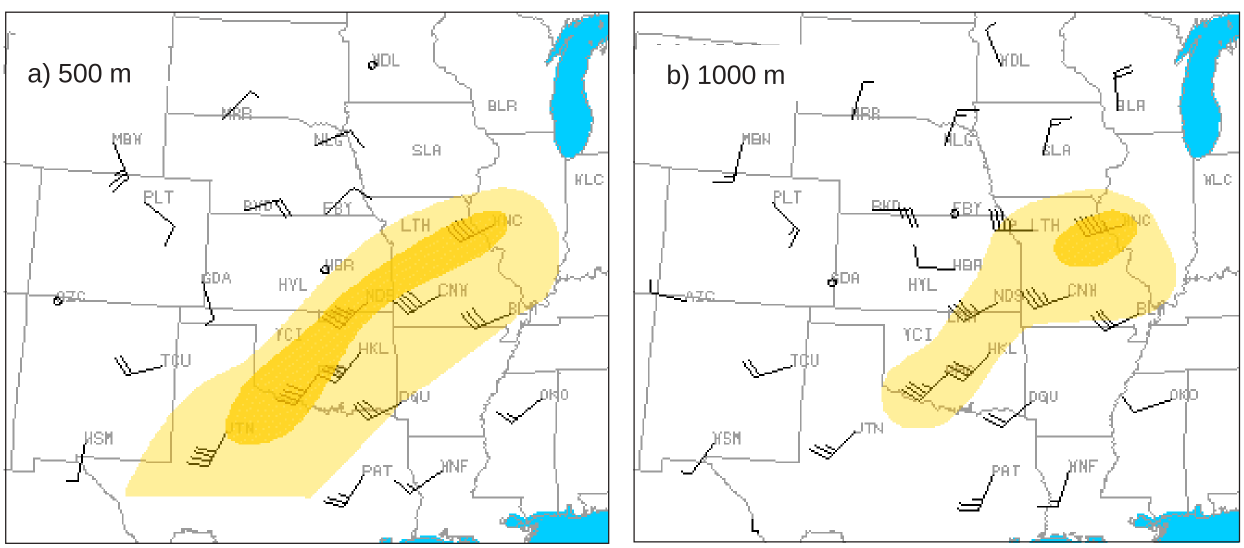

Figure 22. Analysis of wind profiler data at 0100 CDT, August 19, 2002:
a) 500 m and b) 1000 m. Light shading denotes winds of 30 knots or higher,
and darker shading denotes winds of 40 knots or higher.

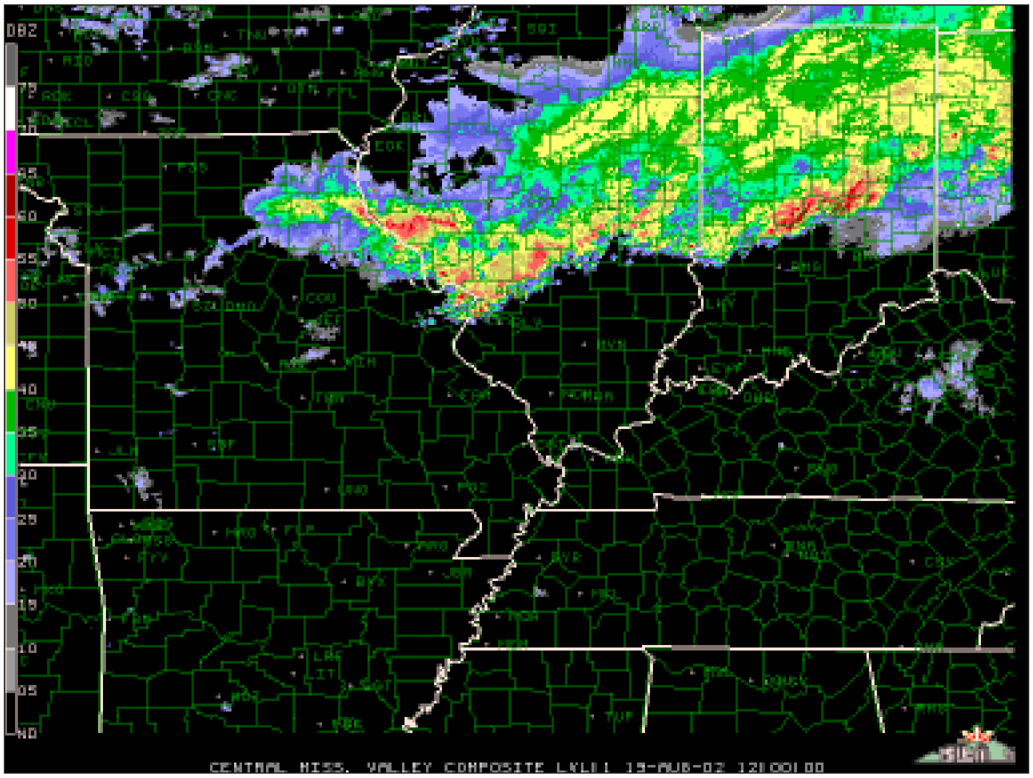

Figure 23. Composite reflectivity radar image at 0700 CDT, August 19, 2002.

Synoptic Weather Conditions Associated with the August 21-22 Rainstorm

The frontal boundary that provided the focus for the heavy rain on August 18-19, 2002, was also a factor in the heavy rain two days later in northwestern Illinois. Following the passage of the 500-mb short wave and associated surface wave on the morning of August 19, the front pushed south to the Ohio River, with a weak area of high pressure building behind it. By 0700 CDT on August 20, the high had moved into lower Michigan, and the western half of the front began returning northward. At 0700 CDT on August 21, the front extended from a low-pressure system along the Nebraska-North Dakota border through central Iowa, then curved southward along the Missouri-Illinois border. Showers and thunderstorms were occurring from northern Wisconsin southwestward through Minnesota, western Iowa, then south to central Oklahoma. Twelve hours later the warm front had progressed further north and east, and at 1900 CDT extended along the Iowa-Minnesota border across southern Wisconsin and into southern lower Michigan. The 12-hour frontal positions between the occurrences of the two storm events are shown (Figure 24).

At 1500 CDT on August 21, a wide band of showers and thunderstorms extended from southeastern Minnesota across central Wisconsin and into northern lower Michigan. Most of this convection was located north of the surface frontal boundary. A line of scattered thunderstorms also was evident from near LaCrosse, Wisconsin, south to Ottumwa, Iowa. By 1700 CDT, this southern line of surface-based storms was nearly solid and extended from east of LaCrosse to just northeast of Ottumwa. The line moved through northwestern Illinois between 1730 and 1830 CDT, the first of the heavy thunderstorms to cross the area during this event (Figure 25).

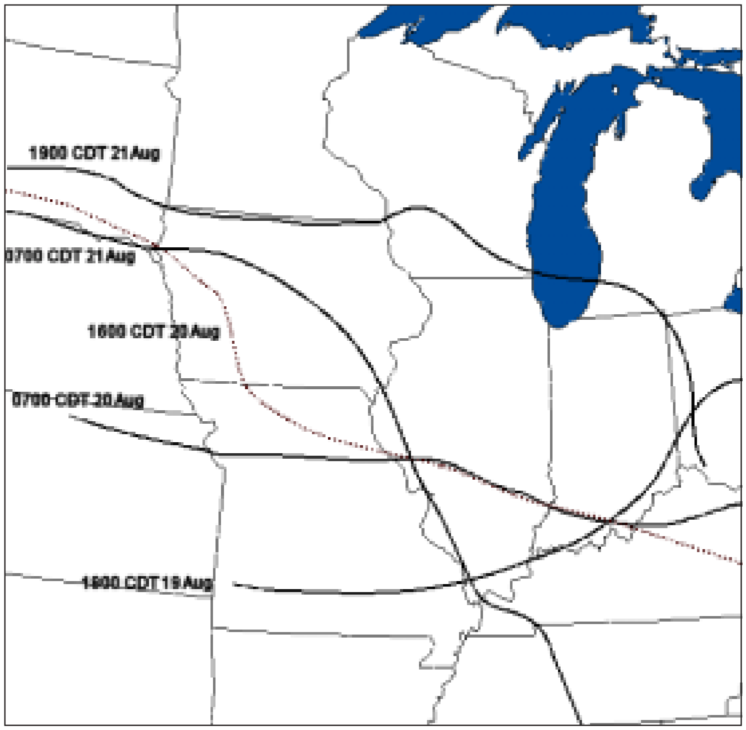

Figure 24. Location of frontal systems between 1900 CDT, August 19, and 1900 CDT, August 21, 2002.

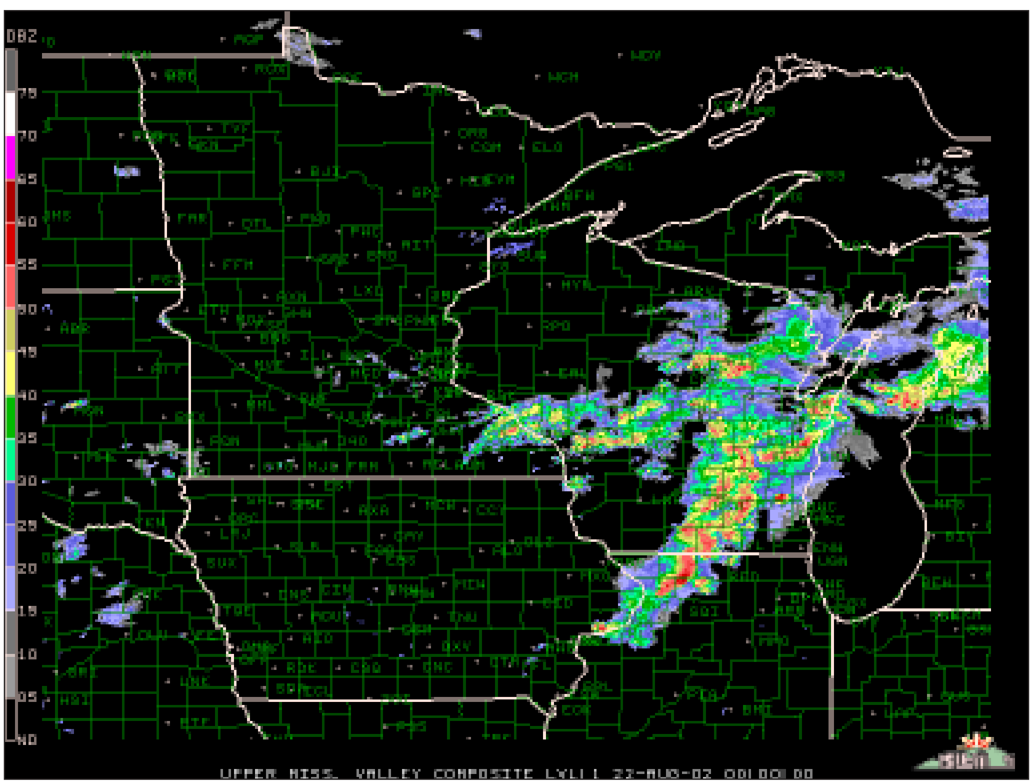

Figure 25. Composite reflectivity radar image at 1900 CDT, showing a line of thunderstorms moving through southern Wisconsin and northwestern Illinois, August 21, 2002.

Ample moisture was evident by 1900 CDT on August 21. An area of surface dewpoints 75°F or higher extended from central Illinois into northeastern Missouri, then north through eastern Iowa (Figure 26). Maximum surface moisture converged over eastern Iowa. Precipitable water values equal to or greater than 2 inches extended from eastern Nebraska into northwestern Illinois (Figure 27). A 30-knot LLJ was evident at both the 500-m and 1000-m levels extending from central Oklahoma into northwestern Illinois (Figure 28). The LLJ extended up through the 850-mb level (approximately 1500 m), providing strong transport of moisture through the lower levels of the atmosphere (Figure 29). The 40-knot LLJ maximum was located over eastern Iowa and northwestern Illinois. The deep layer of 40-knot winds extended from 850 mb (1532 m) to 679 mb (3430 m) on the Davenport sounding at 1900 CDT. The lifted index computed from the

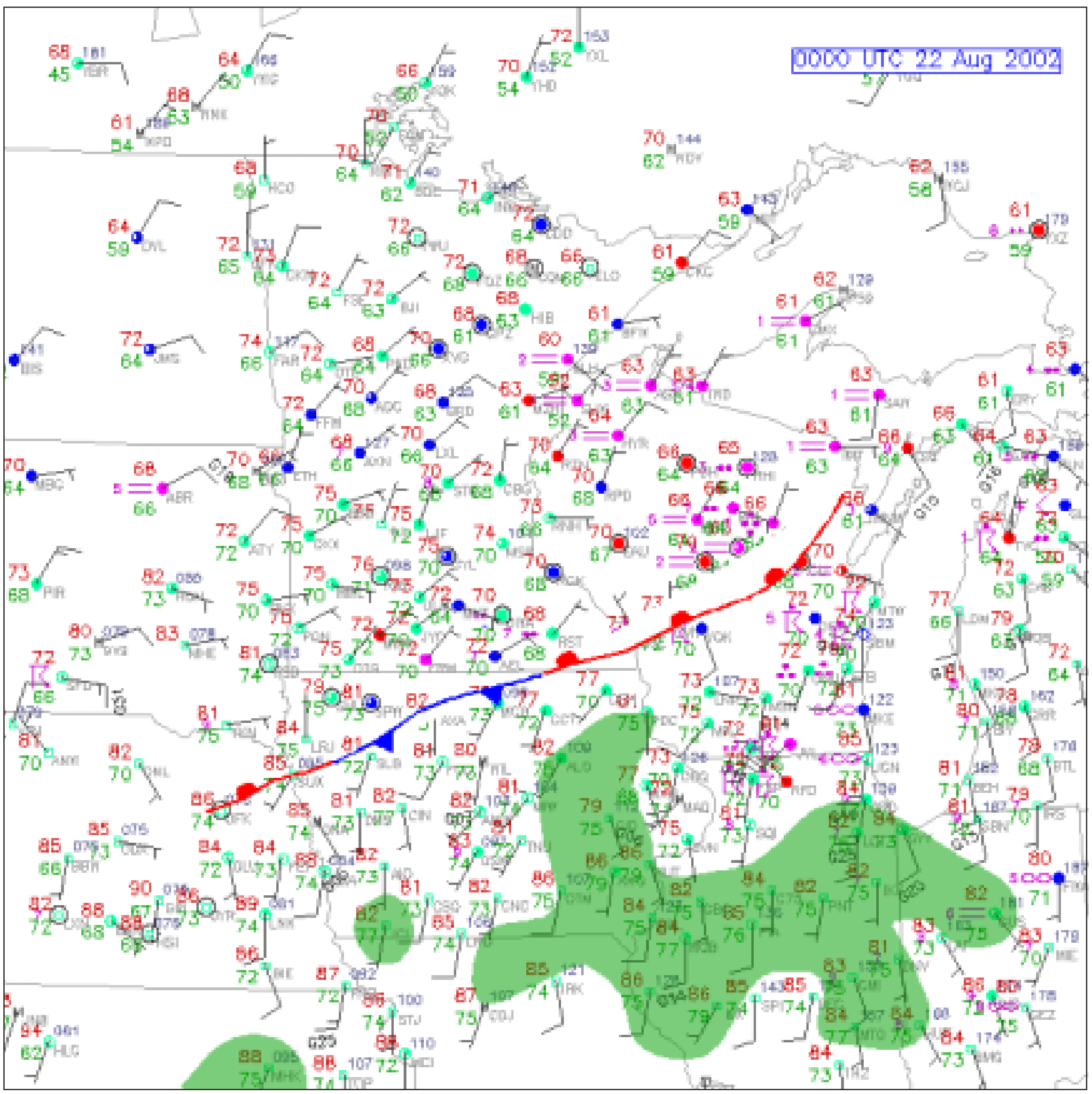

Figure 26. Surface analysis for upper Midwest at 1900 CDT, August 21, 2002.
Shading denotes dewpoint temperatures of 75°F or higher.

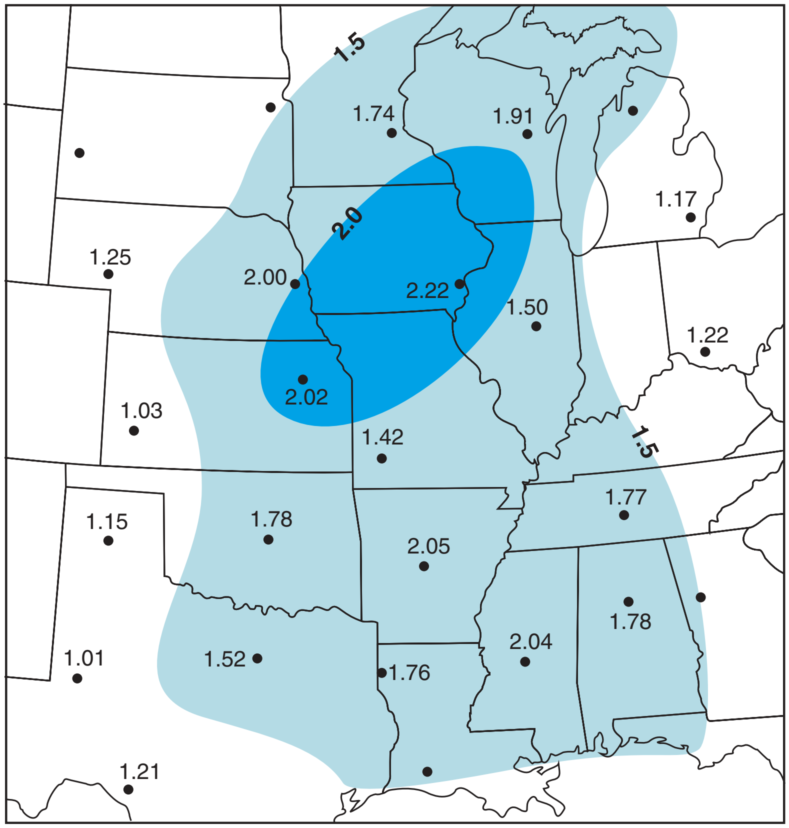

Figure 27. Precipitable water (inches) at 1900 CDT, August 21, 2002.

1900 CDT sounding at Davenport was -5.7, indicating very unstable conditions. At 500 mb, a short wave west of Kansas City at 0700 CDT on August 21 had moved into eastern Iowa, and another short wave was evident upstream with its axis extending from northern Colorado into northeastern New Mexico. This was reflected on the surface by a trough of low pressure extending from northern Nebraska to southwestern Colorado.

Between 1900 and 2000 CDT, a second line of storms began to develop from southwestern Wisconsin into northeastern Illinois. By 2200 CDT, the line extended from north of Waterloo, Iowa, to Madison, Wisconsin. In the next hour, the line of storms continued to grow and intensify, extending from Milwaukee, Wisconsin to Dubuque, Iowa, to Waterloo, Iowa (Figure 30). The line of storms also became oriented more west to east, rather than the southwest-northeast orientation observed when the line of storms began to develop.

Wind profiler analyses at 0100 CDT August 22 (Figure 31) depicted a 40-45 knot LLJ at 500 m from central Oklahoma into western Illinois. Heavy thunderstorms extended from the Chicago area across northern Illinois and southern Wisconsin into Iowa. Thunderstorms continued to develop and move across this area for the next six hours. By 0600 CDT on August 22, the storms had begun to weaken and move to the south and east (Figure 32). At 1000 CDT, the line of showers and some thunderstorms extended from Chicago to an area between Burlington, Iowa, and Quincy, Illinois (Figure 33).

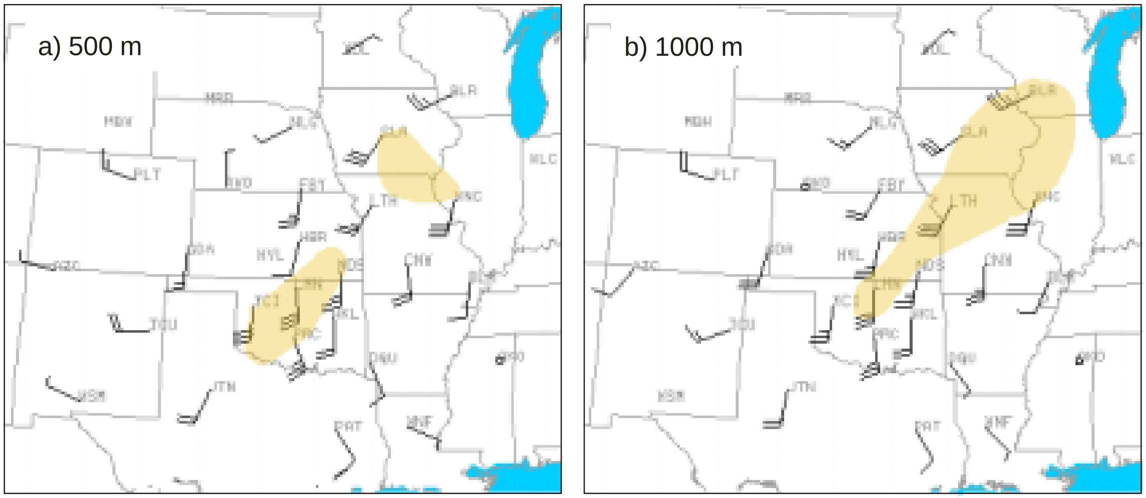

Figure 28. Analysis of wind profiler data at 1900 CDT, August 21, 2002: a) 500 m and b) 1000 m. Light shading denotes winds of 30 knots or higher.

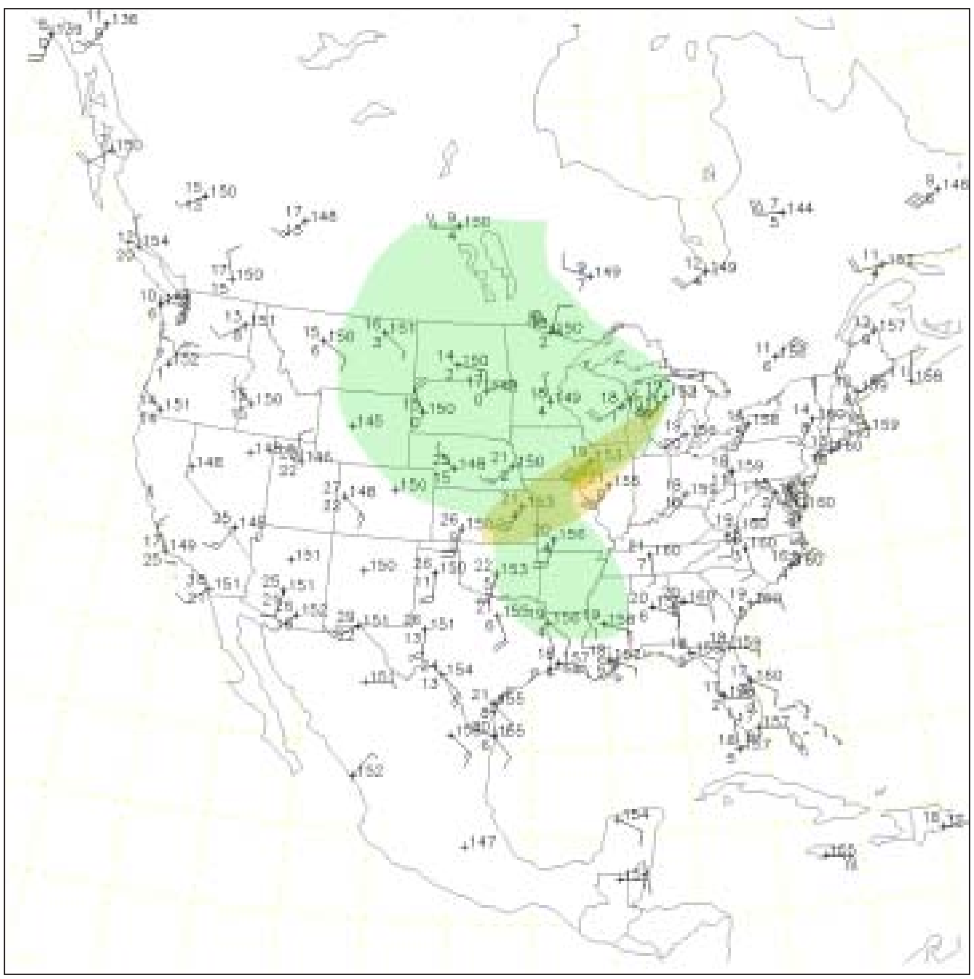

Figure 29. The 850-mb analysis at 1900 CDT, August 21, 2002. Light shading denotes area of winds >30 knots, and darker shading denotes winds >40 knots. Green shading depicts dew point depressions of 5°C or less.

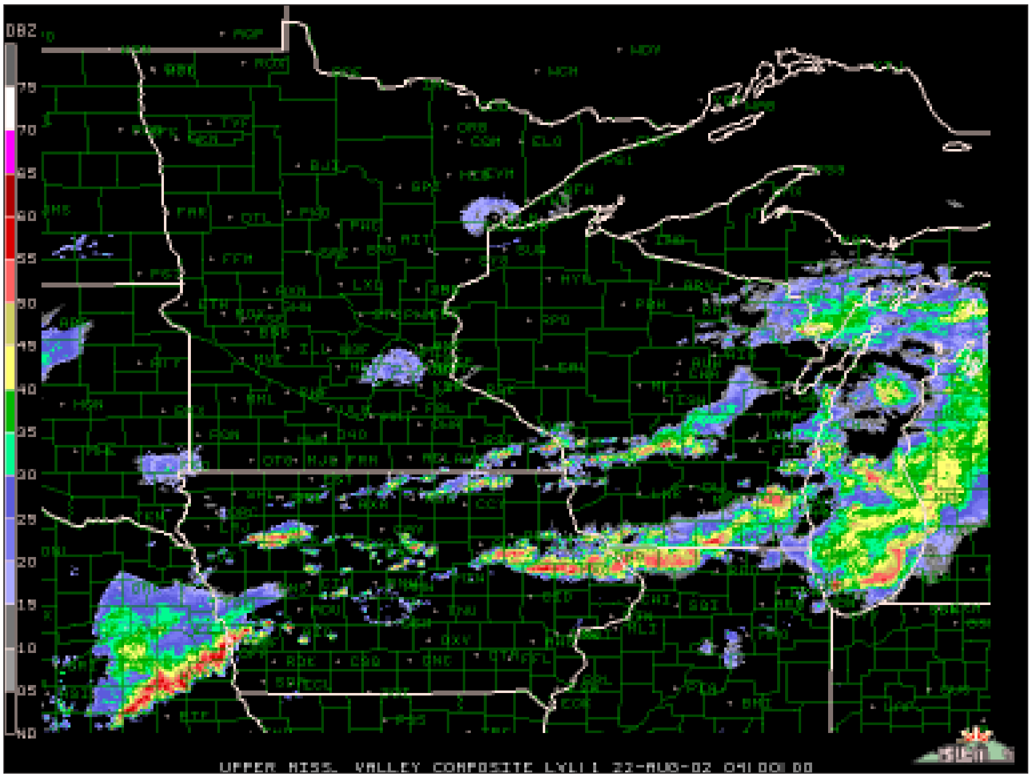

Figure 30. Composite reflectivity radar image at 2300 CDT, August 21, 2002.

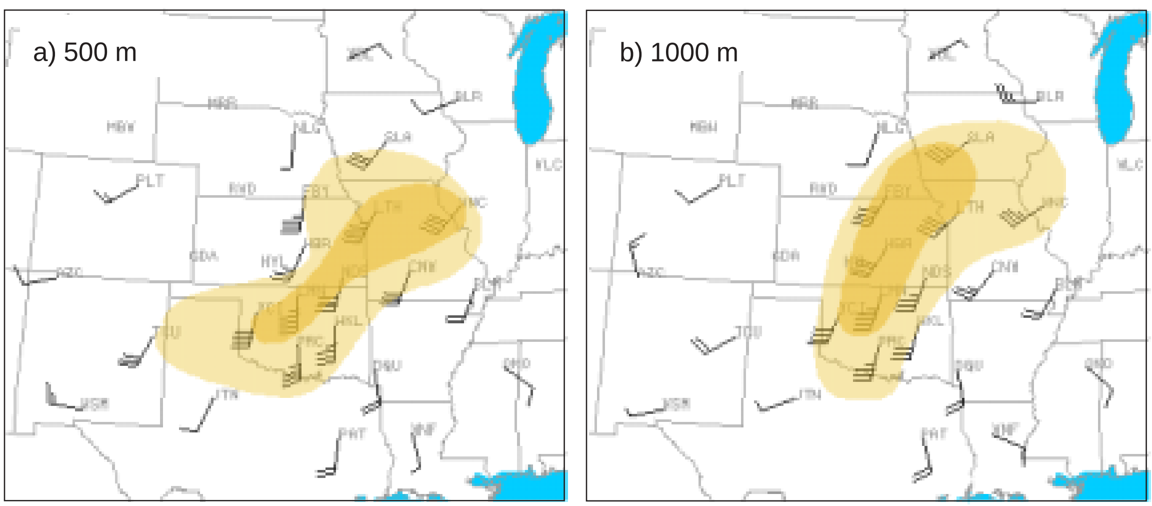

Figure 31. Analysis of wind profiler data at 0100 CDT, August 22, 2002:
a) 500 m and b) 1000 m. Light shading denotes winds of 30 knots or higher,
and darker shading denotes winds of 40 knots or higher.

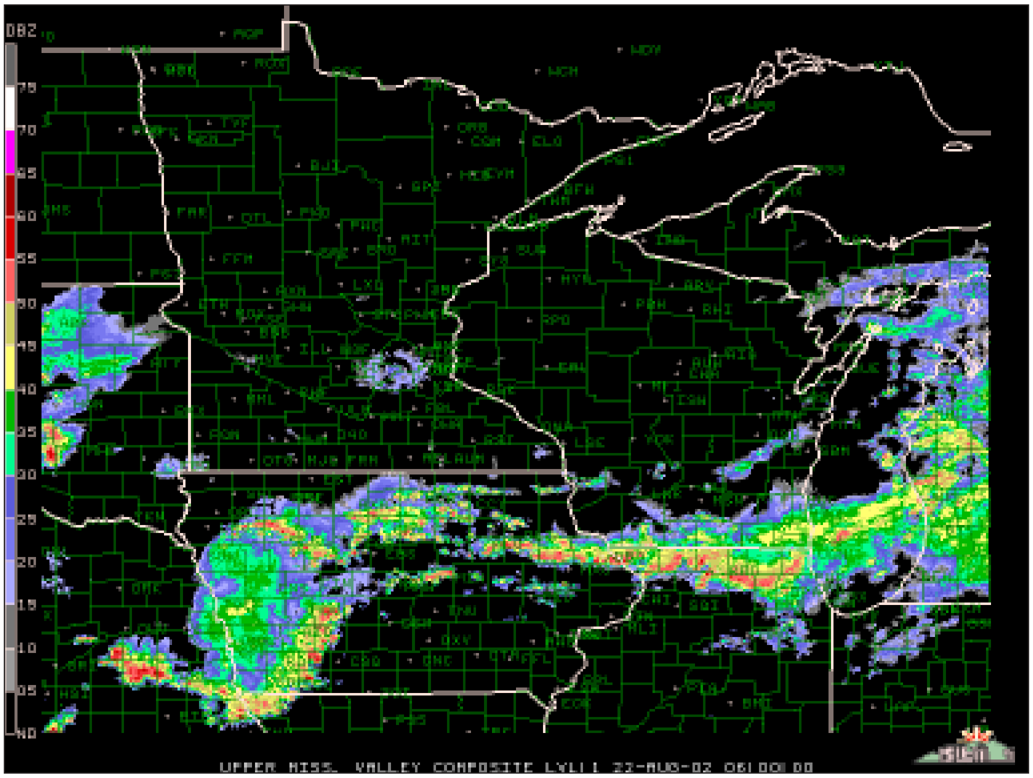

Figure 32. Composite reflectivity radar image at 0100 CDT, August 22, 2002.

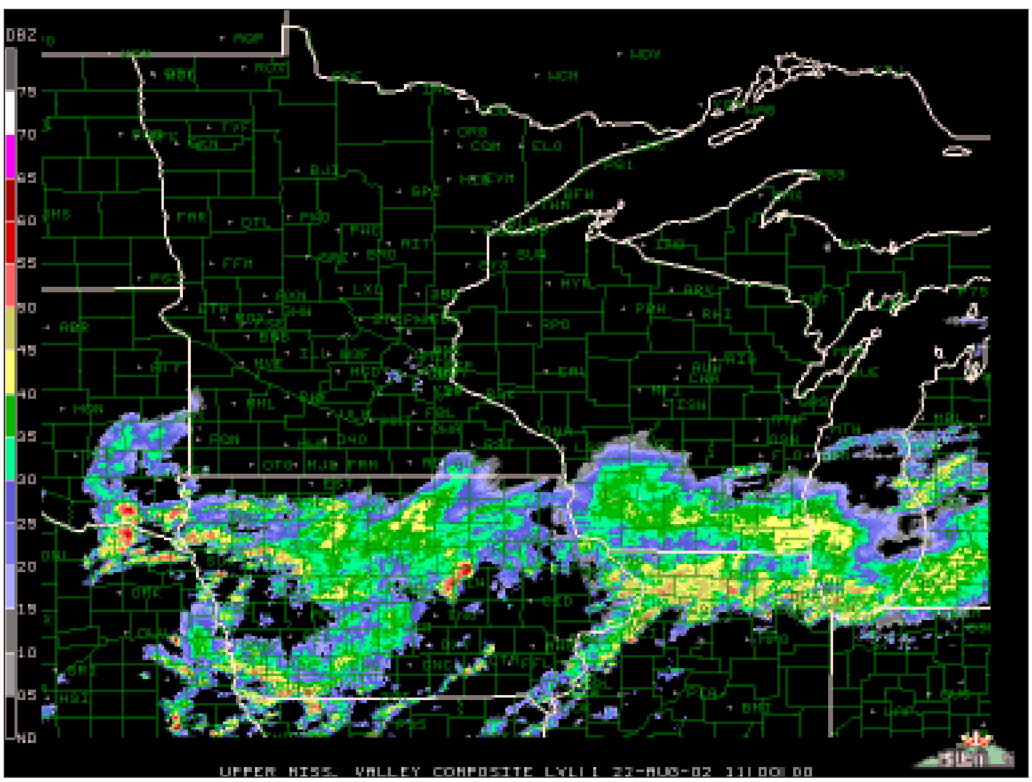

Figure 33. Composite reflectivity radar image at 0600 CDT, August 22, 2002.

Summary

A combination of synoptic conditions extremely favorable for heavy rain caused the strong thunderstorms that developed on the night of August 18 and the resulting excessive rainfall in east-central Illinois and west-central Indiana. A surface front had stalled over the Midwest, providing a boundary favorable for thunderstorm development. More significant, however, was the development of a nocturnal LLJ that concentrated the flow of deep moisture along a broad axis in Missouri, Iowa, and Illinois. The continuous supply of deep moisture and the approaching surface and upper level waves supported the initiation of convection favorable for training thunderstorms in the warm air in central Illinois and western Indiana. A strong area of surface moisture convergence, with its axis aligned roughly parallel to the front, was overlain by a strong LLJ. This persistent LLJ extended through a deep layer, enhancing moisture convergence. These conditions have been shown to be favorable for the development of training thunderstorms (Junker et al., 1999).

The August 21-22 storm developed under similar synoptic conditions, including a strong stationary boundary, deep moisture, the development of a strong LLJ prior to the onset of heavy rain, and an approaching upper level short wave (in this case a succession of waves). This series of two or three 500-mb short waves traversing Iowa and northern Illinois probably contributed to the continuous thunderstorm development over northwestern Illinois.

In both cases, the training storms developed in the warm sector of the system.The thunderstorms weakened after the passage of the surface and upper level waves and coincided with the veering of the LLJ.

Previous studies (Maddox et al., 1979) have shown mesoscale convective systems develop in abnormally moist conditions (precipitable water values of 1.4 inches or higher) and occur at the nose of the LLJ maximum. In both August storms, precipitable water values well exceeded this value: near 1.7 inches in eastern Illinois on August 19, and 2.2 inches in northwestern Illinois on August 22. The spring season in the western Midwest and central High Plains had been the fourth wettest since 1896, which created high evapotranspiration values that helped provide the high precipitable water values, a key circumstance noted for helping to create a prior intense rainstorm in the Midwest (Changnon and Kunkel, 1990). Furthermore, in both cases, the area of excessive rainfall was pinpointed by the intersection of the surface moisture convergence axis with the nose of the LLJ. Major features of conditions associated with these two storms were very similar to those identified after study of the 26 rainstorms between 1950 and 1979 (Huff, 1979).

Impacts

The two mid-August record rainstorms, one affecting northern Illinois and eastern Iowa and the other affecting east-central Illinois and western Indiana, created several short-term physical and socioeconomic impacts on the region. However, the heaviest rainfalls associated with both storms occurred in rural areas, thus limiting the storm-related damages. While numerous minor injuries were reported, no deaths were attributed to either storm. Road and basement flooding was reported; however, when compared with the impacts of recent rainstorms over the Chicago metropolitan region during recent summers (Changnon, 1999; Changnon and Westcott, 2002), the socioeconomic losses were much smaller. For example, basements of more than 300,000 Chicagoland homes flooded due to the rainstorm on August 2, 2001, whereas only 400 Chicago homeowners reported basement flooding as a result of the event on August 21-22, 2002. Some homeowners from East Dubuque, Illinois, to Winnetka, Illinois, including residents in Stockton, Freeport, Rockford, Belvidere, Marengo, and Park Ridge, experienced flood-related damages (*Chicago Tribune*, August 22, 2002).

The two heavy rains in August 2002 also created several agricultural impacts. For example, low-lying fields adjacent to rivers in Jo Davies and Stephenson Counties (northwestern Illinois) were partly flooded, and some crops were ruined. However, after the two heavy rains of August 18-22, agricultural experts assessed the impacts to Midwestern crops. Their views are reflected in the comments of an Illinois Extension specialist who stated on August 20, "This August precipitation will lead to higher average crop yields than would have occurred," and further indicated "the heavy rains would help the soybeans, but were too late to improve corn yields" (Bridson, August 26, 2002). By late August, these "improving prospects for soybean yields" had affected grain trading and lowered the bean prices (Bridson, September 2, 2002). Soybean prices had been climbing steadily during the hot, dry summer, and the price for November 2002 soybeans had climbed to $5.80 per bushel by August 10, but fell to $5.35 per bushel by August 28, a result of the two heavy rains.

August 18-19 Storm

The period prior to the record rainfall on August 18-19 in east-central Illinois was unusually dry and drier than conditions in northern Illinois preceding the August 21-22 rainstorm [which also produced rains that affected central Illinois during August 22-23 (Figure 6)]. Precipitation totals and departures from average were examined for 60 days and 15 days prior to the rainstorm for the central and east-central climate divisions where the August 18-19 storm occurred. During the 60 days prior to the storm (6/15/02-8/15/02), 62 percent of the average rainfall fell in the central Illinois division, and 72 percent of average fell in the east-central Illinois division. In the 15 days prior to the rainstorm (8/01/02-8/15/02), only 59 percent of average rainfall occurred in central Illinois, and 55 percent of average rainfall occurred in east-central Illinois. These precipitation anomalies produced very dry soil conditions with negative impacts on corn and soybean development, especially during July and early August. On August 11, reports of farmers across the region revealed that soil moisture was short across 91 percent of the area (*Farm Week*, September 2, 2002).

Conditions in four east-central Illinois basins (Figure 34) where heavy rains fell were examined to determine the hydrologic impact of these storms on flow levels (Table 2). Basin areas ranged in size from 262 to 1,290 square miles (mi^2). Two basins (the North Fork and Middle Fork of the Vermilion River) are part of the larger Vermilion River basin. As shown in Table 2 two basins had rather short historical flow records, affecting assessment of their peak discharges. Hydrographs of three basins are presented (Figure 35).

All four basins were experiencing flow amounts at or below average for this time of year, and three of the basins had daily flows less than 100 cubic feet per second (cfs) prior to the rainstorms. Heavy rains created peak flows (two basins exceeded 10,000 cfs) that rated in the middle part of the distribution of annual peak discharges. Despite the high flows the heavy rains created, flow levels returned to near normal in only 19-25 days.

The hydrologic impacts of the August 18-19 rainstorms were evaluated by comparing them with those of a recent rainstorm when wetter pre-storm conditions existed. All four basins experienced a peak annual discharge after a regional rainstorm on June 14-17, 1998. This four-day period brought 3-5 inches of rain to the area, totals less than those experienced in August 2002.

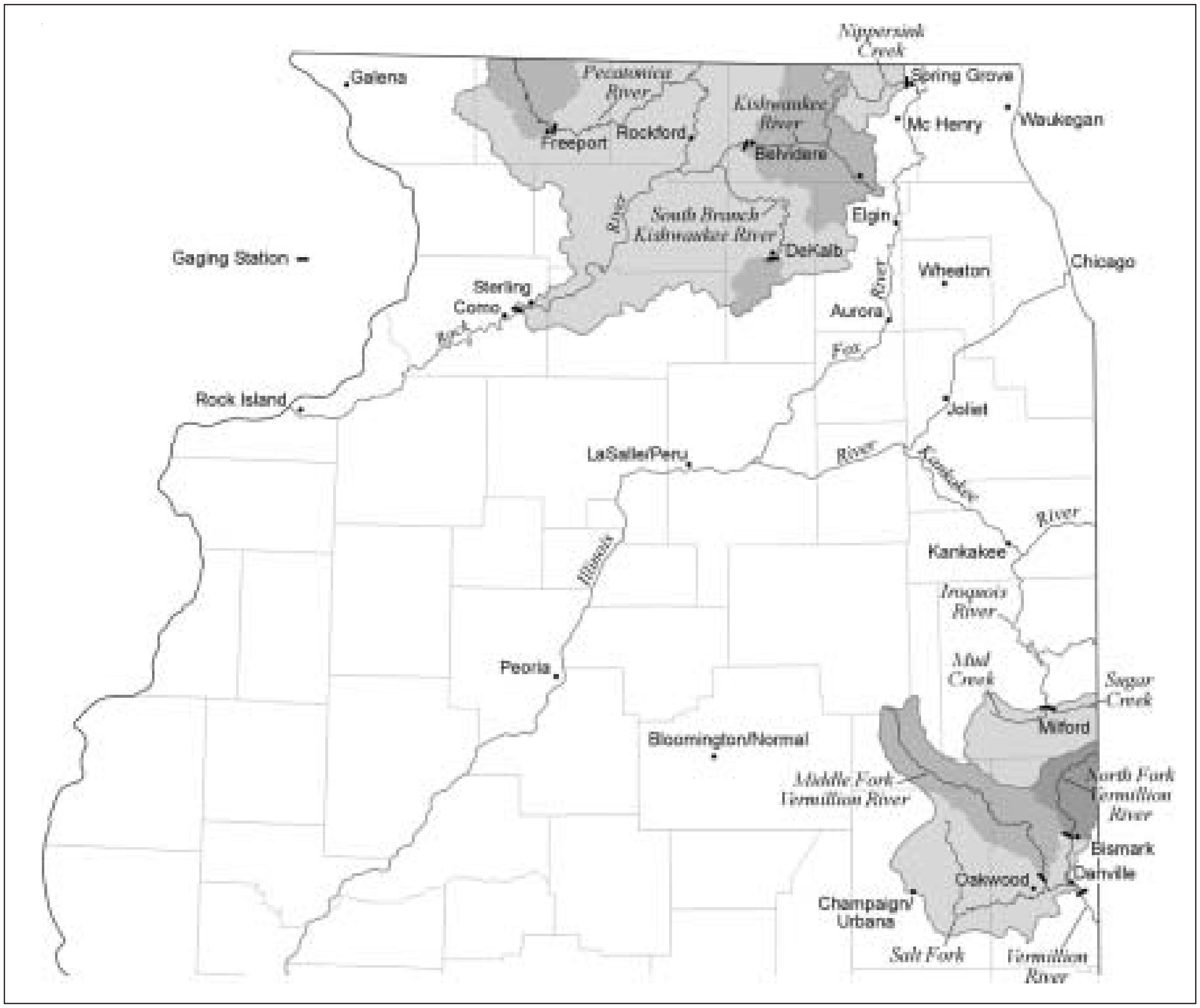

Figure 34. Map of central and northern Illinois basins assessed for streamflows.

However, pre-storm precipitation in 1998 in east-central Illinois was 159 percent of normal for the 60 days prior to the event and 205 percent of normal 15 days prior to the event, pre-storm conditions quite different than in August 2002. The wetter 1998 conditions are reflected in the pre-storm flow levels of the four basins (Table 3). All four basins were experiencing flow levels less than 200 cfs prior to the August 2002 rainstorm, but they were experiencing flow levels exceeding 2500 cfs prior to the 1998 event. Peak flows associated with the June 14-17, 1998, rainstorm were similar to those in 2002 for three of the four basins. Only the Vermilion River at Danville registered a peak flow nearly twice that of the August 2002 value. Each peak flow after the 1998 event ranked as an annual peak discharge. Peak flows generally ranked higher than those that occurred after the 2002 event, even though less rain had occurred. The Vermilion River at Danville experienced its 8th highest annual peak discharge since 1915. In terms of impacts, the period of time (in days) for flows to return to near normal was two to three times longer in 1998 than in 2002. By August 25, 2002, only 11 percent of region's soil moisture was reported by farmers as short, a dramatic drop from pre-storm values of 91 percent (*Farm Week*, September 2, 2002). Soil moisture measurements for the 0-40 inch depth across the region showed 70 percent

Table 2. Impacts of Heavy Rains of August 18-19, 2002, on Four Central Illinois Basins

Basin Characteristics

Drainage basin	*Basin area, mi²*	*Peak discharge record*
Middle Fork		
Vermilion at Oakwood	432	1979-present
North Fork		
Vermilion at Bismark	262	1989-present
Vermilion at Danville	1290	1915-present
Sugar Creek at Milford	446	1949-present

August 2002 Streamflow Conditions

Basin	*Pre-storm Flow level, cfs*	*Peak flow, cfs*	*Peak vs. pre-peak difference, cfs*	*Days until normal flow*	*Rank of 2002 and peak annual discharge year*
Middle Fork					
Vermilion at Oakwood	38	5,420	5,382	25	13:1924
North Fork					
Vermilion at Bismark	28	12,300	12,272	25	3:1914
Vermilion at Danville	189	12,200	12,011	25	49:1988
Sugar Creek at Milford	26	3,940	3,914	19	43:1955

of average values on July 16, dropping to 40 percent by August 15. The soil moisture value was 125 of average on September 1, however.

The heavy rains of August 18-19 fell primarily over rural areas and small towns in central Illinois. Impacts were limited to minor field and road flooding. Although some of the worst hit areas experienced some crop damage, most agricultural advisors indicated that most of the rainfall soaked into the ground, rather than ponding because pre-storm soil conditions were so dry. Homeowners who had been watering yards and gardens throughout most of the summer welcomed the heavy rains. Losses from the storm were $75,000.

A soybean weather-yield model, SOYGRO, based on soil and crop conditions in the east-central climate division, was used to predict soybean yields with and without the heavy August rains in this region. Model outcomes indicated that the late August rains contributed an additional five bushels per acre valued at $5.30 per bushel (harvest price), which represented $26.50 added value per acre. The district included 1,430,000 acres of soybeans, and the rains produced added yields worth $37.9 million in Illinois. Had the two heavy August rains not occurred, the harvest price could have exceeded $5.30 per bushel, but yields in central Illinois would have been much lower. There was no marked change in corn yields because the rains came too late in the growing season to be beneficial.

August 21-22 Storm

The heaviest rainfall associated with this late summer event fell primarily in a west-north-west to east-southeast direction from eastern Iowa (Dubuque) through northern Illinois into the northern suburbs of Chicago (Figure 2). The antecedent moisture conditions, based on rainfall anomalies prior to the event, indicated that the summer (6/15/02-8/15/02) generally had been drier than average in the two northern Illinois climate divisions (75 percent of the average in northwestern Illinois and 69 percent of average in northeastern Illinois). These conditions

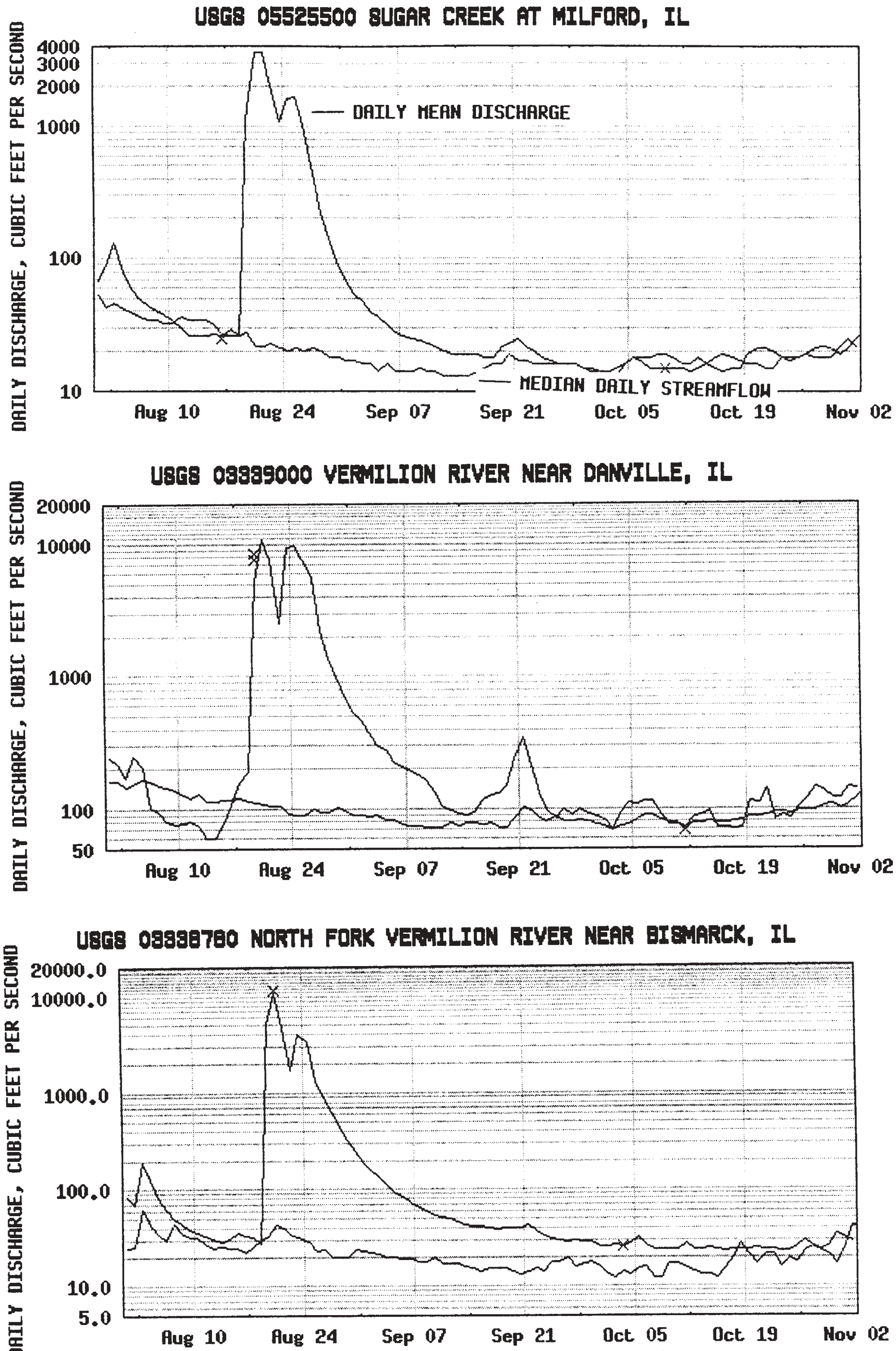

Figure 35. Hydrographs for three basins in east-central Illinois.

Table 3. Streamflow Conditions, June 14-17, 1998

Basin	*Pre-storm low level, cfs*	*Peak flow, cfs*	*Peak vs. pre-peak difference, cfs*	*Days until normal flow*	*Rank of 2002 and peak annual discharge year*
Middle Fork					
Vermilion at Oakwood	2,860	5,800	2,940	64	12: 1924
North Fork					
Vermilion at Bismark	3,320	9,240	5,290	50	5: 1914
Vermilion at Danville	11,200	24,600	13,400	78	8: 1988
Sugar Creek at Milford	2,500	4,600	2,100	67	3: 1955

changed somewhat in the two-week period just prior to the rainstorm when district rainfall was 9 percent above average in northwestern Illinois and 14 percent above average in northeastern Illinois. Nevertheless, the dry summer conditions are why soil moisture in northern Illinois was rated by farmers as 62 to 80 percent short across northern Illinois (*Farm Week,* September 2, 2002) prior to the heavy rains of August 21-22. Regional soil moisture values for the 0-40 inch depth were 75 percent of average on August 15.

Five basins in northern Illinois (Figure 34) were examined to determine the hydrologic impact of this storm on flow levels (Table 4). Not all were located in the main swath of heavy rain. Heavy rainfall had the least impact on the South Branch of the Kishwaukee basin upstream of the DeKalb area, which received 2-3 inches of rain. The five basins ranged in size from approximately 78 to 8,735 mi^2. Hydrographs for three basins are presented in Figure 36.

The peak discharge in all basins was noted and compared to the pre-storm flow level (Table 4). The peak discharge occurred 1-2 days after the rainstorm ended, with the delay dependent on the basin size and time to accumulate floodwaters. The changes in flows from pre-storm to peak discharge were large. Flows on three basins (Pecatonica River at Freeport, Rock River at Como, and Kishwaukee River at Belvidere) increased by 3,000 cfs, which registered as the annual peak discharge for 2002. Annual peak discharge values for the three basins occurred in the middle to lower parts of the distribution of the historic annual peak discharges, suggesting that these rainstorms were impressive, but not extraordinary in hydrologic terms. As shown, 20-24 days were required to return to an average flow for these three basins, an outcome similar to that for the four central Illinois basins affected by the August 18-19 storm. These results reveal that large amounts of the rains infiltrated the dry soils. By August 25, soil moisture across northern Illinois was defined by farmers as only 10 percent short, compared to 62 to 80 percent prior to the storm (*Farm Week*, September 2, 2002).

Two basins, the Kishwaukee River at DeKalb and Nippersink Creek at Spring Grove, were located just outside of the area with heavier rainfall totals, which explains why these basins did not register an annual peak discharge. The change in discharge from the pre-storm amount to the peak flow was approximately 100 cfs for each basin, considerably less than for the other three basins. It took a week or less for streamflow levels of the two basins to return to near average levels.

Hydrologic conditions of the five basins were compared with conditions produced by another recent north-central Illinois heavy rainstorm (August 5-6, 1996), allowing further assessment of the August 2002 hydrologic impacts. Although rainfall amounts associated with the 1996

Table 4. Impacts of Heavy Rains on August 21-22, 2002, on Five Northern Illinois Basins

Basin Characteristics

Drainage basin	*Basin area, mi^2*	*Peak discharge record*
Pecatonica at Freeport	1,326	1914-present
Rock River at Como	8,735	1915-present
Kishwaukee at Belvidere	538	1940-present
Kishwaukee at DeKalb	78	1926-1933 and 1980-present
Nippersink at Spring Grove	192	1966-present

August 2002 Streamflow Conditions

Basin	*Pre-storm Flow level, cfs*	*Peak flow, cfs*	*Peak vs. pre-peak difference, cfs*	*Days until normal flow*	*Rank of 2002 and peak annual discharge year*
Pecatonica at Freeport	33	5,330	4,697	20	47: 1989
Rock River at Como	2,150	13,300	11,150	24	79: 1988
Kishwaukee at Belvidere	125	3,680	3,555	24	35: 1963
S. Kishwaukee at DeKalb	0.49	93	92.5	5	No rank
Nippersink at Spring Grove	39	145	106	7	No rank

storm were generally 3-5 inches, less than those in the 2002 storm, precipitation in the 1996 storm fell over much wetter ground. In the 60 days prior to the August 1996 rainstorm, above average rainfall had occurred (24 percent above average in northwestern Illinois and 46 percent above average in northeastern Illinois), and soils in the region were already saturated. Record precipitation over much of northern Illinois on July 17-18, 1996, created the saturated conditions and unusually high streamflow values throughout the region just 20 days prior to the rainstorm on August 5-6, 1996.

Streamflow conditions prior to the August 1996 event suggest that flow levels were above average for all five basins (Table 5) and more than double the magnitude of August 2002 pre-storm conditions (Table 4). For example, prior to the 1996 event the Kishwaukee River at DeKalb had a pre-storm value of 96 cfs, whereas the 2002 pre-storm value was 0.49 cfs (almost no flow).

The peak flow associated with the 1996 rainstorm exceeded that of the 2002 event in three of the five basins compared. Similar to the 2002 event, three basins experienced a high peak annual discharge (Table 5). However, the major difference between these two storm events is the length of time before the post-storm streamflow returned to its average seasonal value. Except for Nippersink Creek at Spring Grove, it took more than 20 days to return to a normal flow in 1996, and the flow was above average for more than 40 days after the storm on the Pecatonica and Rock Rivers. This result was quite similar to the wet (1996) versus dry (2002) pre-storm comparison made for central Illinois.

Other storm-related impacts included flooded cars, swamped backyards, and travel delays. High water partially blocked two interstates in the Chicago region, I-290 and I-94, for several hours, with impacts on thousands of commuters (*Chicago Tribune*, August 22, 2002). Several drivers in the Chicago suburbs abandoned their stranded cars on flooded streets. The heavy rain also caused delays and cancellations of 22 flights at Chicago's O'Hare International Airport and flooding that shut down two of Chicago's commuter rail lines. Several suburban retention ponds overflowed, causing localized flash flooding. The Chicago Deep Tunnel system filled quickly,

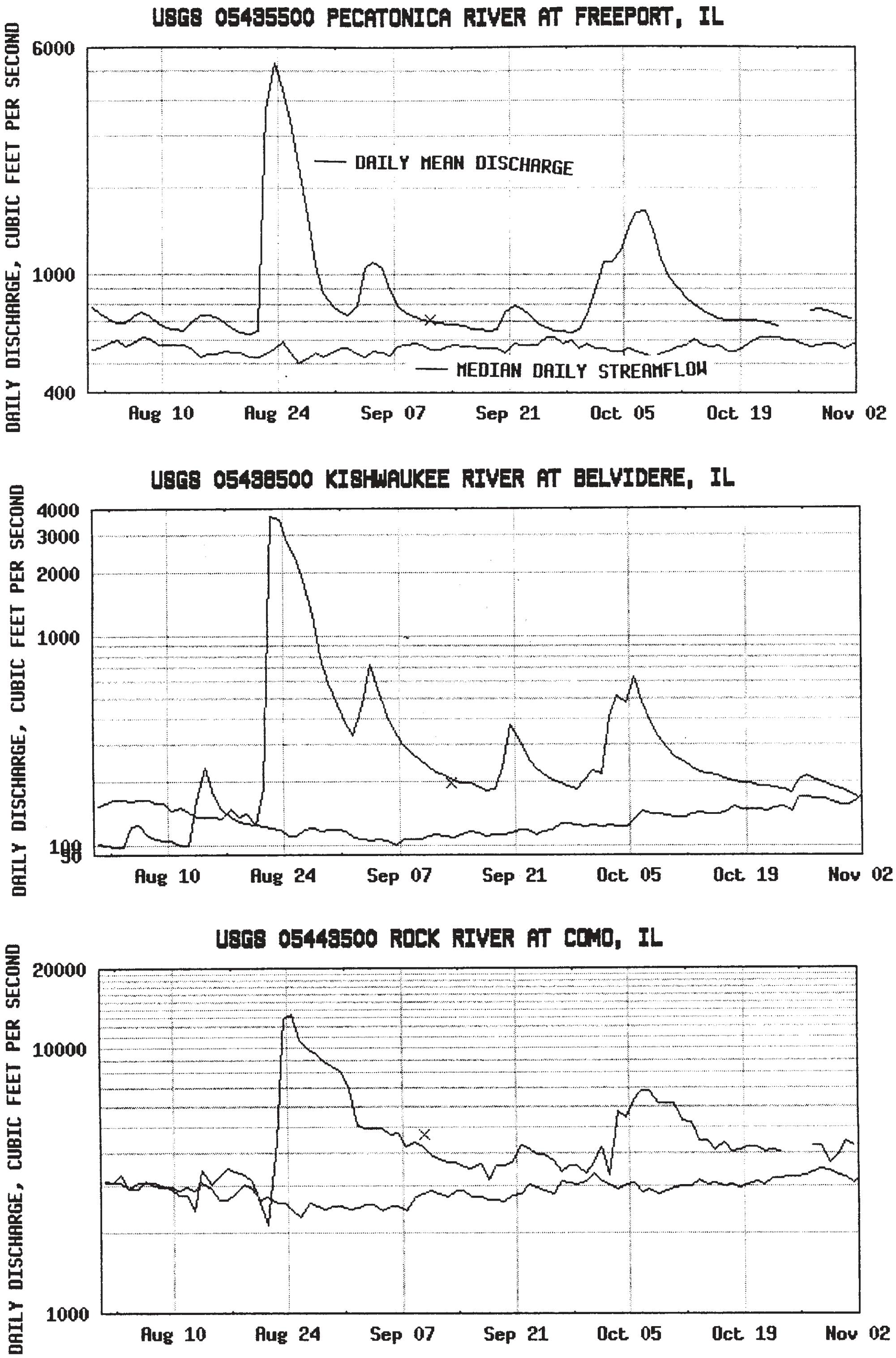

Figure 36. Hydrographs for three basins in northern Illinois.

Table 5. Streamflow Conditions, August 5-6, 1996

Basin	*Pre-storm Flow level, cfs*	*Peak flow, cfs*	*Peak vs. pre-peak difference, cfs*	*Days until normal flow*	*Rank of 2002 and peak annual discharge year*
Pecatonica at Freeport	1,240	1,760	520	41	No rank
Rock River at Como	8,630	20,500	11,870	41	60: 1988
Kishwaukee at Belvidere	260	1,880	1,620	22	52: 1963
S. Kishwaukee at DeKalb	96	1,130	1,034	22	9: 1930
Nippersink at Spring Grove	85	205	120	9	No rank

and more than one billion gallons of untreated storm water and wastewater were released into Lake Michigan, forcing beach closures.

Some rural roads across northern Illinois were washed out or damaged, requiring repairs. Both U.S. Route 20 and Illinois Route 78 near Stockton were closed for a short period due to flooding. Direct impacts of the record rains appeared to be less than expected. Dave Schuster, assistant chief, Dubuque Fire Department, summed up the view of many people, “As much rain as we had, we did not have any calls for service.” Heavy rains, 6-7 inches, across the Rockford area caused local flooding of streets, some basements, and city parks near the Rock River (*Rockford Register Star,* August 23, 2002). The local flooding did not last more than 48 hours, and damages were minor, less than $30,000. The storms also led to power outages for 6,700 Rockford customers. Based on past flood loss assessments, total damages from this Illinois-Iowa storm were an estimated $250,000.

Several persons in northwestern Illinois and eastern Iowa observed that the heavy early summer rains on June 2-3, 2002, had produced much greater impacts (six eastern Iowa counties were designated as disaster areas) than the August 21-22 rainstorm. Although people did not like experiencing two major rainstorms in one year, they reported being better prepared for the second event. Furthermore, the timing of the rainstorms, one early in the growing season when crops were just beginning to grow versus late summer when crops were mature (and consuming large amounts of water daily) with a full plant canopy had an impact on the degree of flooding and resulted in quite different losses in agricultural regions.

Most farmers in rural regions of northern Illinois indicated they had welcomed the rainfall associated with the August 21-22 event, especially in terms of their soybean crops. The rains were too late to help the corn crop, but numerous farmers expressed a belief that the rains would help the soybean crop by adding more pods and increasing yields. Before the storm moisture in the soil at the 0- to 40-inch depth was 75 percent of average, but it was up to 110 percent of average on September 1. The SOYGRO weather-yield model with soil and other conditions representative of northern Illinois was used to predict soybean yields with and without the heavy rains of August 21-22. The results indicated that the late season rainfall improved yields about 1.2 bushels per acre. Benefits of rains in late August were realized because a significant number of soybean fields had to be replanted in mid-June (after heavy rains in early June), and thus were not as far along in their growth cycle as usual. Illinois and Iowa climate divisions that received moderate to heavy rains on August 21-22 contained 2,565,000 acres of soybeans, and the addition of a bushel per acre at fall prices of $5.30 per bushel resulted in an added value of the rains, estimated at $13.6 million.

Summary

Assessment of conditions with 36 prior rainstorms during 1951-2001 revealed that all these rainstorms had damaging physical and economic impacts much greater than those from the two August 2002 rainstorms. Review of these 36 rainstorms revealed all had occurred after three or more months of average to much above average rainfall. Thus, the two August 2002 rainstorms were the first heavy rainstorms investigated that occurred in areas that experienced much below average rainfall for two or more prior months. The considerable magnitude of the August 2002 rainstorms, and the low magnitude of their socioeconomic losses in contrast to those of other similar earlier rainstorms, is seen as a result of the exceptionally dry pre-storm conditions. The August 2002 storms fell on parched soils that allowed much greater infiltration and restoration of soil moisture, with less surface runoff as a result. Consequently, Midwestern farmers in storm zones enjoyed increased soybean yields. Estimated yield gains were \$13.6 million (northern Illinois and eastern Iowa) and \$37.9 million (east-central Illinois).

Although many flood-related impacts are related to the peak discharge level associated with a flood or heavy rain, it appears that economic losses magnify when above average flows continue for long periods after the storm. This scenario appears to occur when pre-storm conditions are average to wetter than average. Furthermore, depending on the growth stage of the crop, floods or heavy rains on dry soils can be beneficial for agriculture.

Conclusions

This comprehensive assessment of two major rainstorms in the Midwest was conducted as part of the research program of the Midwestern Regional Climate Center (MRCC). This program focuses on assessments of major regional storm events and climate extremes. These investigations typically include describing the event in detail, assessing its climatological significance, identifying principal atmospheric conditions that led to the event, and defining environmental and socioeconomic impacts. Previous MRCC studies have included the 1988 drought, the odd weather conditions of 1989, the floods of 1993, a giant rainstorm in 1996, the extremes of the 1997-1998 cold season related to El Niño, the heat waves of 1995 and 1999, and a record-setting massive hailstorm in 2001.

The two August 2002 rainstorms, one centered in Illinois and Indiana on August 18-19 and another in Iowa, Illinois, and Wisconsin on August 21-22, created record-setting point rainfalls >10 inches and >12 inches, respectively. Return intervals of both storms' heavy rain amounts for 3-, 6- and 12-hour durations exceeded once in 100-year values.

In many respects the characteristics of the two storms were similar to those of 36 past Illinois-centered rainstorms during 1951-2001 that also were investigated in comparable detail. All the rain fell in 24 hours or less and most in 8 hours or less. Heaviest rains occurred at night. The major axis of storm areas was west-east oriented. The areal extent of the region with >2 inches covered more than 9,000 square miles. Synoptically, conditions were similar to those of some past rainstorms. The storms developed south of a west-east-oriented front, precipitable water values were exceptionally high, >1.7 inches, and the frontal position and LLJ stream proximity trained thunderstorms along the same path.

The two August 2002 rainstorms had two features that were quite different from those in any past rainstorm assessed since 1951, however. The two storm events occurred just 2.5 days apart in relatively adjacent areas: no other major past storms had occurred in such close time proximity. The closest incidence of past storms was 12 days, an interval that separated two summer 1957 storms, one in southern Illinois-Indiana, and another in central Illinois-Indiana.

A second major difference related to pre-storm precipitation and soil moisture conditions. Both August storms occurred in areas where rainfall had been much below normal for 2.5 months before the storm, creating much below normal soil moisture and droughtlike conditions for crops. In contrast, all prior 36 major rainstorms occurred after two-month or longer periods of average to much above average rainfall. Ironically, both August storms occurred in localized areas that had experienced below normal rainfall since June 1, whereas surrounding areas had experienced above average rainfall.

This pre-storm dryness greatly affected impacts from the two August storms. Neither storm produced the magnitude of property and crop damages of comparable storms. Estimated damages and losses from the August 21-22 storm were $250,000, and those from the August 18-19 storm were $75,000.

Because soils were very dry in mid-August 2002, a much greater percentage of the total storm rainfall infiltrated the soil, resulting in less runoff. High early peak flows occurred in river basins where heaviest rains fell and were sufficient to rank as annual peaks for 2002, but flows quickly dropped and returned to normal levels 10-22 days after the storms. This return to normal levels is two to three times faster than in the 36 prior storms with wetter pre-storm conditions. As a result, some flood-related losses occurred immediately after the August storms, but flooding quickly dissipated and was concentrated largely on lands adjacent to rivers and major streams in the core of the storms. Flood-related losses were minimal, and the major economic impact of the two August storms related to the added soil moisture and, in turn, had positive effects on maturing soybean crops. Spring weather conditions had delayed soybean planting, and crops were in the pod-filling stage and shy of soil moisture when the storms occurred. The heavy rains replenished soil moisture, leading to increased soybean yields, which caused the market price of soybeans to fall. Added yields at the resulting fall price were worth an estimated $13.6 million in northern Illinois-Iowa and $37.9 million in east-central Illinois, a total in excess of $51 million.

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