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THE BLACK HILLS—RAPID CITY FLOOD OF JUNE 9—10, 1972: A DESCRIPTION OF THE STORM AND FLOOD

Report prepared jointly by the U.S. Geological Survey
and the National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF THE INTERIOR • U.S. DEPARTMENT OF COMMERCE

GEOLOGICAL SURVEY PROFESSIONAL PAPER 877

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By FRANCIS K. SCHWARZ, LAWRENCE A. HUGHES, and E. MARSHALL HANSEN
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FOREWORD

The U.S. Geological Survey and the National Weather Service have a long history of cooperation in monitoring and describing the Nation's water cycle—the movement of water as atmospheric moisture, as precipitation, as runoff, as streamflow, as ground water, and finally, through evaporation, its return to the atmosphere to begin the cycle over again. The cooperative effort has been a natural dovetailing of technical talent and responsibility: the National Weather Service as the Federal agency responsible for monitoring and predicting atmospheric moisture and precipitation, for forecasting river flow, and for issuing warnings of destructive weather events; and the U.S. Geological Survey as the primary agency for monitoring the quantity and quality of the earthbound water resources.

This report represents another step in the growth of our cooperative efforts. In some ways, this closer working arrangement has been spurred by five major flood disasters that have struck the Nation in the last 5 years. In August 1969, the remnants of Hurricane Camille caused flooding of the James River and other streams in central Virginia that left 152 people dead or missing. In February 1972, the failure of a coal-waste dam sent a flood wave down the Buffalo Creek valley of West Virginia, leaving 118 people dead or missing. On June 9, 1972, extremely heavy rains over the eastern Black Hills of South Dakota produced record-breaking floods on Rapid Creek and other streams, leaving 237 dead and 8 missing. Beginning on June 18, 1972, the remains of Hurricane Agnes produced floods in the eastern United States from Virginia to New York that killed 117 people in what has been called the worst natural disaster in American history. Most recently, the spring 1973 floods on the Mississippi River produced a record 89 days of floodflow at Vicksburg, Miss., and 78 days at St. Louis, Mo.; inundated more than 11 million acres of land; and damaged over 30,000 homes.

These disasters have underlined the need to know more about and respect the force and flow of floodwater and have given impetus to further cooperation between the U.S. Geological Survey and the National Weather Service to combine their respective studies and information about flood events into single, unified reports. Hopefully, this documentation of the Black Hills–Rapid City flood will aid the understanding of such flood disasters and will help improve human preparedness for coping with future floods of a similar catastrophic magnitude.

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THE BLACK HILLS-RAPID CITY FLOOD OF JUNE 9-10, 1972: A DESCRIPTION OF THE STORM AND FLOOD

By FRANCIS K. SCHWARZ, LAWRENCE A. HUGHES, and E. MARSHALL HANSEN, of the National Weather Service, and M. S. PETERSEN and DONOVAN B. KELLY, of the U.S. Geological Survey

ABSTRACT

On June 9, 1972, an almost stationary group of thunderstorms formed over the eastern Black Hills of South Dakota near Rapid City and produced record amounts of rainfall and flood discharges. Nearly 15 inches of rain fell in about 6 hours near Nemo, S. Dak., and more than 10 inches of rain fell over a 60-square-mile area. The resulting floods were the highest ever recorded in South Dakota. At least 18 of the 27 streams where peak flows were computed experienced flows that exceeded the 50-year flood.

At least 237 people died in the Black Hills flood and 8 people were still listed as missing 6 months after the flood. Another 3,057 people were injured, and total damage is estimated to have exceeded $160 million.

As documented by radar and satellite images and by radiosonde observations, as well as by much other weather data, the unusual and excessive rainfall was partly the result of a strong, low-level, easterly airflow that forced moist air upslope over the Black Hills. This sustained orographic effect helped the air to rise, cool, become very unstable, and release its moisture in repeating thunderstorms. Another important contributing factor was the unusually light winds at higher levels. Those light winds did not disperse the moist air or move the thunderstorms along to prevent the extreme concentration of rainfall. Instead, these conditions allowed heavy rainfall to remain almost stationary along the eastern slopes of the Black Hills.

Rainfall data from 24 observing stations and from over 200 miscellaneous sites show that all reported rains greater than 4 inches fell on the eastern slopes of the Black Hills. At least 6 inches of rain fell over a 300-square-mile area that lies primarily between 4,000 and 5,000 feet elevation.

Almost all the flood peaks occurred between 2230 MDT on June 9 and 0100 MDT on June 10, 1972, in a flood belt about 40 miles long and 20 miles wide along the eastern slopes of the Black Hills. This belt extended from Sturgis, S. Dak., on the north to Hermosa, S. Dak., on the south, with Rapid City near the center. To document the flood, peak discharge determinations were made at 49 sites. Records show that about 13,000 acre-feet of water flowed through Rapid City during the 2 days of flooding. At one point during the night of June 9, the floodwaters rose about 3.5 feet in 15 minutes. Coming off the slopes of the Black Hills, the flood peak traveled the 22 miles between Deer Creek and Rapid City in about 3.5 hours.

THE BLACK HILLS–RAPID CITY FLOOD: AN EXTREME STORM, A FLOOD, AND HUMAN TRAGEDY

June 9 was the first day of one of the early weekends of the 1972 summer season in Rapid City. Along with the area's 50,000 residents, the first of the year's expected 6 million visitors to the Black Hills were in Rapid City (fig. 1) looking forward to the start of the "Dakota Days" celebration. The day ended in tragedy: 237 dead, 8 missing, 3,057 injured, 1,335 homes and 5,000 automobiles destroyed, and total damage in excess of $160 million in the Black Hills area.

This report is primarily designed to describe and reconstruct the unusual physical events surrounding this disaster: the unusual weather conditions that produced nearly 15 inches of rain in 6 hours at one location and more than 10 inches of rain over some 60 square miles and the resulting extreme flood. Although the physical facts of the storm and resulting flood are the primary subject of this report, any description of the Black Hills–Rapid City flood of 1972 would be incomplete without a chapter on the human tragedy that resulted.

SCOPE AND ACKNOWLEDGMENTS

The large amount of information needed to document the Black Hills flood required the cooperation and effort of many individuals and government agencies. Their aid and the data they supplied are gratefully acknowledged.

At the heart of this report is a core of basic data: precipitation measurements from some 240 locations; flood-discharge measurements at 49 sites; and flood profiles surveyed along 19 miles of Rapid Creek. Added to this are bits of vital information from many sources: radar images of the storm from Na-

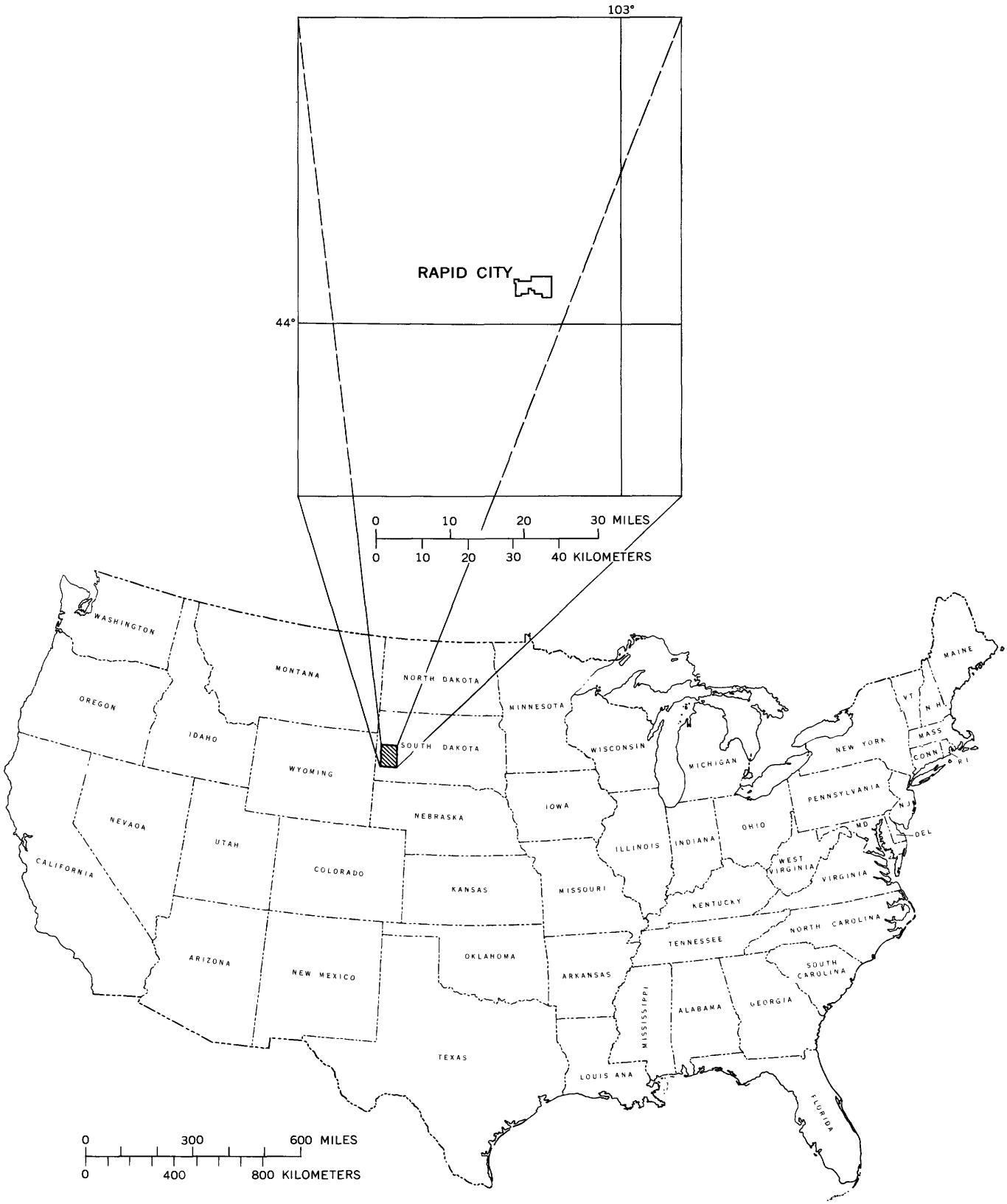


FIGURE 1.—Location of flood area. Rapid City and the flood area lie along the eastern slopes of the Black Hills in west-central South Dakota.

tional Weather Service and U.S. Air Force stations; satellite images of the continental and regional weather patterns; readings from radiosonde observations; the weather and flood observations of eyewitnesses; a detailed engineering survey with special computations; and a comparison with previous floods and storms. The effort and skill of our coworkers, including the Geological Survey field hydrologists stationed at Rapid City and those detailed to Rapid City from Colorado, Illinois, Kansas, Missouri, Nebraska, North Dakota, and South Dakota, and the National Weather Service meteorologists and observers on duty in Rapid City and at headquarters in Kansas City and Washington, D.C., made possible the collection and interpretation of the extensive meteorological and hydrological data related to this unusual storm and the resulting flood.

We also acknowledge the direct assistance of the U.S. Bureau of Reclamation and the National Forest Service who furnished much data as well as men to assist with the fieldwork. The U.S. Army Corps of Engineers and the National Guard also greatly aided our efforts in the field. Finally, we thank the residents of the Black Hills for their assistance in documenting this natural disaster.

CONVERSION FACTORS

English units have been used in much of this report. The following factors may be used to convert the English units published herein to the International System of Units (SI).

Multiply English units	*By*	*To obtain SI units*
inches (in.)	25.4	millimeters (mm)
	.0254	meters (m)
feet (ft)	.3048	meters (m)
miles (mi)	1.609	kilometers (km)
knots (kts)	1.853	kilometers per hour (km/hr)
	.5148	meters per second (m/s)
square miles (mi^2)	2.590	square kilometers (km^2)
cubic feet (ft^3)	28.32	cubic decimeters (dm^3)
	.02832	cubic meters (m^3)
cfs-day [(ft^3/s)-day]	2447	cubic meters (m^3)
	2.447×10^{-3}	cubic hectometers (hm^3)
acre-feet (acre-ft)	1233	cubic meters (m^3)
	1.233×10^{-3}	cubic hectometers (hm^3)
	1.233×10^{-6}	cubic kilometers (km^3)
cubic feet per second (ft^3/s)	28.32	liters per second (l/s)
	28.32	cubic decimeters per second (dm^3/s)
	.02832	cubic meters per second (m^3/s)

METEOROLOGIC SETTING

PRECIPITATION AVERAGES AND EXTREMES

Precipitation in the Black Hills averages 24 inches a year, considerably greater than the 16 inches in the surrounding plains (U.S. Dept. of Commerce, 1968). The higher precipitation is accounted for by the greater frequency, longer duration, and sometimes greater intensity of storms along the terrain slopes, as compared to the frequency, duration, and intensity of storms over the relatively smooth terrain of the adjoining plains. The slopes provide the slight triggering or lift of nearly saturated air that is sufficient to begin showers. Directly west of Rapid City the mean terrain slope is approximately 100 feet per mile, while farther to the south, west of Hermosa, the mean slope increases to 200 feet per mile. Monthly precipitation maps show that the 24 inches of precipitation is fairly well distributed throughout the year (U.S. Dept. of Commerce, 1968).

Maximum 1-day rainfalls of record tend to occur more frequently and also tend to be higher in the Black Hills than in the neighboring plains. From about 1913–63, the average of maximum 1-day rainfalls of record for 12 stations in the Black Hills (elevations over 4,000 ft) was 4.4 inches, compared with 3.6 inches for 9 South Dakota stations (elevations of 2,000 to 4,000 ft) located in the area surrounding the Black Hills (Jennings, 1952, unpub. summary tabulations National Weather Service). The maximum 1-day rainfall from both groups of stations is the same, 7.1 inches.

Hydrologic conditions in the Black Hills area of South Dakota were not abnormal immediately prior to the events of June 9–10, 1972. Scattered showers occurred throughout the area on several days during the early part of June, but generally the quantity of rain that fell was small (0.2 in. or less). Pactola Dam, however, had higher rainfall amounts reported on June 2, 3, and 5, with 0.81 inches, 0.61 inches, and 2.49 inches, respectively, recorded for those days. These amounts of rainfall saturated the soil, and although there were only small scattered showers from June 5 to the date of the flood, the soil was probably still wet from the previous rains. These conditions would increase the amount of runoff and quicken the time of concentration for the flood of June 9.

Some judgment on the rarity of the reported value of 15 inches in about 6 hours on June 9–10, 1972, can be obtained by a comparison of the greatest 6-hour amounts that occurred during a nearly uniform period of record at several stations. Published summaries on the greatest 6-hour rainfall depths are available for 38 recording rain-gage stations in South Dakota for an average of 12 years of record. The greatest 6-hour amount of the three recorders in the Black Hills is 4.36 inches recorded at Spearfish (the average of the maximum amounts for the three

stations is 2.85 inches). The greatest amount at the 35 stations outside the Black Hills is 4.52 inches recorded at Howard (average of the maximum amounts for the 35 stations is 3.01 inches). Because the Black Hills area is represented by fewer stations, there is a much higher probability of recording an extreme amount outside the Black Hills than in them. Even so, it can still be inferred from the data that the Black Hills are not particularly more likely to have heavy short-duration rains than the surrounding area.

Detailed maps of rainfall frequency for the Black Hills of South Dakota have been prepared in an unpublished study by the National Weather Service. In addition to using rainfall-frequency values computed for stations with precipitation observations, the relations between rainfall-frequency values and meteorologic, climatologic, and topographic factors were used to interpolate between stations. The 100-year 6-hour precipitation-frequency map shows an elongate 3.6-inch rainfall-depth center between the 4,000- and 5,000-foot contours on the eastern slopes of the Black Hills; this depth decreases to 3.4 inches over the plains to the east of the 3,000-foot contour. North and south of the Black Hills values decrease to less than 3 inches.

STORM-CENTERED MAXIMUMS

Although useful in comparing long-term precipitation rates, the 6-hour precipitation figures recorded at rain-gaging stations only rarely record the maximum amount of precipitation produced during a storm. With few exceptions, recorder stations are not located at the center of peak rainfall. The maximum reported rainfall in the Black Hills flood, the storm-center maximum of 15 inches of rain in just over 6 hours measured near Nemo, S. Dak., in a "bucket survey" conducted following the storm, should only be compared with other similar storm-centered values measured on the northwestern Great Plains. Some 132 such storms have been analyzed in the northwestern Great Plains States of North Dakota, South Dakota, Kansas, Montana, Wyoming, and Colorado (U.S. Army Corps of Engineers, 1945). Of these, 10 storms had point rainfall values of 10 inches or more in 6 hours and two exceeded the 15-inch, 6-hour precipitation of the Black Hills storm (table 1).

Outstanding for northwestern Great Plains is the Cherry Creek, Colo., storm of May 30–31, 1935, with two station 6-hour values of 24 inches of precipitation. These amounts were measured approximately 150 miles apart, one at an elevation of 3,500 feet, the other at about 6,000 feet. One other storm, centered near Stanton, Nebr., on June 11, 1944, also exceeded the Black Hills storm with a reported 15.5 inches of precipitation.

TABLE 1.—*Storms exceeding 10 inches in 6 hours over 10-square-mile areas in the northwestern Great Plains*

Location	Date	Average depth (inches)	Maximum station depth (inches)
Near Burlington, Colo	May 30–31, 1935	20.6	24.0
Near Stanton, Nebr	June 11, 1944	13.4	15.5
Near Nemo, S. Dak	June 9–10, 1972	---	15.0
Near Neosho Falls, Kans	Sept. 12, 1926	13.4	13.6
Grant Township, Nebr	June 3–4, 1940	13.0	(1)
Greeley, Nebr	June 5, 1896	12.0	(1)
Near Colorado Springs, Colo	June 17, 1965	11.5	12.8
Near Greeley, Nebr	Aug. 12, 1966	11.4	11.8
Springbrook, Mont	June 19, 1921	10.5	(1)
Near Pueblo, Colo	June 3, 1921	10.4	(1)
Sharon Springs, Kans	May 30, 1938	10.0	(1)

[1] Insufficient data to distinguish between maximum station value and average depth over 10 square miles.

Probable maximum precipitation (PMP) is defined as the maximum precipitation amount that would result from an optimum combination of meteorological factors. For a given location and time of the year, it represents the estimated greatest depth of precipitation meteorologically possible for a given duration. Its derivation involves the judicious selection of a set of synoptic conditions relevant to the area and season under consideration which satisfies the maximization requirement. The probable maximum precipitation for Rapid City and vicinity for June 9–10, shown in figure 2, was interpolated between the May and June maps shown in Hydrometeorological Report No. 33 (Riedel and others, 1956). For purpose of comparison, the actual rainfall amount of 12.8 inches recorded by Rapid City gage 5NW for a duration of 12 hours (fig. 16) constitutes about 65 percent of the probable maxi-

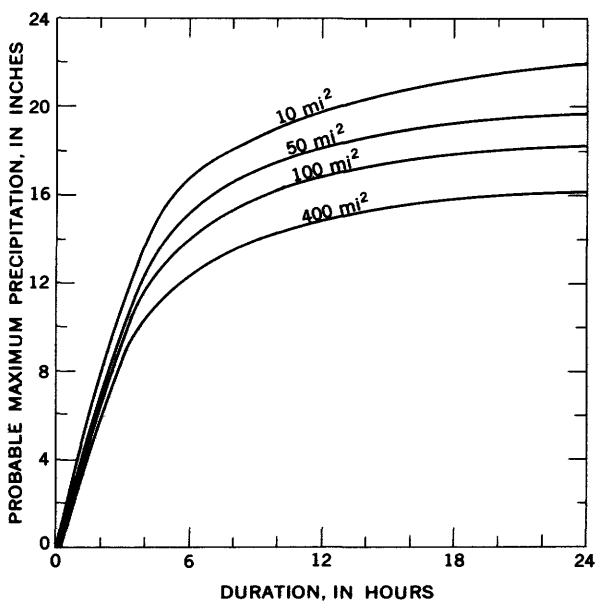


FIGURE 2.—Probable maximum precipitation amounts for Rapid City and vicinity, June 9–10.

mum precipitation for a 10-square-mile area. The highest storm rainfall amount of 15 inches in just over 6 hours was reported near Nemo from a "bucket survey." Using a duration of 6 hours and an area coverage of 10 square miles, this highest observed rainfall near Nemo would constitute about 90 percent of the probable maximum precipitation. These comparisons provide some insight with regard to the severity of the storm.

Heavy rains have occurred previously in the Black Hills but were not measured. Notable is the storm of June 1907. Although rain measurements were not available for the Black Hills, 7.1 inches was caught in 24 hours on June 12–13 at Fort Meade (elev 3,600 ft) near the northern foothills. Hermosa, south of Rapid City, measured 1.80 inches in 2 days. A record 24-hour rainfall of 7.1 inches at Custer (elev 5,300 ft) on April 17, 1920, was apparently caused by a local intense thunderstorm. Of the 14 stations then reporting in the Black Hills, the second highest daily rain was 2.10 inches. On July 13, 1962, heavy local rains occurred in the Black Hills. Ten rainfall stations in and near the Black Hills averaged about 1 inch in a day (13th or 14th) ranging from a low of 0.15 to a high of 1.64 inches.

THE ROLE OF OROGRAPHY IN PRODUCING EXTRAORDINARY RAINFALLS

The exact role of orography is difficult to determine in situations where extraordinary rains from persisting, or repeating, thunderstorms occur. The maximum areal storm rainfall amount (depth-area-duration data) has been determined for nearly 700 storms in the eastern two-thirds of the United States, including more than 50 storms that produced rainfalls of 10 inches or more in 6 hours or less. The vast majority of these extraordinary rains occurred over terrain which could not give significant vertical uplift. In those cases where orography does appear to play a role, the terrain usually acts only as a mechanism for "fixing" or holding in place the persisting or reoccurring massive and efficient rain-producing thunderstorms.

The Smethport, Pa., storm of July 17–18, 1942, which produced more than 30 inches of rainfall in an estimated 4½ hours, occurred where ground slopes were not a significant factor in producing uplift currents. Likewise, the Camille-generated massive repeating thunderstorms of August 19–20, 1969, in Virginia, produced a 20-inch rainfall center in a basically nonorographic region, (Schwarz, 1970) although the first impressions were that the terrain played a substantial role. The Camille storm again demonstrated that the thunderstorm mechanism itself, fueled by the latent heat of condensation, was of overriding importance. Closer to the setting of the Black Hills downpour, the Cherry Creek, Colo., storm of May 30–31, 1935, produced two relatively comparable rainfall centers of 24 inches in about 6 hours. One of the centers was located where terrain-produced vertical air currents of consequence were not possible.

These cases of extraordinary rains strikingly emphasize the fact that the thunderstorm mechanism itself, unaided by orographic lifting, is capable of producing the largest observed rains of record for durations of 6 hours or less. In the Black Hills storm of June 9–10, 1972, terrain played a somewhat greater role than in the extraordinary storms just discussed, especially in increasing the rainfall volume and concentrating the greatest rainfall amounts in an elongate pattern parallel to the mean terrain contours. A more definite answer to the importance of terrain effects must await more detailed study of this unusual storm in particular, and, more generally, of the flood-producing, massive efficient thunderstorm phenomenon itself.

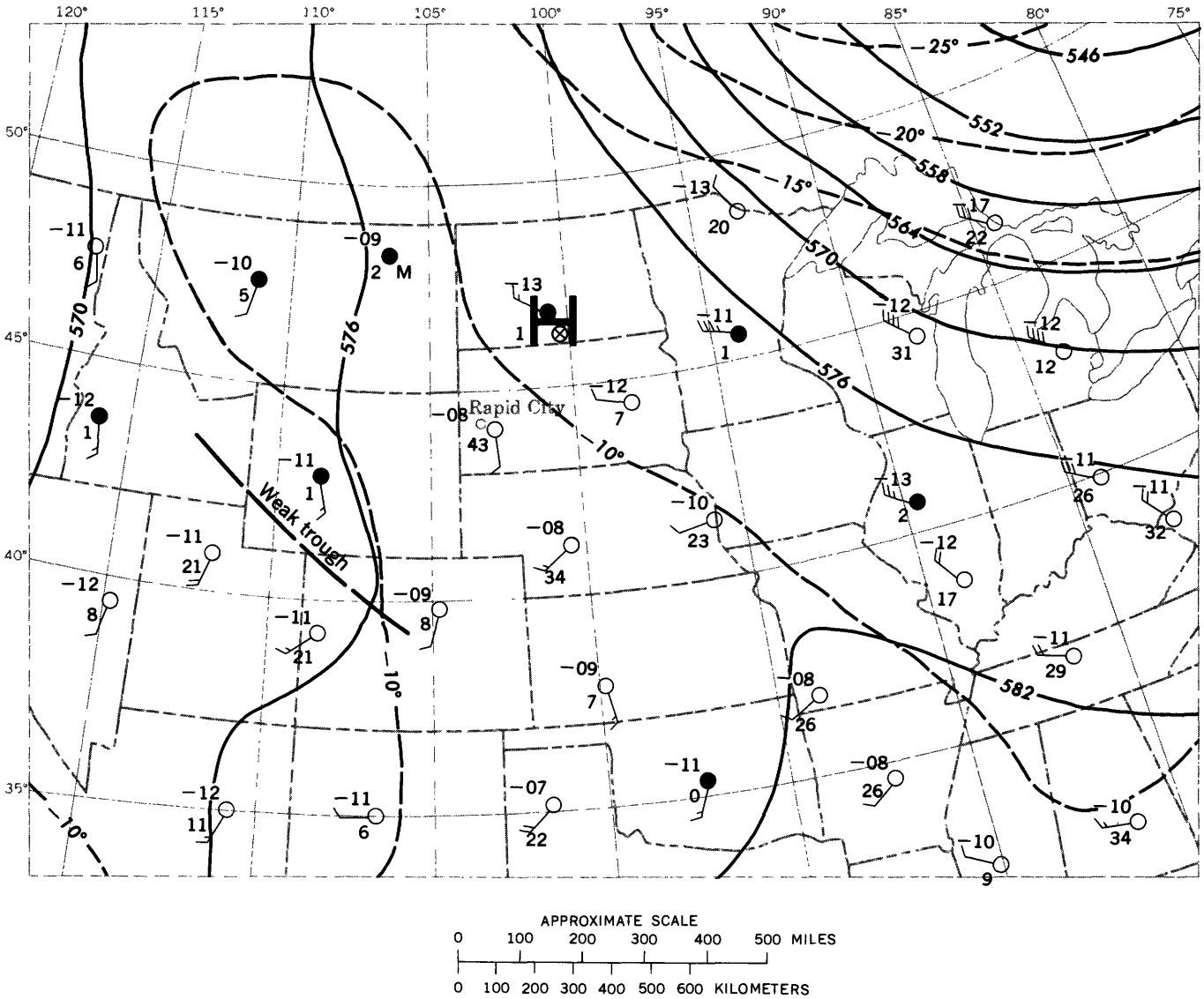
THE BUILDING STORM

Extraordinary events do not have ordinary explanations. The rainfall that began in the Black Hills on the afternoon of June 9, 1972, fits such a category. Although it is difficult to explain the exceedingly complex systems that cause extraordinary rains, the following section provides a discussion of atmospheric phenomena considered important in the production of this unusual rainfall. Ongoing and future studies will have to thoroughly investigate the mesoscale features before such extraordinary rainfall events can ever be explained fully.

In brief, the unusual and excessive rainfall was partly the result of a strong low-level easterly airflow that forced moist air upslope over the hills. This sustained orographic effect helped the air to rise, cool, become very unstable, and release its moisture in repeating thunderstorms. Another important contributing factor was the unusually light winds at higher atmospheric levels. These light winds did not disperse the moist air or move the thunderstorms along to prevent the extreme concentration of rainfall. Instead, these conditions allowed heavy rainfall to remain almost stationary along the eastern slopes of the Black Hills.

UPPER-AIR CONDITIONS

The upper-air configuration prior to the storm shows a prominent, fairly stationary, long-wave ridge over the Great Plains with the 500-mb (millibar) ridge line just to the east of Rapid City (fig. 3). There was also a very weak smaller scale trough oriented northwest-southeast through southwest



EXPLANATION

Observation station

Upper number is air temperature, in degrees Celsius. Lower number is depression of dewpoint temperature below air temperature, in degrees Celsius. Shaft indicates wind direction. Barbs on shaft indicate wind speed, in knots. Long barb = 10 knots; short barb = 5 knots. M *indicates missing data for that element*

Geographic center of maximum height

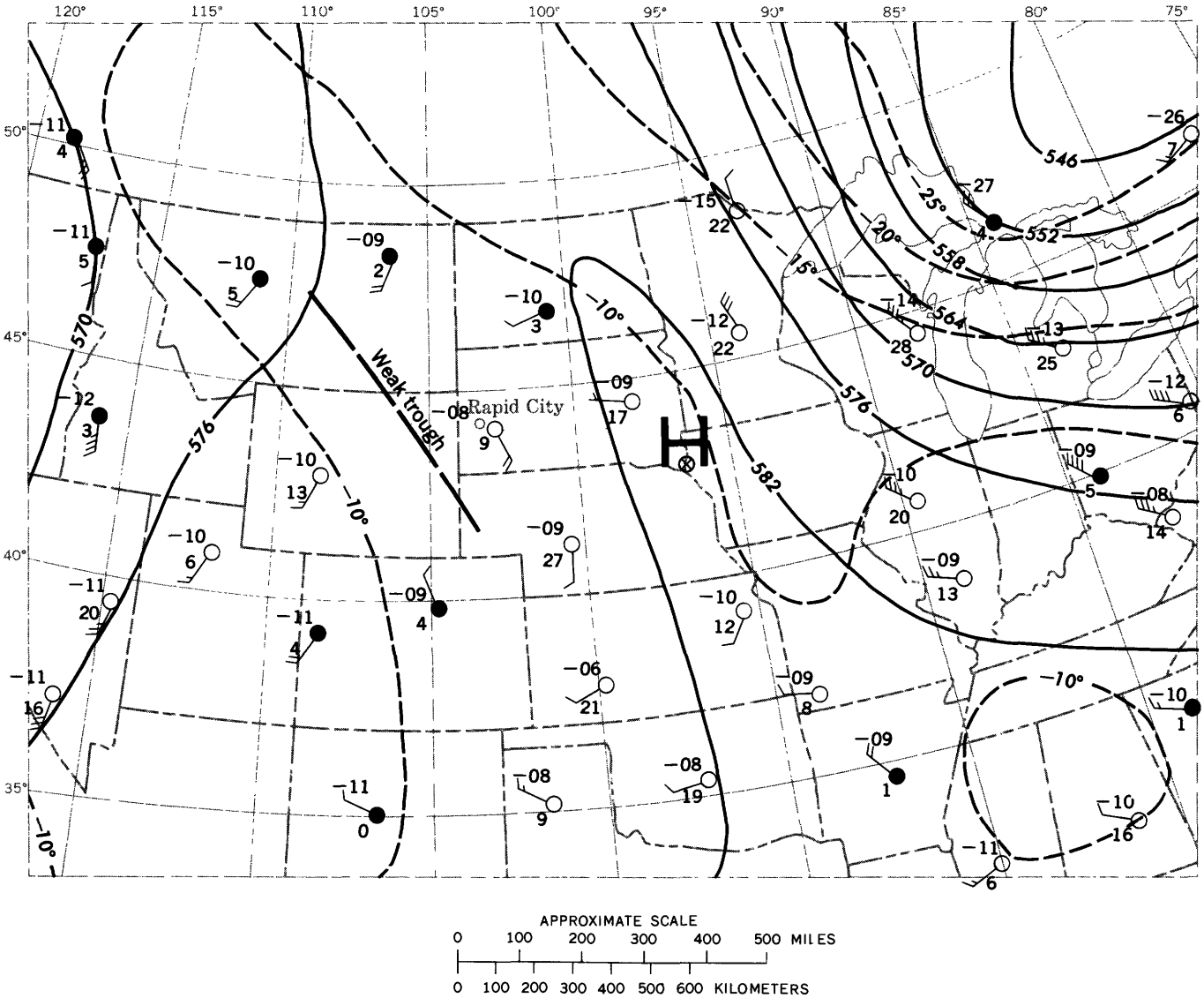
Pressure-surface height contour

Shows height of 500-mb pressure surface in tens of meters. Contour interval 60 meters. Datum is mean sea level

Line of equal air temperature

Interval 5 degrees Celsius

FIGURE 3.—Upper-air configuration prior to storm. Left chart: 500-mb analysis, 0600 MDT



EXPLANATION

Observation station

Upper number is air temperature, in degrees Celsius. Lower number is depression of dewpoint temperature below air temperature, in degrees Celsius. Shaft indicates wind direction. Barbs on shaft indicate wind speed, in knots. Long barb = 10 knots; short barb = 5 knots

Geographic center of maximum height

582

Pressure-surface height contour

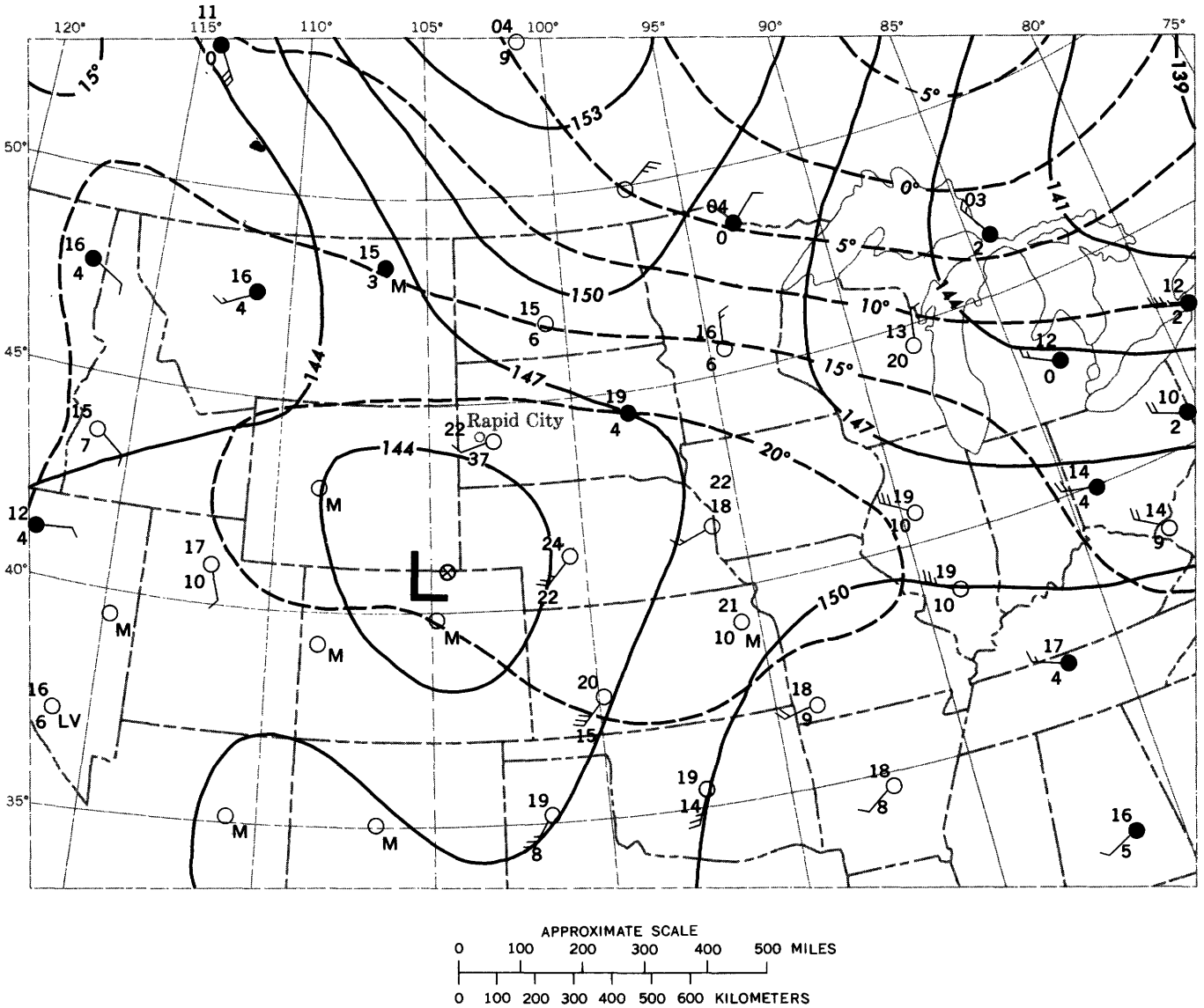
Shows height of 500-mb pressure surface in tens of meters. Contour interval 60 meters. Datum is mean sea level

−20°

Line of equal air temperature

Interval 5 degrees Celsius

(1200Z), June 9, 1972. Right chart: 500-mb analysis, 1800 MDT, June 9, 1972 (0000Z, June 10).



EXPLANATION

Observation station

Upper number is air temperature, in degrees Celsius. Lower number is depression of dewpoint temperature below air temperature, in degrees Celsius. Shaft indicates wind direction. Barbs on shaft indicate wind speed, in knots. Long barb = 10 knots; short barb = 5 knots. LV *beside the station indicates light and variable winds. Speed lees than 3 knots.* M *indicates data are missing either because of an instrument malfunction or because the constant pressure surface is below the terrain elevation for the station*

Geographic center of minimum height

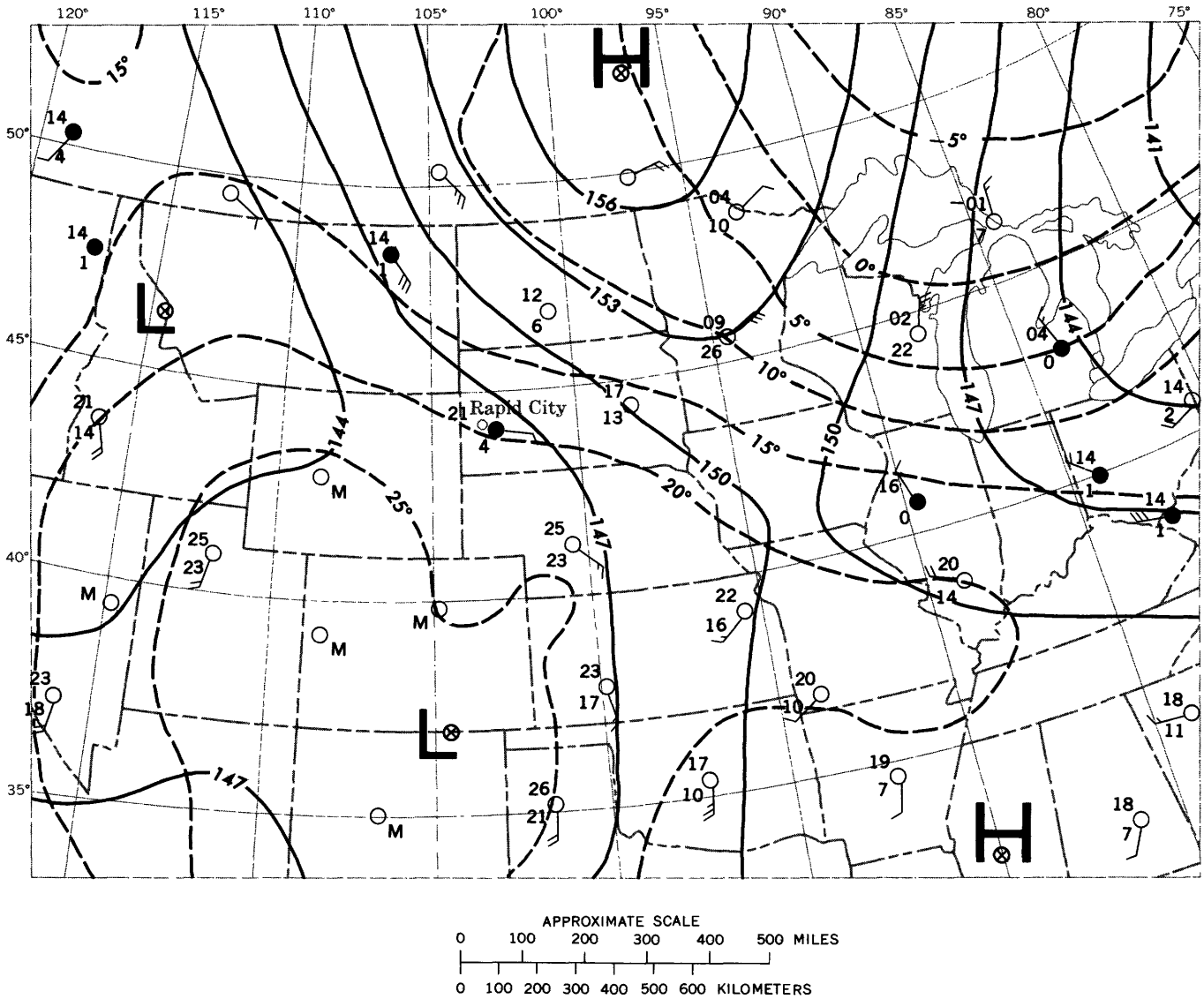
Pressure-surface height contour

Shows height of 850-mb pressure surface in tens of meters. Contour interval 30 meters. Datum is mean sea level

Line of equal air temperature

Interval 5 degrees Celsius

FIGURE 4.—Upper-air configuration prior to storm. Left chart: 850-mb analysis, 0600 MDT



EXPLANATION

Observation station

Upper number is air temperature, in degrees Celsius. Lower number is depression of dewpoint temperature below air temperature, in degrees Celsius. Shaft indicates wind direction. Barbs on shaft indicate wind speed, in knots. Long barb = 10 knots; short barb = 5 knots. M *indicates data are missing either because of an instrument malfunction or because the constant pressure surface is below the terrain elevation for the station*

Geographic center of maximum height

Geographic center of minimum height

Pressure-surface height contour

Shows height of 850-mb pressure surface in tens of meters. Contour interval 30 meters. Datum is mean sea level

Line of equal air temperature

Interval 5 degrees Celsius

(1200Z), June 9, 1972. Right chart: 850-mb analysis, 1800 MDT, June 9, 1972 (0000Z, June 10).

Wyoming. By 1800 MDT (mountain daylight time), on June 9 (0000Z (Greenwich mean time), June 10), the trough had moved into northeast Wyoming. An important characteristic of the upper-air conditions was the prevalence of light winds aloft through the Dakotas and westward that indicated the lack of a steering current. This allowed the massive thunderstorms to stay in approximately the same area for hours.

The 850-mb charts for June 9 at 0600 MDT (1200Z) and for June 9 at 1800 MDT (0000Z, June 10) show both a large Canadian high-pressure system centered well north of the North Dakota border and a weak low-pressure system centered near the Colorado-Wyoming border (fig. 4). These two broad-scale features moved southward during the next 12 hours and provided a flow of air from a general southeasterly direction over South Dakota.

The 850-mb map for 0600 MDT does not reflect low-level moisture in Nebraska, just south of South Dakota. Temperature dewpoint depressions of 22°C and 18°C at 0600 MDT (1200Z) give 850-mb dewpoints of 2°C and 4°C, respectively, at North Platte, Nebr., and Omaha, Nebr. Just to the north, however, at Huron, S. Dak., the moisture at 850-mb was quite high, with a reported 19°C temperature and 4°C temperature dewpoint depression, giving a dewpoint of 15°C. In contrast, over Rapid City at 0600 MDT (1200Z), measurements showed the dewpoint to be −15°C (fig. 5). A cyclonic curvature of the flow resulted from a combination of a southwesterly flow over Nebraska and a southeasterly flow over South Dakota. This cyclonic curvature at the 850-mb level probably resulted in a low-level convergence that helped to transport vertically the high surface moisture (discussed later). By 1800 MDT on June 9 (0000Z, June 10), a significant increase in moisture at 850-mb is noted over Rapid City where the dewpoint has risen 32 degrees to an unusually high value of +17°C.

The main feature of the upper-level charts appears to have been the prevalence of only light winds. The broad-scale features of the upper-air charts contained no significantly strong indicators that would suggest an exceptionally heavy rainfall.

SURFACE WEATHER FEATURES

Prior to the South Dakota rain, a large high-pressure system in Canada was pushing slowly southward. Early on June 9th, the leading edge of this colder air mass stretched west-southwestward across southern Lake Michigan, and westward into South Dakota, from a weak Low near northeastern New York State. The main feature of the low-level flow over South Dakota was its easterly direction throughout most of the 9th. Thus, it was given an upslope motion by both the large-scale slope of the Great Plains and the more pronounced local terrain of the Black Hills.

To the south of the leading edge of the cooler air mass, the prevailing weather systems were quite weak. Warm, moderately moist air was characteristically present on a synoptic scale (a concentrated tongue of high moisture is discussed later). On the National Meteorological Center surface charts for June 9, the surface front was positioned close to, but generally a little north of, the Rapid City area. Figures 6*A–D* show the surface maps for the period of 0600–1500 MDT (1200Z–2100Z), June 9, prior to the rains. A weak low-pressure system existed early on the 9th in eastern Colorado and western Nebraska. This low-pressure center remained weak and rather diffuse, and it appeared to move a little southward during the day. The weakness of the systems to the south of the leading edge of the cooler air produced weak pressure gradients and light winds on a synoptic scale.

Although a surface front was nearby, and upslope flow from the east prevailed, it must be kept in mind that both of these surface synoptic-scale features occur many times without producing heavy, much less exceptional, rainfall. Thus, neither the broad-scale upper-air features, nor the broad-scale surface features indicated the storm would bring unusually heavy rainfall.

Figures 7*A–D* show the 3-hour surface maps during the period of heavy rainfall over the Black Hills. The winds, cloud cover, temperature, dewpoint, and significant weather characters have been included to clarify the variation that occurred with both time and space. Of interest is the zone of thunderstorms in the vicinity of the front and the area of shower activity that extended to the south of Rapid City along the eastern Colorado border.

A strong influx of a rather narrow band of high moisture, related to mesoscale effects that increased the wind, appears to have been an important low-level feature contributing to this unusual deluge. To investigate this feature, a study was made of the development of surface pressure gradients directed upslope in the Black Hills using some of the surface geostrophic winds at grid points over the contiguous United States routinely computed by the National Weather Service in Kansas City with techniques developed by Sangster (1960). The winds at the nearest grid point to Rapid City, 40 nautical miles northeast, are shown in table 2.

Since the airflow pattern was almost stationary

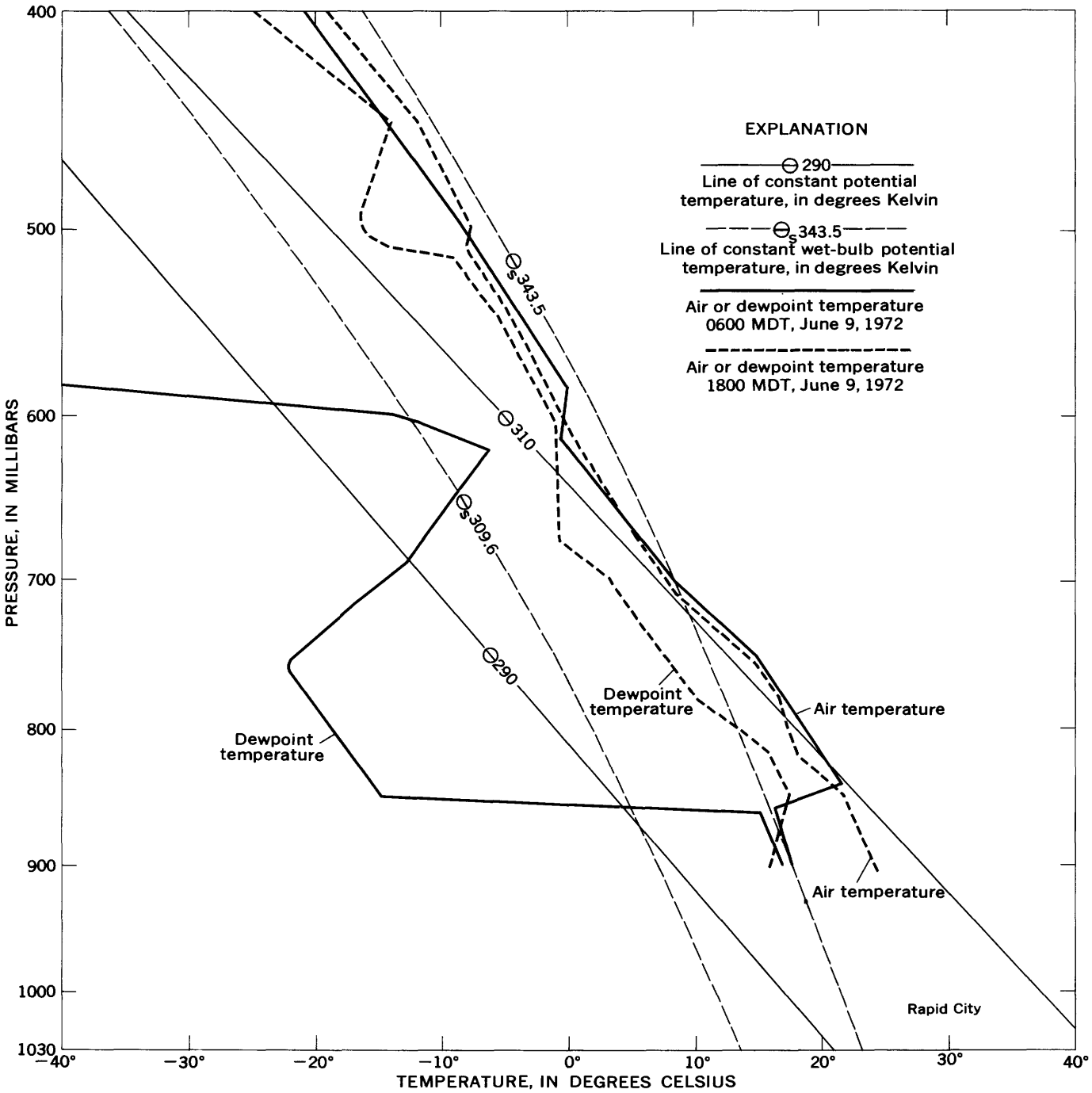
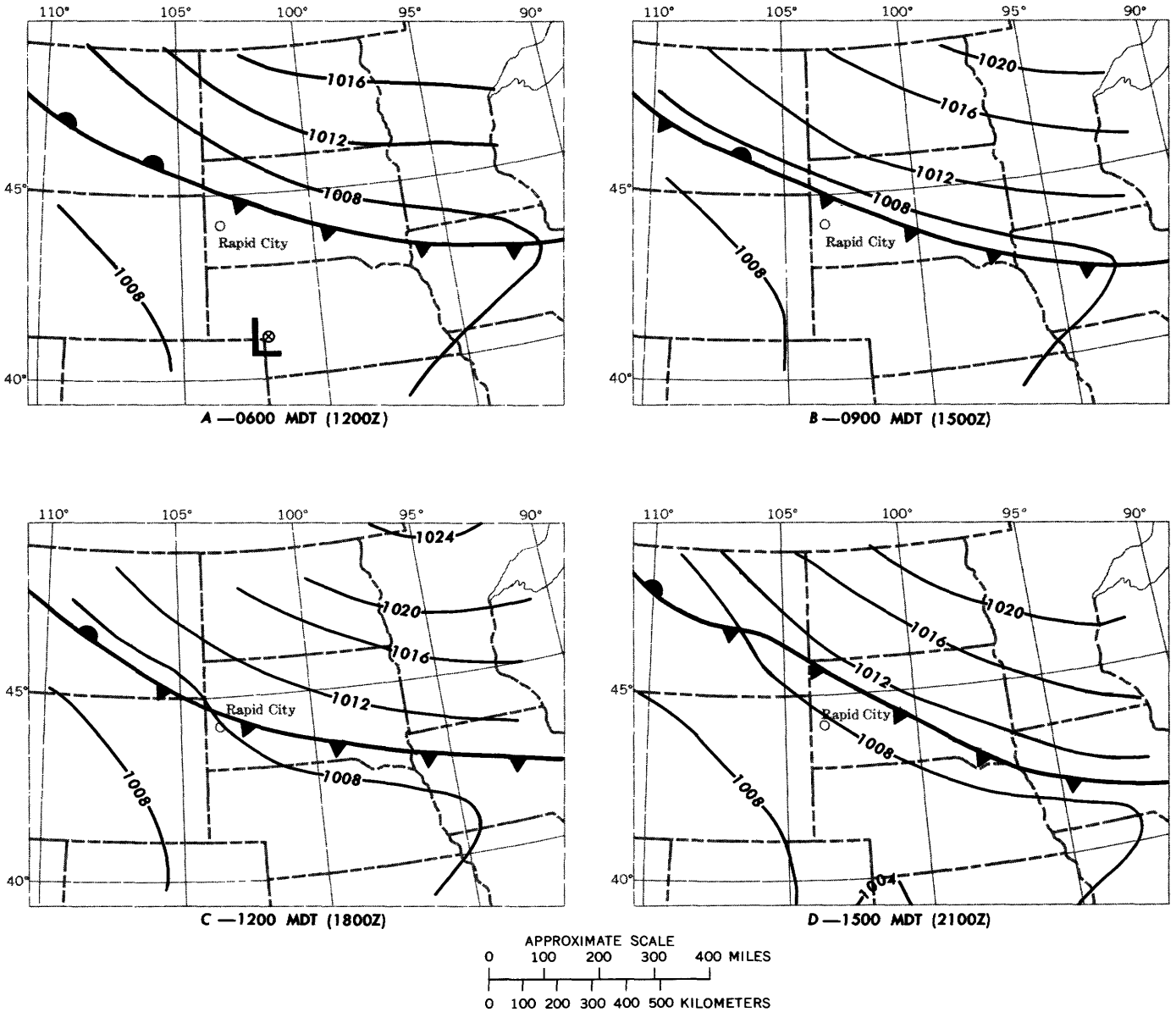


FIGURE 5.—Upper-air soundings for Rapid City.

and had only slight curvature, gradient winds would have differed little from these values. The pronounced afternoon wind maximum caused strong terrain-induced lifting because of the nearly north-south orientation of both the general terrain contours and the sharp rises of the Black Hills. Observed hourly surface winds at the Rapid City Weather Service Office for the storm period (fig. 8) may be compared with the computed surface geostrophic winds (table 2).

Hourly weather reports at Rapid City highlight the repetitive nature of the thunderstorm activity. Thunderstorms began at the airport station a little before 2000 MDT. Thunderstorms of various intensities were reported continuously for all observations until just before the 0200 MDT June 10 obser-



EXPLANATION

1008

Line of equal atmospheric pressure at sea level
Interval 4 millibars

Geographic center of low-pressure system

Warm front

Cold front

Stationary front

FIGURE 6.—Surface analysis. *A*, 0600 MDT (1200Z), June 9, 1972. *B*, 0900 MDT (1500Z), June 9, 1972. *C*, 1200 MDT (1800Z), June 9, 1972. *D*, 1500 MDT (2100Z), June 9, 1972.

TABLE 2.—*Surface geostrophic wind direction and speed for a point 40 nautical miles northeast of Rapid City S. Dak. on June 9–10, 1972*

Time (MDT)	*Direction/speed (degrees/knots)*
0600	110°/15
0900	100°/22
1200	120°/29
1500	130°/38
1800	130°/45
2100	130°/31
0000	130°/18

vation. Such a continuation of thundershower activity is typical of extreme rains that produce flooding over drainage areas as large as several hundred square miles.

It appears that the large-scale weather effects were weak but oriented to augment any mesoscale factors favorable for upward motions or for the triggering of thunderstorms. Because most of the precipitation fell in a north-to-south band along the first major upslopes west of Rapid City, the local terrain appears to have been effective in at least triggering thunderstorms in an environment of prevailing low-level easterly winds that brought in large amounts of moisture.

MOISTURE CONSIDERATIONS

An analysis of the surface dewpoints of the air mass feeding into the storm area from the east showed they were quite close to the maximum 12-hour persisting dewpoint values for the region and season (U.S. Department of Commerce, 1968, p. 59). Where differences in elevations prevail, an accurate portrayal of surface moisture is not possible unless the dewpoints are reduced to a common level. Reducing surface dewpoints to 1,000-mb has proved a useful procedure for storm-moisture analysis. An accepted technique of adjusting surface dewpoints to the 1,000-mb level is to assume the variation with elevation was equivalent to the adiabatic temperature lapse rate for saturated air. Such an adjustment was applied to dewpoints on the 3-hour surface maps from 0900 MDT (1500Z), through 1800 MDT (0000Z, June 10), June 9 to produce a map of composite 1,000-mb dewpoints for the period (fig. 9). A narrow band of 1,000-mb dewpoints, close to maximum values for the season and area, provided a concentrated supply of low-level moisture that was carried into the heavy rain area by the low-level easterly winds. Figure 10 shows the hourly trend in 1,000-mb dewpoints on June 9, 1972, for Rapid City and demonstrates how the dewpoints slowly approached a maximum persisting value of 72.5° F before the heavy rain.

Upper-air soundings for Rapid City (fig. 5) show a dramatic change in moisture and stability through depth between the morning and the evening of the 9th. Previous studies of extreme thunderstorm rain have shown that when there is high-moisture influx at low levels, the presence of a mechanism (or mechanisms) to produce or enhance low-level convergence of this air will result in thunderstorms that quickly transport the low-level moisture through deep layers.

Additional insight into the Rapid City storm is derived from a mesoscale study using satellite pictures and Sangster's surface charts. Because the winds were southerly from about the 850-mb level up to the 500-mb level and because the air was quite dry in this layer southward of Rapid City (see fig. 3), an increase in mean moisture over the Black Hills would be difficult to explain on the basis of mid-level advection. However, a feature that could have contributed materially to the low-level wind maximum (table 2) and somewhat to the increased mid-level moisture was associated with a mesoscale cloud mass first noticed near the northeastern tip of Colorado in a satellite photograph for 0836 MDT (1436Z) on the 9th. This cloud mass had moved to near Rapid City by 1454 MDT (2054Z) (figs. 11*A–D*). The hourly weather reports show a cloud base in this area to be at about 7,000 feet, with some associated rain starting in the mid-afternoon. The surface geostrophic vorticity charts (not shown) show the relation between the vorticity field and this cloud mass. The charts indicate a vorticity maximum in eastern Colorado at 0000 MDT June 9 (0600Z, June 9) that splits in two. The northern maximum moved with the cloud mass seen in the satellite photographs to create another vorticity maximum near Rapid City at 1800 MDT on the 9th (0000Z, June 10), the time of strongest upslope wind and shortly after the start of the heavy rains.

The movement of the vorticity system caused the pressure at Rapid City to hold steady during the day, with the pressure to the east rising as the high-pressure center pushed south. These conditions materially increased the low-level wind and the upslope motion in later afternoon. The mid-level increase in moisture made the uplift more effective in causing saturation. Shortly after 1800 MDT on the 9th, (0000Z, June 10), the mesosystem, then approximately over the Black Hills, impinged on the almost-stationary front and moved southeastward along it. The front then moved southward as a cold front, ending the rains in the Black Hills.

Thus, the mesosystem seen in both the satellite and special surface charts may have been the primary cause of the unusual intensity of the weather, providing initial mid-level moisture, the strong

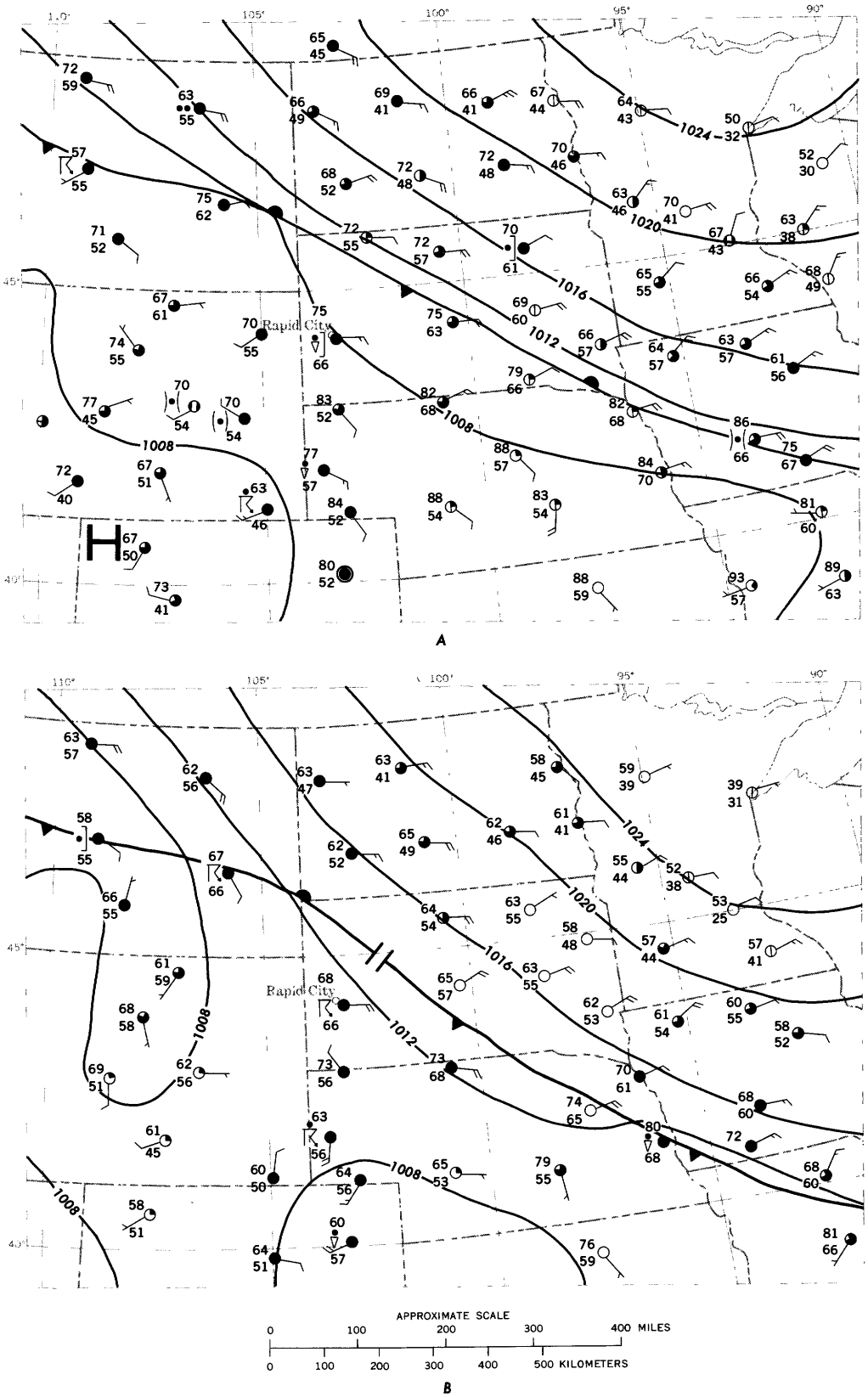
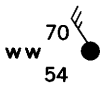


FIGURE 7.—(For explanation see facing page.)

EXPLANATION



Observation station

Upper number is air temperature, in degrees Fahrenheit. Lower number is dewpoint temperature, in degrees Fahrenheit. Shaft indicates wind direction. Barbs on shaft indicate wind speed, in knots. Long barb = 10 knots; short barb = 5 knots. A circle around the station indicates the wind is calm

PRESENT WEATHER (ww)

Lightning visible, no thunder heard

Precipitation within sight, reaching the ground, but distant from station

Precipitation within sight, reaching the ground, near to but NOT at station

Thunder heard, but no precipitation at the station

Thunderstorm (with or without precipitation) during past hour, but NOT at time of observation

Rain (NOT freezing and NOT falling as showers) during past hour, but NOT at time of observation

Showers of rain during past hour, but NOT at time of observation

Intermittent rain (NOT freezing), slight at time of observation

Continuous rain (NOT freezing), slight at time of observation

Slight rain shower(s)

Slight or moderate thunderstorm without hail, but with rain

SKY COVER

clear	40 percent	70 or 80 percent
10 percent	50 percent	90 percent
20 or 30 percent	60 percent	100 percent

Geographic center of high-pressure system

Warm front

Cold front

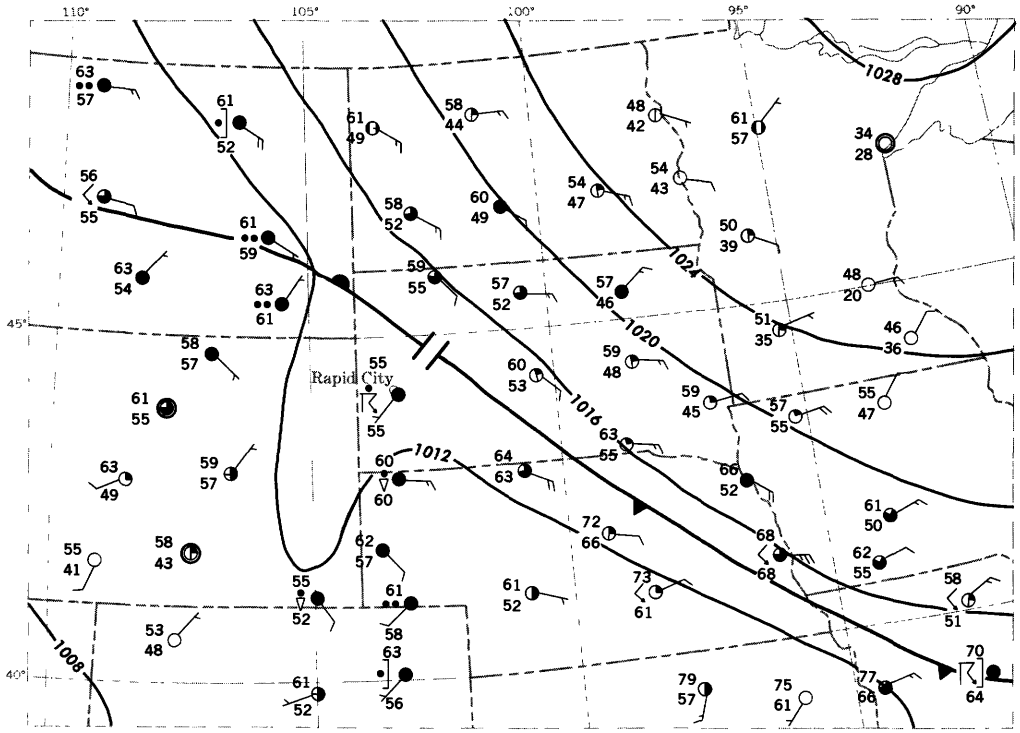
Stationary front

1012

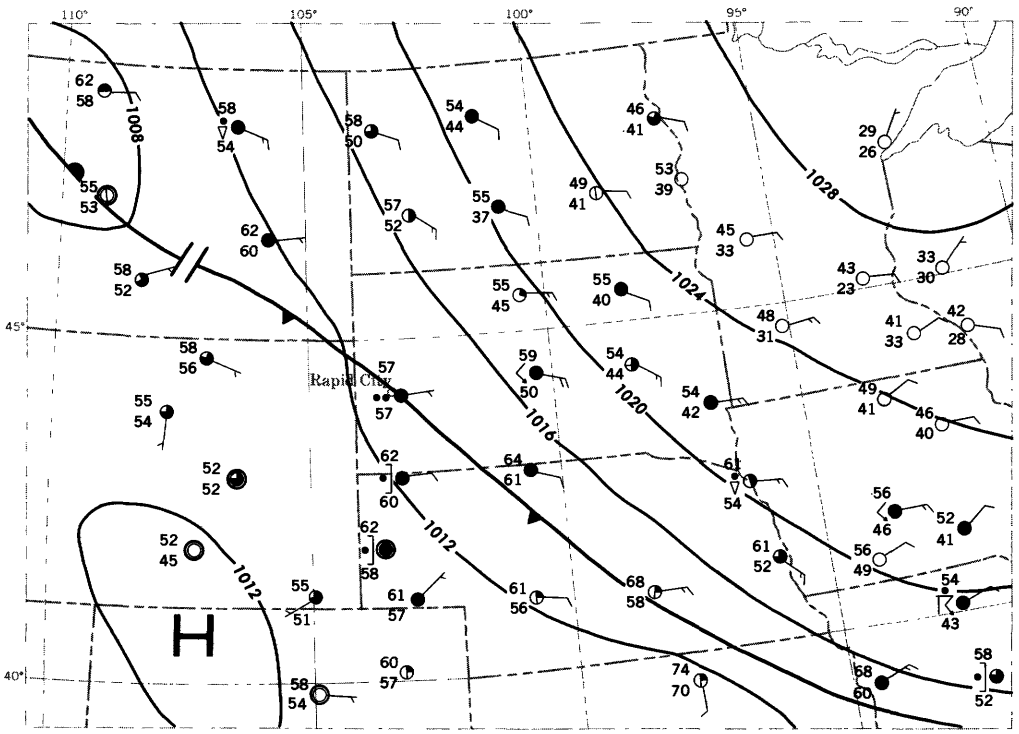
Line of equal atmospheric pressure at sea level

Interval 4 millibars

FIGURE 7.—Surface analysis. *A*, 1800, MDT June 9, 1972 (0000Z, June 10). *B*, 2100 MDT, June 9, 1972 (0300Z, June 10). (For *C* and *D* parts see following pages.)



C



APPROXIMATE SCALE

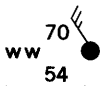
0 100 200 300 400 MILES

0 100 200 300 400 500 KILOMETERS

D

FIGURE 7.—Surface analysis—Continued.

EXPLANATION



Observation station

Upper number is air temperature, in degrees Fahrenheit. Lower number is dewpoint temperature, in degrees Fahrenheit. Shaft indicates wind direction. Barbs on shaft indicate wind speed, in knots. Long barb = 10 knots; short barb = 5 knots. A circle around the station indicates the wind is calm

PRESENT WEATHER (ww)

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Intermittent rain (NOT freezing), slight at time of observation

Continuous rain (NOT freezing), slight at time of observation

Slight rain shower(s)

Slight or moderate thunderstorm without hail, but with rain

SKY COVER

clear	40 percent	70 or 80 percent
10 percent	50 percent	90 percent
20 or 30 percent	60 percent	100 percent

Geographic center of high-pressure system

Warm front

Cold front

Stationary front

1012

Line of equal atmospheric pressure at sea level

Interval 4 millibars

FIGURE 7.—Surface analysis—Continued. *C*, 0000 MDT (0600Z), June 10, 1972. *D*, 0300 MDT (0900Z), June 10, 1972.

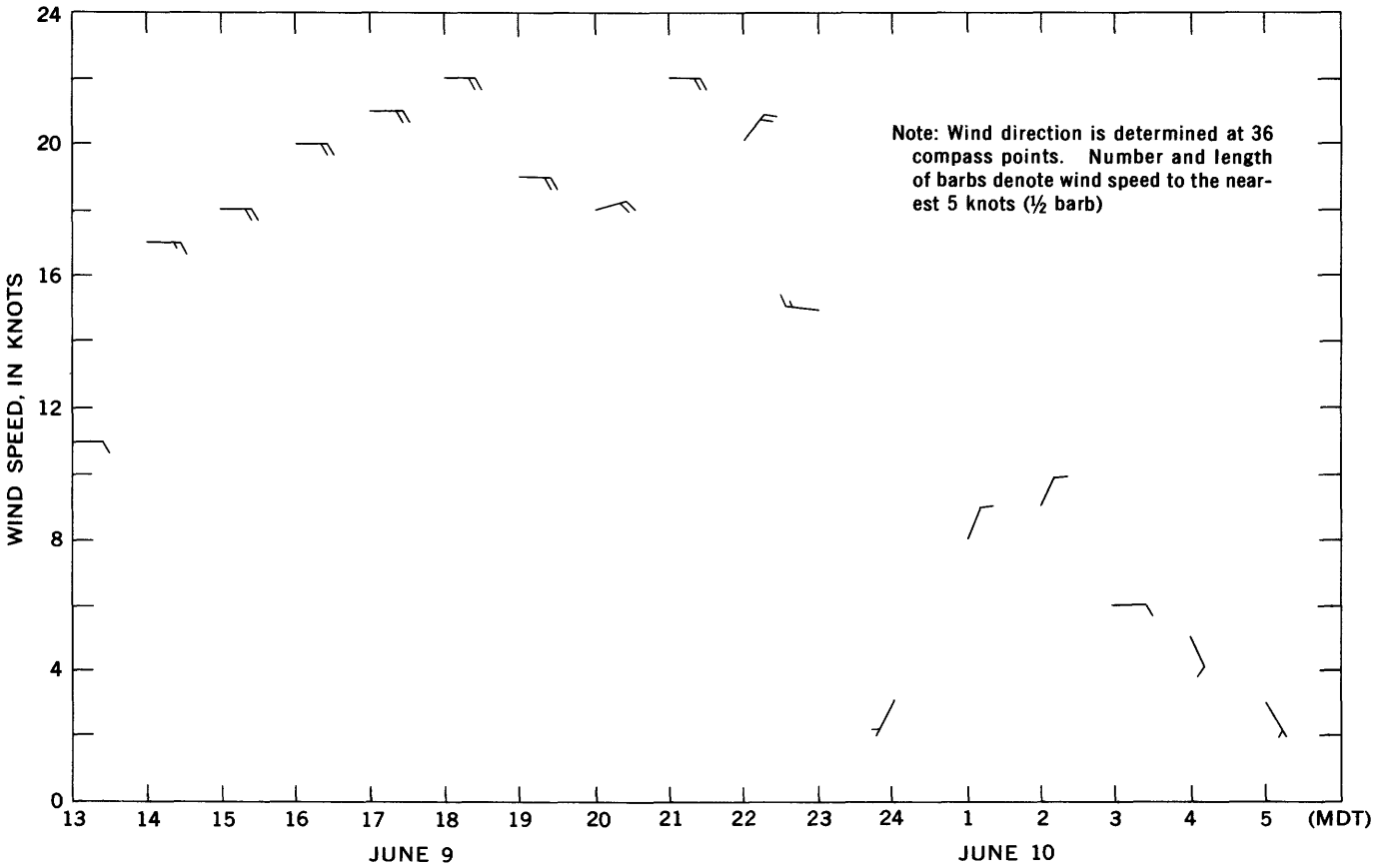


FIGURE 8.—Hourly surface winds observed at Rapid City Weather Service Office, June 9–10, 1972.

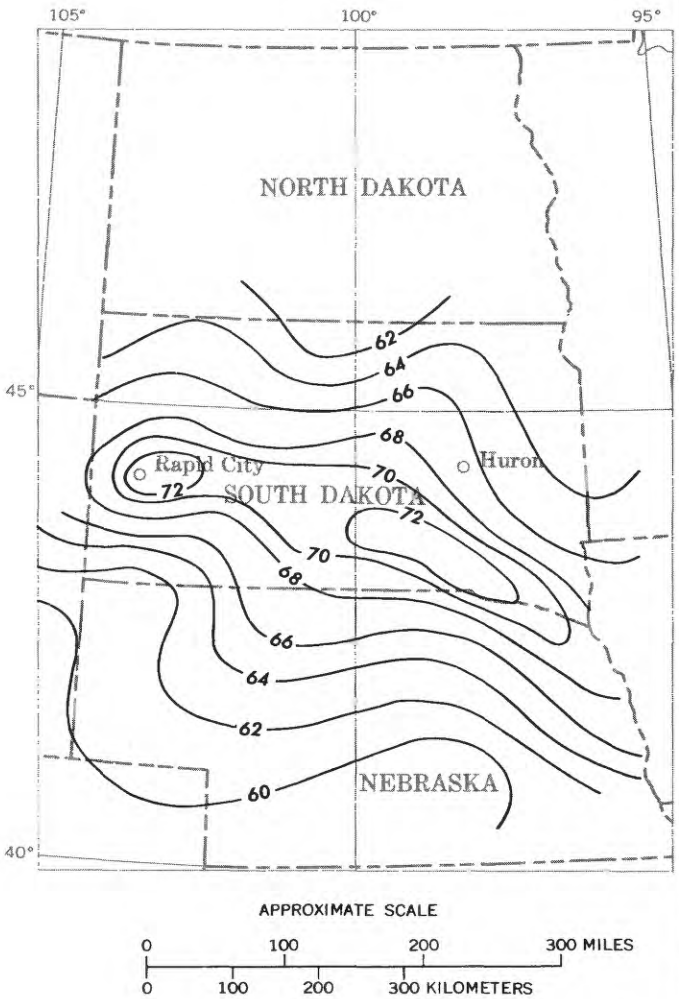
winds (aided by the advancing cold front), and the strong terrain-induced vertical motion that contributes to such unusual rains. Without the mesosystem, the rains probably would not have been devastating.

RADAR INDICATIONS

The radar at Ellsworth Air Force Base was operative for only part of the period of intense rains on the evening of the 9th. Figure 12 shows the PPI scope radar image at 2230 MDT (0430Z, June 10), during the period of intense rain near Rapid City and Pactola Dam. The echo just to the right of the center of the radar scope is just east of the region of largest rainfall amounts for the storm. The other PPI photograph available from the Ellsworth radar for 1930 MDT (0130Z, June 10), (not shown), shows a large area of precipitation extending north-northwest to south-southeast just west of Rapid City.

Although nearly 250 miles away, the National Weather Service radar at Huron, S. Dak., showed echoes of the large persisting thunderstorm tops over the Black Hills during the period of heavy rainfall. At this distance, these echoes came from clouds that had built higher than 40,000 feet and were considerably taller than any other echoes observed from Huron. A composite of these echoes (fig. 13) during the period 1800 MDT, June 9 to 0100 MDT, June 10 (0000–0700Z, June 10) indicates the concentration of high-level echoes over the eastern slopes of the Black Hills and suggests a line of echoes from thunderstorms to the southeast that also appears on the satellite photographs. The observation of these echoes at extreme range in South Dakota is similar to the observation of distant radar echoes of prolonged thunderstorm-produced rain in Virginia associated with the remnants of Hurricane Camille, August 19–29, 1969. Echoes of Camille thunderstorms in Virginia were persistently detected some 200 miles away by the Pittsburgh, Pa., radar (Schwarz, 1970).

An hour-by-hour comparison shows close agreement between echo positions and areas of high precipitation rates. Because of the extreme distance between the Huron radar station and the Black Hills storm, some error in position, on the order of 15 miles, is caused by atmospheric refraction. If echo positions were adjusted 15 miles to the west, six out



EXPLANATION

60

Line of equal dewpoint temperature

Interval 2 degrees Fahrenheit. Based on composite of 1000-millibar dewpoints

FIGURE 9.—Composite 1,000-mb dewpoints (°F).

of seven precipitation rates greater than 1.0 inch per hour would be covered by a Huron-detected echo. Thus, as in the Camille case, radar echoes at large distances may perform a useful function in recognizing potential for extreme rains, even though uncertainties exist as to the exact locations and amounts.

THE RAIN

Rainfall data from 24 Weather Service observing stations, with either recording or nonrecording rain gages (fig. 14), were supplemented by over 200 rainfall reports from other agencies and from surveys after the flood. These data were used to produce an isohyetal map for the storm (fig. 15).

According to the available rainfall data for the Black Hills storm (tables 3, 4, and 5), a maximum storm value of 15 inches of rain fell near Nemo, S. Dak., about 16 miles northwest of Rapid City.

All rainfalls greater than 4 inches occurred on the east slopes of the Black Hills. The area of approximately 300 square miles that received a minimum of 6 inches of rainfall lies primarily between 4,000 and 5,500 feet elevation (fig. 15). Numerous areas that received 10 or more inches of rain are scattered within this area. The largest 10-inch center, covering approximately 39 square miles, is about 15 miles west-northwest of Rapid City. The second largest center, of approximately 19 square miles, is about 15 miles southwest of Rapid City.

There does not appear to be a simple or direct relation between maximum rainfall centers and terrain features at these locations except for the slight indication that east-facing valleys may have contributed to some forced convergence of the prevailing low-level winds.

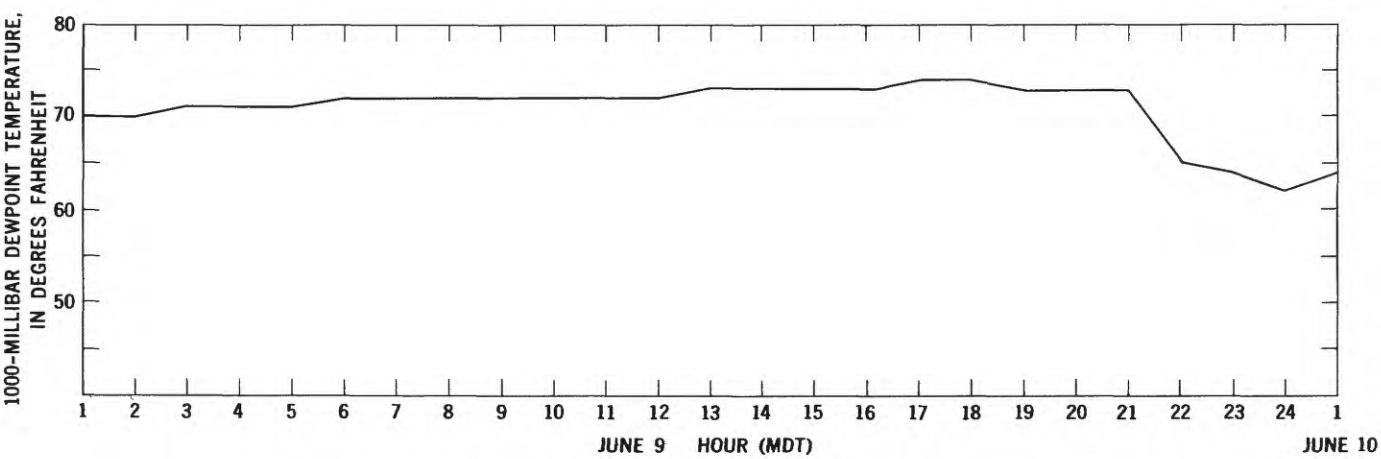


FIGURE 10.—1,000-mb dewpoints at the Rapid City Weather Service Office (°F).

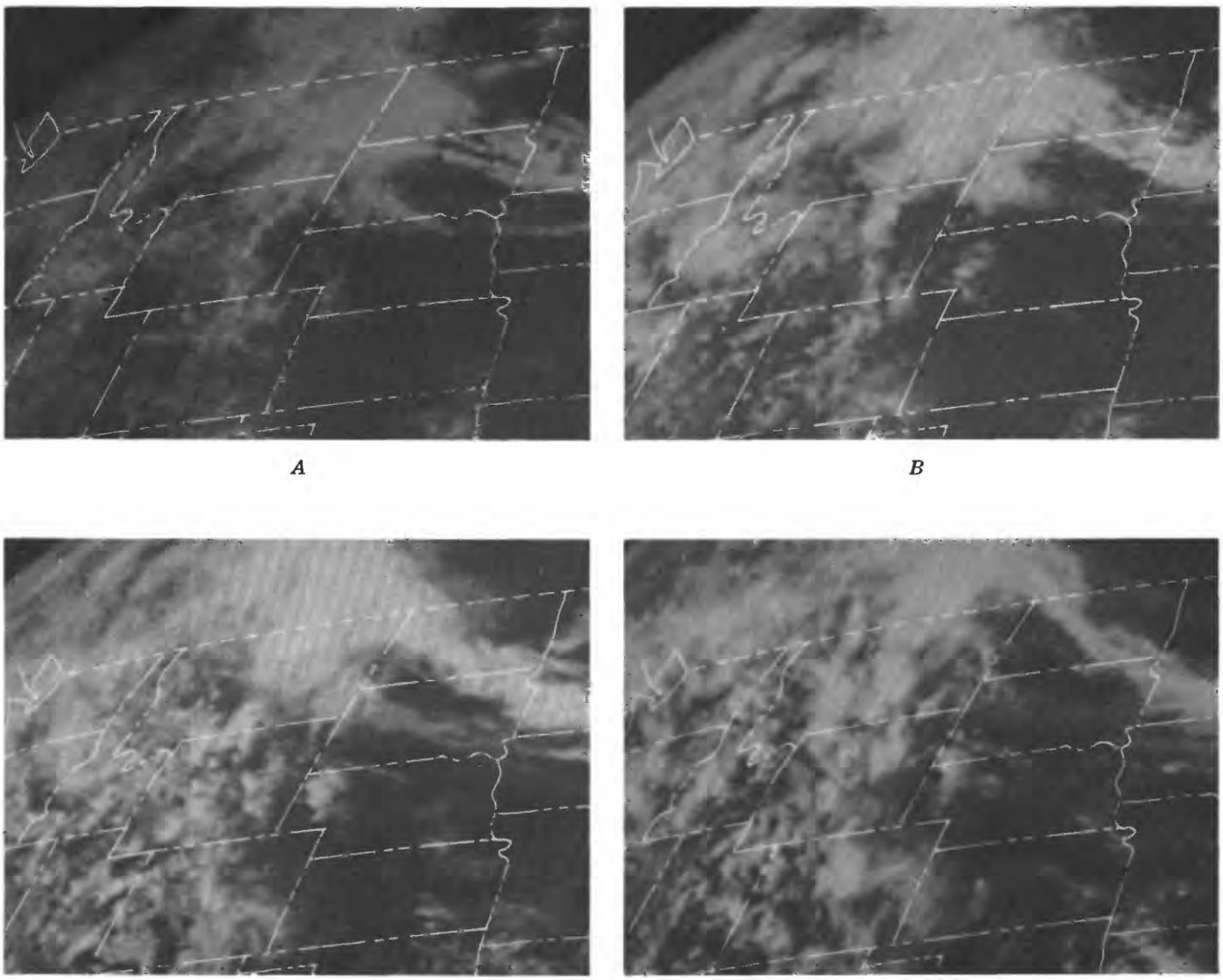


FIGURE 11.—Cloud cover. *A*, 0836 MDT (1436Z), June 9, 1972. *B*, 1024 MDT (1624Z), June 9, 1972. *C*, 1239 MDT (1839Z), June 9, 1972. *D*, 1454 MDT (2054Z), June 9, 1972.

VARIATION OF RAINFALL WITH TIME

Mass curves of rainfall for the six recording gages and one nonrecording rain gage where storm rainfall exceeded 4 inches show the variation of rainfall with time (fig. 16).

The curves of figure 16 and the other recording gage data (table 5) indicate that almost all the rains at individual stations occurred within a 12-hour period. Even more striking, these mass curves show that 85–96 percent of the total rainfall occurred within 6 hours. Because the rain did not begin or end simultaneously at each station, however, the duration of the storm for the area encompassed by the 4-inch precipitation line was about 16 hours.

Although the recorder-gage data show that the onset of rainfall progressed from north to south, a more detailed description of storm development can be obtained from visual observations made by a number of individuals in the Rapid City area. Photographs of radar echoes from Ellsworth AFB and the South Dakota School of Mines lend support to the visual descriptions. The earliest signs of convective activity began about 1330 MDT, (1930Z), in Wyoming, approximately 60 miles west-northwest of Rapid City. Additional cells developed during the next 3 to 4 hours along the eastern edge of the Black

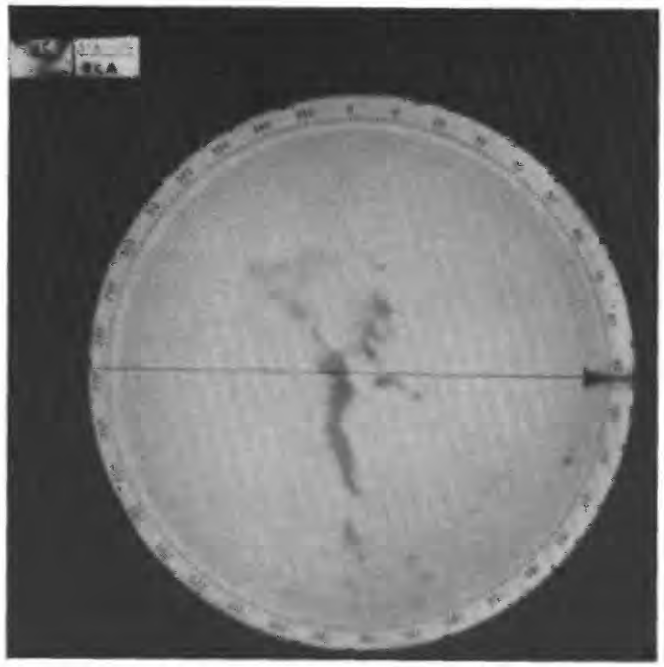


FIGURE 12.—Radar image at 2230 MDT, June 9 (0430Z, June 10), during the period of intense rainfall near Rapid City. The echo just to the right of the center of the radar scope is slightly east of the region that received the most rainfall during the storm.

Hills about 25 miles north of Rapid City and began building farther south. By 1800 MDT (0000Z, June 10), a nearly solid line of cells extended from the northern edge of the Black Hills to just west-northwest of Rapid City.

Stations A2 NFS and A5 NFS, roughly 25 miles northwest of Rapid City, were the first of the recorder stations to receive rainfall, beginning about 1500 MDT (2100Z), June 9. These stations operated by the South Dakota School of Mines are two of seven gages in close proximity that recorded between 8.1 and 11.82 inches of rainfall. Rainfall at Plot 67 and Arboretum (two of three gages located at site NFS in figure 14) began about 1600 MDT (2200Z), but totaled only 5.51 and 5.14 inches, respectively.

According to the meteorologist-in-charge at the National Weather Service Office at Rapid City, almost simultaneously with the development of convection cells north of Rapid City, a line of thunderstorms developed to the southeast at about 1500 MDT (2100Z) and moved toward the west-northwest with subsequent cells forming on the trailing end of the line. These cells increased markedly in intensity during the next hour or two, and by 1800 MDT (0000Z, June 10), the line of thunderstorms had become almost solid. Rain began falling at Pactola Dam at about 1700 MDT (2300Z) as the leading edge of a line of thunderstorms reached there from the southeast.

Between 1800 (0000Z) and 1930 MDT (0130Z, June 10) the gap filled in between the line of thunderstorms south of Rapid City and the initial thunderstorm development northwest of Rapid City to form a continuous line of thunderstorms covering the eastern slopes of the Black Hills. This system appeared to drift slowly eastward after about 2200 MDT (0400Z, June 10), although light showers persisted to the west for several hours.

In the vicinity of Rapid City the heaviest rainfall continued until about midnight (fig. 16). At the Rapid City airport, most of the rain fell between 2230 MDT on the 9th (0430Z, June 10), and 0100 MDT (0700Z) on the 10th; little rain fell after 0400 MDT (1000Z) on June 10.

THE FLOOD

Because the Black Hills floods of June 1972 were caused by a concentrated group of thunderstorms, most of the rain fell in a short period of time. Consequently, many of the flood peaks occurred at approximately the same time, between 2230 MDT on June 9 and 0100 MDT on June 10. At least 18 of the 27 streams where peak flows were computed experienced flows that exceeded the 50-year flood (a flood that is equaled or exceeded on the long-term average of only once every 50 years) as defined by Patterson (1966).

The extreme flooding was largely confined to a flood belt about 40 miles long and 20 miles wide along the eastern slopes of the Black Hills, from Sturgis on the north to Hermosa on the south and with Rapid City near the center. Most of the streams draining this flood belt continue to flow their separate ways eastward until they reach the Cheyenne River about 30 miles east of the Black Hills.

Peak discharges for this flood were determined at 49 sites in the flood-affected area. Table 6 compares these data to the maximum stages and discharges experienced at the same sites in previous floods. The sites are numbered and listed in downstream order and are shown in figure 17.

RAPID CREEK

The flood in the Rapid Creek basin is significant because of the severe damage done in the Rapid City area. The stream flows through the center of Rapid City, where most of the flood plain has been developed for homes and businesses. A few other streams in the vicinity had flooding comparable to that of Rapid Creek, but did not flood densely populated

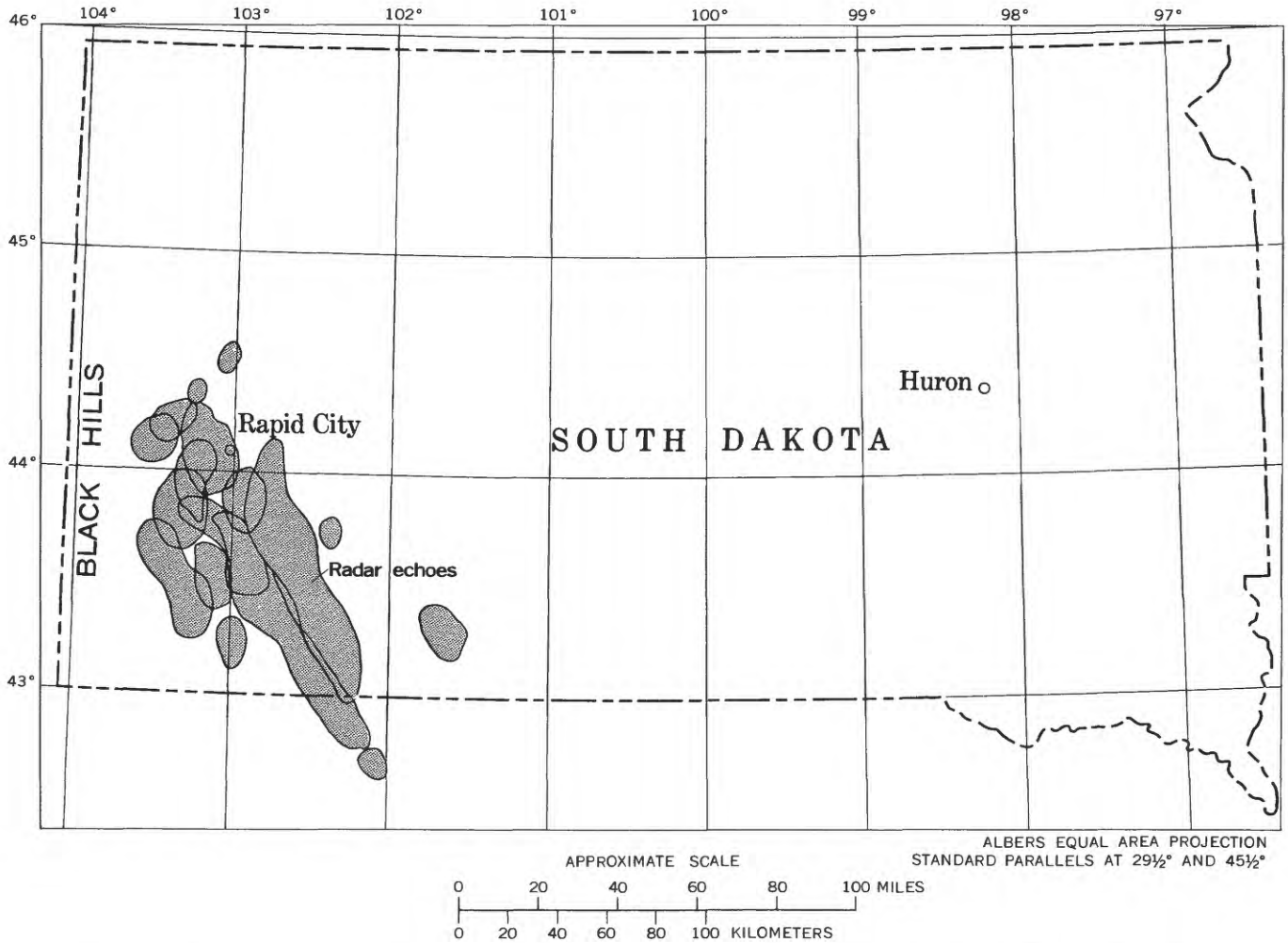


FIGURE 13.—Composite radar echoes, 1800 MDT, June 9, to 0100 MDT, June 10 (0000–0700Z, June 10), 1972.

areas. Consequently, they received less public attention.

The total drainage area of the Rapid Creek basin upstream from the Canyon Lake Reservoir is 371 square miles; however, only about 51 square miles, the area downstream from the gage on Rapid Creek below Pactola Reservoir, contributed to the flood runoff. Prior to the storm on June 9, Pactola Reservoir was receiving an inflow of from 60 to 70 cfs (cubic feet per second) and was discharging 74 cfs. On June 9 at 1600 MDT, inflow to Pactola Reservoir began to increase, but discharge from the reservoir was held steady at 74 cfs. Inflow to Pactola Reservoir continued to increase until approximately 2000 MDT, when it reached a peak of about 2,200 cfs. Releases from the reservoir were maintained at 74 cfs until midnight, when outflow from the reservoir was cut off completely, and no water was released until 2000 MDT on June 13, when a discharge of 105 cfs began. Therefore, it can be seen that because of Pactola Reservoir the upper 320 square miles of the Rapid Creek basin played no significant role in the Rapid City flooding.

The heavy rainfall over the Rapid Creek basin was concentrated over streams that enter Rapid Creek in the 9 miles between Pactola Reservoir and the Rapid Creek gage above Canyon Lake Reservoir. The principal streams entering Rapid Creek in this reach are Deer Creek, tributary from the north, and Prairie Creek and Victoria Creek, tributary from the south. Peak discharge of Deer Creek was determined at the Deer Creek campground to be 3,530 cfs from a drainage area of 4.28 sq mi, a unit runoff of 825 cfs per sq mi. The peak discharge of Victoria Creek at Victoria Lake dam was determined to be 6,860 cfs from a drainage area of 6.71 sq mi, a unit discharge of 1,020 cfs per sq mi. The peak on Prairie Creek could not be determined but was estimated to be about 5,500 cfs.

Rapid Creek peaked at 31,200 cfs at the gage

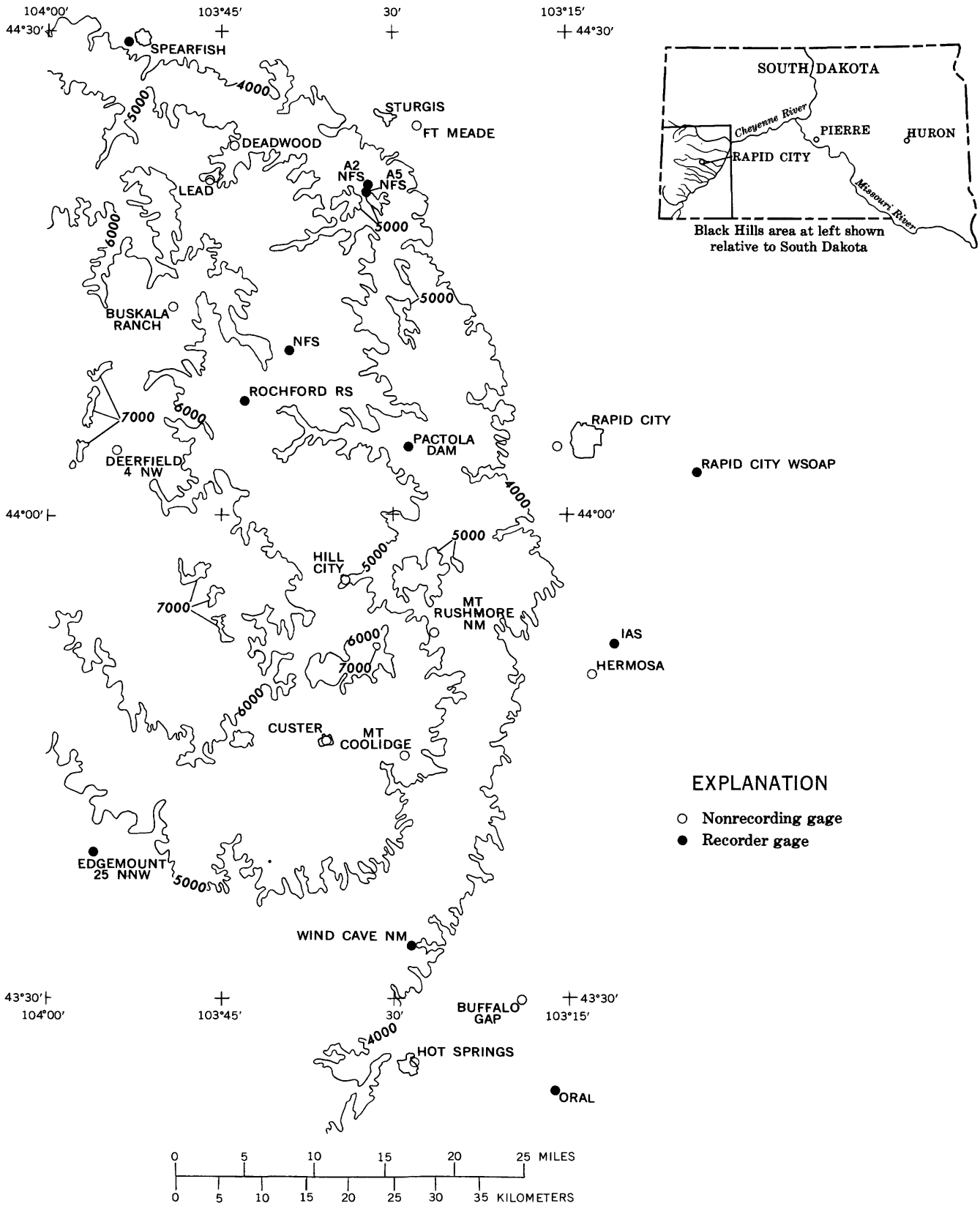


FIGURE 14.—Station locations and 1,000-foot elevation contours.

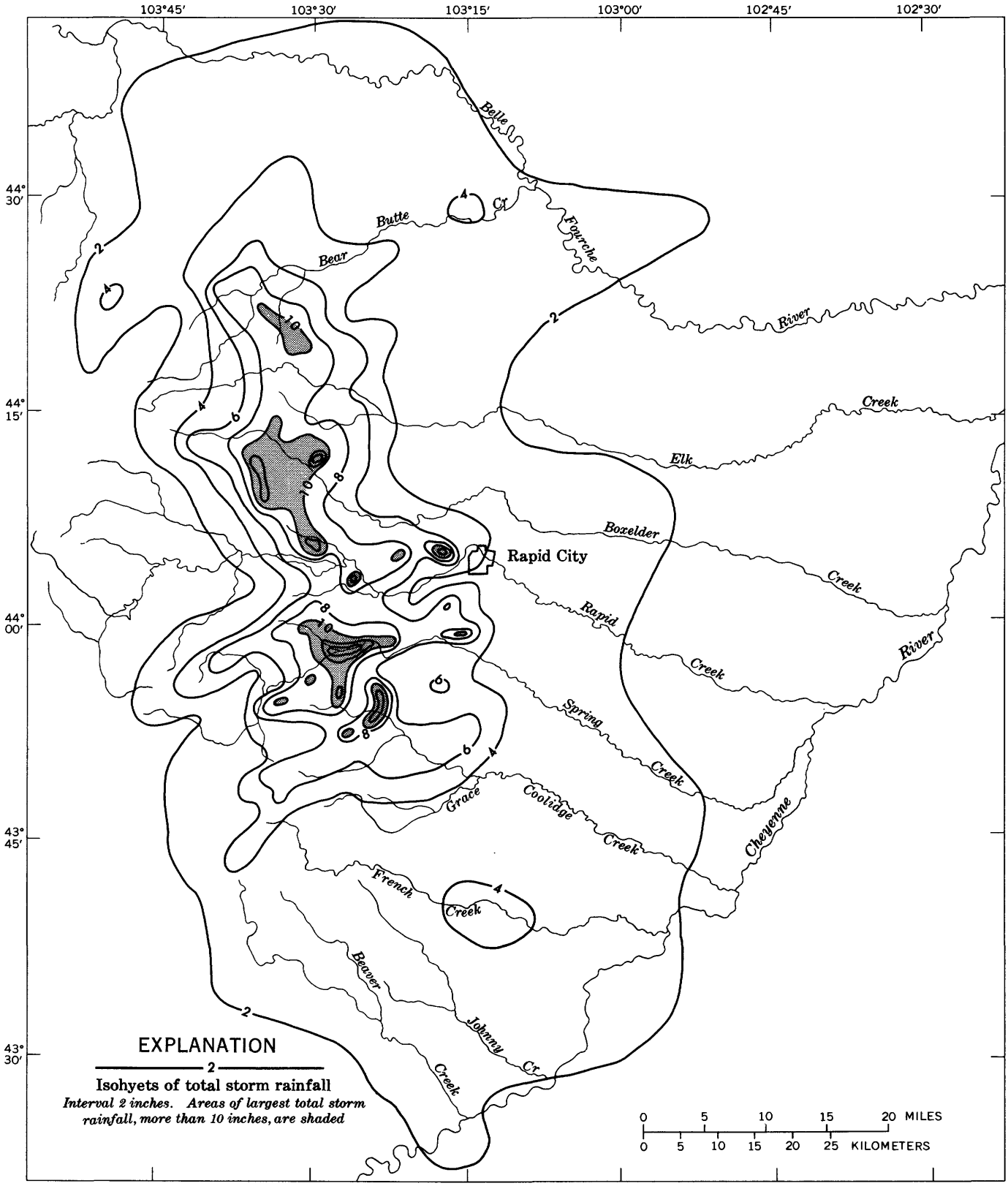


FIGURE 15.—Total storm isohyetal map for June 9–10, 1972. Rainfall occurred within a 16-hour period. Data based on climatologic network and supplemented by about 200 unofficial precipitation reports.

TABLE 3.—*Total rainfall, June 9–10, at miscellaneous gaging stations in the Black Hills*

[The following data have been collected through the cooperative efforts of the National Weather Service, Bureau of Reclamation, Forest Service, Corps of Engineers, South Dakota School of Mines, Black Hills Water Conservancy District, and the help of the general public. Most of the rain fell during a period from 6:30 p.m. June 9 to 12:30 a.m. June 10 (MDT). Additional data on intensity from recording gages will appear in the publication under hourly precipitation data]

County	Township	Range	Section	Quarter section	Total rainfall	Type [1]	Remarks [2]
Butte	8N	6E	29	SW ¼	2.02	A	8055
Butte	8N	3E	31	NE ¼	2.21	A	8001
Custer	3S	4E	18	SE ¼	3.0	B	David Renshaw 3 in. Water Coffee Can
Custer	3S	4E	24	NW	4.5	A	Roy Brummelt R–1, Custer
Custer	4S	7E	1		2.6	B	3N Fairburn
Custer	2S	8E	8	NW ¼	4.25	B	4N Hermosa
Custer	2S	8E	18	SE ¼	5.0	B	2N Hermosa
Custer	3S	4E	23	SE	3.9	A	Custer, S. Dak.
Custer	3S	6E	27	NW ¼	3.05	A	8032
Custer	3S	4E	23	NW ¼	3.75	A	8031
Custer	4S	3E	1	CNTR	2.20	A	8107
Custer	3S	7E	24	NE ¼	2.75	A	8036
Custer	3S	7E	16	NE ¼	3.53	A	8033
Custer	3S	9E	9	NE ¼	2.05	A	8037
Custer	6S	9E	17	NW ¼	2.75	A	8088
Custer	4S	7E	28	NW	3.0	A	Tim Conrad R–25, 2W Hwy 79, French Creek, Fairburn
Custer	2S	8E	32	C	3.1	B	Hermosa
				RC	2.76	A	Beth Kukuk R–70, 1022 Quincy, Rapid City
Custer	3S	4E	23	NE	3.5	B	Custer
Custer	2S	8E	32	NE	3.0	A	Wayne Warren R–81, Hermosa
Custer	4S	4E	5	NW	2.2	B	Jim Carson NFS
Custer	5S	4E	13	SW	2.25	B	Pringle
Custer	5S	4E	33	SE	2.1	B	4 SW Pringle Hwy 89
Custer	4S	3E	26	SE	1.25	B	9 SW Custer
Custer	6S	9E	14	SW	2.3	B	
Custer	3S	3E	32	SW	1.0	B	10 W Custer Hwy 16
Custer	3S	9E	3	SE	1.75	B	
Custer	4S	7E	6	NW	3.2	B	
Custer	3S	4E	26	NE	4.6	B	Evaporation
Custer	3S	5E	21	W ½	3.8	B	
Custer	3S	4E	1	SW	4.5	B	
Custer	4S	4E	15	SE	3.7	B	
Custer	5S	8E	14	SW ¼	3.5	B	
Custer	3S	11E	9	SE ¼	1.5	B	
Custer	3S	9E	9	N ½	2.08	A	
Custer	4S	10E	3	NW ¼	2.6	B	
Custer	4S	10E	13	E ½	1.7	B	
Custer	2S	10E	29	W ½	2.33	B	
Custer	2S	10E	30	SW ¼	2.75	B	
Custer	6S	9E	13	NW ¼	2.6	B	
Custer	6S	9E	24	SW ¼	2.25	B	
Custer	6S	9E	19	E ½	3.75	B	
Custer	5S	8E	33	SE ¼	3.25	B	
Custer	6S	7E	12	NW ¼	2.0	B	
Custer	6S	8E	33	NE ¼	2.75	B	
Custer	5S	9E	34	NW ¼	2.65	B	
Custer	5S	8E	2	NW ¼	4.0	B	Estimated
Custer	6S	6E	3	SE ¼	3.0	B	
Custer	6S	6E	9	N ½	2.8	B	
Custer	6S	6E	14	SE ¼	3.2	B	
Custer	6S	5E	25	E ½	1.6	B	
Custer	6S	6E	10	SE ¼	2.8	B	
Custer	4S	7E	27	NE ¼	5.0	B	French Creek R–79
Custer	6S	6E	22	NE	3.25	B	3 W Buffalo Gap
Custer	6S	6E	24	NE	3.1	A	Weather Bureau-Buffalo Gap
Custer	3S	6E	8	NE	4.23	A	Black Hills Playhouse
Custer	2S	5E	30	C	4.48	A	8103
Custer	3S	7E	24	NE	3.13	A	8034
Custer	4S	7E	11	SW	3.5	B	
Custer	3S	6E	5	SE ¼	4.67	B	
Custer	3S	6E	22	SW ¼	3.21	A	
Custer	3S	8E	7	NW ¼	3.35	A	
Custer	4S	3E	4	NW ¼	1.0	A	
Custer	4S	6E	26	SW ¼	3.2	A	
Custer	4S	7E	12	CE ¼	2.6	A	
Custer	5S	9E	32	SE ¼	3.5	A	
Custer	6S	4E	31	NW ¼	.75	B	
Custer	6S	7E	29	CS ½	3.1	A	

See footnotes at end of table.

TABLE 3.—*Total rainfall, June 9–10, at miscellaneous gaging stations in the Black Hills*—Continued

County	Township	Range	Section	Quarter section	Total rainfall	Type [1]	Remarks [2]
Fall River	7S	6E	2	NE ¼	3.0	B	
Fall River	7S	8E	16	SE ¼	1.5	B	
Fall River	7S	5E	31	NW ¼	2.7	B	
Fall River	7S	5E	8	SW ¼	1.7	B	
Fall River	7S	5E	20		.75	B	4W of Hot Springs
Fall River	7S	4E	19	C	.75	A	
Fall River	7S	5E	30	E ½	2.5	A	
Fall River	7S	7E	33	CE ½	2.5	A	
Fall River	7S	8E	8	SW ¼	1.7	A	
Fall River	7S	8E	31	NW ¼	2.70	B	
Fall River	8S	6E	4	SE ¼	.90	A	
Lawrence	5N	4E	18	SE	8.0	B	Garbage Can
Lawrence	3N	4E	18	SE	3.0	B	David Renshaw
Lawrence	5N	4E	18	SW ¼	3.75	A	8004
Lawrence	7N	3E	26	NW ¼	2.85	A	8002
Lawrence	6N	2E	24	NW ¼	1.85	A	8097
Lawrence	3N	1E	31	NE ¼	.50	A	8109
Lawrence	4N	3E	25	SE ¼	2.99	A	8013
Lawrence	3N	3E	24	SE ¼	6.65	A	8105
Lawrence	6N	4E	10	CNTR	4.36	A	8003
Lawrence	4N	3E	17	SE ¼	1.60	A	8012
Lawrence	3N	5E	16	SW ¼	8.15	A	8102
Lawrence	2N	4E	4		5.94	A	3 Rain Gages 5.90 to 5.94 in. R–57
Lawrence	3N	5E	16	SW ¼	10.00	B	Garbage Can 13 in. Reduced to 10.90 in.
Lawrence	3N	5E	16	SW ¼	10.00	A	NW Nemo 6 p.m. to 2 a.m.
Lawrence	3N	5E	27	NE	15.0	--	Woodrow Weathers R–71 (Verified) Nemo Job Corps
Lawrence	6N	4E	1	NE	5.0	B	Ms. Fred Swesey, Wash Tub, Whitewood
Lawrence	2N	5E	6	NE	10.55	A	Trout Haven
Lawrence	2N	4E	4	NW	5.51	R	Plot 67
Lawrence	2N	4E	4	NW	5.14	R	Arb.
Lawrence	6N	4E	5	NE	3.0	A	Alvin Jensen, Whitewood
Lawrence	6N	4E	33	NE	5.5	A	Frank Willson, Whitewood
Lawrence	4N	2E	22	NW	2.08	A	Jim Carson NFS
Lawrence	5N	2E	23		5.0	B	Jim Carson NFS (Deadwood)
Lawrence	3N	5E	27	SE	7.5	B	Jim Carson NFS
Lawrence	3N	4E	26	S ½	12.7	B	
Lawrence	4N	4E	33	SW ¼	4.9	B	
Lawrence	3N	4E	6	SW ¼	4.7	B	
Lawrence	3N	4E	18	NE ¼	6.5	B	Est–6.5 to 7.0
Lawrence	3N	5E	31	NW	10.55	A	Pilot Knob
Lawrence	2N	5E	2	SE	8.0	B	South Canyon, Rapid City
Lawrence	2N	5E	7	SW	10.0	B	Jim Carson NFS
Lawrence	2N	4E	12	SE ¼	12.0	B	
Lawrence	2N	7E	5	SE ¼	3.06	A	8068
Lawrence	2N	5E	34	NE	12.0	A	Ms. Joseph Gairtner, N of Pactola R–2 N of Trout Haven, W of Nemo Rd.
Meade	3N	6E	15	SE	4.25	B	Walker—5 gallon Bucket Straight Sides—Rt A Box 96 Piedmont
Meade	7N	6E	35	C	3.75	B	Roy Costell
Meade	5N	5E	25	SW	3.8	A	Blackhills Nat Cemetary
Meade	3N	6E	9	SE	5.75	A	Jack McLean, Piedmont
Meade	2N	7E	8	NW	3.9	A	John Kane, Black Hawk
Meade	4N	6E	32	SE ¼	5.88	A	8008
Meade	5N	9E	34	SW ¼	1.65	A	8073
Meade	4N	7E	18	SE ¼	2.45	A	8071
Meade	6N	6E	12	SE ¼	3.80	A	8082
Meade	7N	7E	13	NE ¼	2.01	A	8084
Meade	3N	9E	3	SE ¼	1.75	A	8064
Meade	6N	6E	33	NW ¼	4.25	A	8080
Meade	5N	7E	24	NW ¼	2.09	A	8075
Meade	5N	5E	15	SE ¼	5.70	A	8006
Meade	4N	6E	4	NE ¼	4.85	A	8078
Meade	5N	7E	1	SW ¼	2.88	A	8076
Meade	4N	6E	18	SE ¼	6.68	A	8007
Meade	6N	10E	21	NE ¼	2.75	A	8036
Meade	2N	10E	19	SE ¼	2.32	A	8049
Meade	7N	6E	30	SW ¼	2.82	A	8083
Meade	6N	5E	13	NW ¼	2.87	A	8081 Norris Roverce
Meade	5N	7E	6	SE ¼	2.41	A	8079
Meade	5N	9E	19	NE ¼	2.00	A	8074

See footnotes at end of table.

TABLE 3.—*Total rainfall, June 9–10, at miscellaneous gaging stations in the Black Hills*—Continued

County	Township	Range	Section	Quarter section	Total rainfall	Type [1]	Remarks [2]
Meade	4N	5E	8		11.82	A	7 Rain Gages 8.1 to 11.82 R–56
Meade	3N	6E	2	SW	4.0	A	John Hauer R–89, 1 N 1 W, Piedmont
Meade	3N	6E	22	SE	3.3	A	John Hauer R–90, 2E of I–90 on Elk Creek Rd.
Meade	5N	6E	5	NW	4.5	B	Chas Rose (Sturgis)
Meade	6N	7E	10	C	4.25	A	Vernon Bachard B–2
Meade	7N	6E	35	C	3.0	B	Don Costell
Meade	7N	6E	17	C	2.75	B	Kenneth Holst (Sturgis)
Meade	6N	5E	12	C	3.3	A	Frank Wicka (Sturgis)
Meade	6N	5E	30	C	4.85	A	E. H. Fallett, Whitewood
Meade	3N	6E	15	SE	4.5	B	Walker, Rt A, Box 96, 1 S Piedmont
Meade	3N	6E	19	C	7.0	B	Don Nelson, Bucket Overflow, Rt 8, Box 103A, Piedmont, By Stage-Barn Canyon R–43
Meade	2N	7E	5	SE ¼	3.06	A	8068
Meade	3N	10E	5	SE	1.65	A	8063
Meade	6N	10E	21	NW	1.15	A	8062
Meade	5N	7E	1	SW	2.68	A	8076
Meade	2N	5E	7		10.55	A	
Meade	3N	5E	27	SW ¼	7.5	A	
Meade	5N	3E	23	SE¼	5.0	A	
Pennington	2N	7E	14	N	4.0	B	Art E. Fland, 4109 W. Chicago, Rapid City
Pennington	1N	7E	7	SW	3.8	B	Emil Magnusson R–28, 2305 Arrow Drive, Rapid City
Pennington	1N	7E	7	SW	3.5	A	Robert Biegler R–30, 319 E. Tallent, Rapid City
Pennington	1S	6E	2	SE	5.5	B	Herb Gross, 2230 Alamo, Rapid City
Pennington	1S	5E	30	SE	5.14	A	Gene Barker R–83, Hill City
Pennington	1N	8E	7	NE	3.20	B	Ken Elliott, St. Andrew Lincoln, Rapid City
Pennington	1S	4E	30	SW	5.2	B	Jim Carson NFS
Pennington	1S	4E	25	SW	4.85	B	Jim Carson NFS
Pennington	1S	5E	20	NW	6.0	B	Jim Carson NFS
Pennington	1N	2E	26	NE	1.2	B	Jim Carson NFS
Pennington	1S	5E	32	NE ¼	8.9	B	Bucket Overflow
Pennington	1S	5E	32	SW¼	12.5	B	Bucket Overflow
Pennington	2S	5E	2	N ½	8.25	B	Bucket Overflow
Pennington	1N	7E	21	N ½	7.0	B	Bucket Overflow
Pennington	1N	7E	33	NW ¼	6.25	B	Bucket Overflow
Pennington	1N	7E	29	SE ¼	7.5	B	Bucket Overflow
Pennington	1N	6E	36	NW ¼	5.6	B	
Pennington	1S	6E	2	SW ¼	11.75	B	
Pennington	1S	6E	9	NW ¼	8.75	B	Bucket Overflow
Pennington	1S	5E	36	NE ¼	12.6	B	
Pennington	1S	5E	22	S ½	10.0	B	
Pennington	1S	5E	19	NW ¼	4.52	A	
Pennington	1S	4E	14	NE ¼	7.0	B	Bucket Overflow
Pennington	2S	5E	2	SW ¼	8.2	B	
Pennington	1S	5E	21	CE	8.0	B	
Pennington	1S	5E	22	SW ¼	8.0	B	
Pennington	1N	5E	34	C	10.6	B	
Pennington	1N	6E	8	NW ¼	8.0	B	
Pennington	2N	7E	31	NW ¼	4.5	B	
Pennington	1N	6E	12	SE ¼	6.0	B	
Pennington	2N	5E	28	C	11.64	A	
Pennington	1S	6E	8	NW ¼	14.01	A	Gage Overflowed 8024
Pennington	1N	3E	6	C	1.89	A	8014
Pennington	1N	2E	26	SW ¼	.50	A	8101
Pennington	2S	3E	24	NE ¼	2.12	A	8099
Pennington	1N	8E	6	SW ¼	3.00	A	
Pennington	1S	4E	14	NE	2.9	A	Julius Hardi R–72, Box 9, Hill City
Pennington	1N	7E	1	NE	5.5	B	M. S. Hausen R–75, Wastebasket 6.25 mi 9th & St. Patrick, Rapid City
Pennington	1S	6E	34	C	12.0	B	Janice Grow R–27, Garbage Can
Pennington	1S	6E	34	C	10.51	A	Sheridan Lake
Pennington	2N	5E	16	SW	10.0	B	
Pennington	2S	6E	8	NE	7.0	B	Owner of Rushmore View Motel Keystone

See footnotes at end of table.

TABLE 3.—*Total rainfall, June 9–10, at miscellaneous gaging stations in the Black Hills*—Continued

County	Township	Range	Section	Quarter section	Total rainfall	Type [1]	Remarks [2]
Pennington	1S	7E	3	SW	5.25	A	Ms. Michael Kloster Key Rt. Box 178 Man Across From Reptile Gardens R–92
Pennington	2N	9E	17	C	2.5	A	Herbert Vadney R–46, 9272 Lincoln Drive EAFB
Pennington	2S	6E	1	SW	5.0	A	Arthur Haub B–3, 4 S Rockerville
Pennington	1S	6E	24	SW	5.0	B	Joe Dunn—Can, 1 S Rockerville B–4
Pennington	1S	6E	28	NW	7.0	B	Dean Johnson—31B, Coffee Can Overflow, 3W Rockerville
Pennington	1S	7E	3	NE ¼	11.0	A	Albert Frame R–52, 30 Gallon Garbage Can 13½ in., Spring Creek Camp Ground
Pennington	2N	5E	16	SW	11.0	B	
Pennington	2S	6E	8	NE	12.0	B	Art Iones—Case of 10 in. Pop Bottles, Keystone
Pennington	2N	5E	31	SE	6.0	A	Greunwald, Silver City
Pennington	2N	6E	35	SW ¼	11.75	A	Container Overtopped, R–74 Straight Sided Flower Urn, Larry Wright, Rt 1, Box 27, 5S Wild Irishman Gulch
Pennington	2S	5E	4	NE	9.5	B	Z Olson B–5, Box 295, Hill City 3 SE Hill City
Pennington	1S	5E	23	NW	9.0	B	Neil Hodges B–6, 4 NE Hill City at Three Forks
Pennington	1S	5E	32	NE	9.0	B	A. W. McCamly B–7, Box 387, Hill City, 1.8 S Hill City
Pennington	1S	6E	28	NE ¼	12.0	A	Dean Johnson R–91, 2–5 Gallon Buckets Tepee Gulch Hwy 16 Cos-Deer Huts
Pennington	2N	7E	32	NE ¼	13.0	A	Cóntainer Overtopped R–31 Glass Tube 7½ Rain Gage Ted Plisterer, Rt 1, Box 34A, 5W RC on Nemo Rd
Pennington	2N	6E	31	SE	13.5	B	Jim Eade—5 Gallon Side Pail R–44, Johnson Siding
Pennington	1N	5E	2	NW	7.0	A	Kathleen Mack R–55, 115 Franklin, Rapid City
Pennington	1S	8E	20	N ½	2.5	B	5 SE Spring Creek
Pennington	1S	8E	22	S ½	3.85	B	2E Spring Creek, Hwy 79
Pennington	2S	6E	18	NW	11.0	B	Glen Tally R–68, Straight Sided Bucket, Grizzly Canyon Keystone, Bucket Overtopped
Pennington	2S	5E	31	SW	6.5	A	Harry Kruse R–67, Box 514, Hill City
Pennington	2S	4E	13	NE	4.5	B	Container Overtopped B–8, Herbert Trumpeter, 4S Hill City
Pennington	1N	4E	31	SE	2.2	A	John McVey
Pennington	1S	6E	12	SE	5.5	A	Larry Jacobson B–9, 1 N Rockerville
Pennington	2N	7E	28	SE ¼	4.70	B	8019
Pennington	1S	7E	28	NW ¼	6.60	B	8023
Pennington	2S	4E	9	NW ¼	2.74	B	8089
Pennington	1N	7E	10	NE ¼	3.51	B	8100 Maralee Dennis
Pennington	1S	5E	12	SE ¼	14.00	B	Round Bottom Boat R–42
Pennington	1S	8E	28	NE	2.50	A	G. Z. Olson, Box 295, Hill City, 3 SE Hill City
Pennington	2S	5E	6	SW ¼	9.0	B	A .W. McCamly, Box 387, Hill City, 2S Hill City
Pennington	1N	5E	10	NE ¼	7.16		AR Cloey Simpson, Keystone Box 155, S End Pactola Dam
Pennington	2N	5E	31	SE	6.0	B	Greunwald, Silver City
Pennington	2N	3E	11	NE	1.7	B	Darrell Kenrison, Rockford
Pennington	2N	5E	34	NE	12.0	A	Joseph Gairtner R–2, 9 in. Rain Gage, N of Pactola
Pennington	1S	4E	16	NE	7.2	B	Newton Fork
Pennington	1N	6E	9	NW	9.5	B	Gayle Jorgenson, Big Piney Subdivision near Rimrock Club, Hisega Turnoff
Pennington	1S	6E	26	SE	5.4	B	2S Rockerville
Pennington	1S	6E	5		10.00	B	Bucket Overflow R–7
Pennington	1S	5E	24	NE ¼	11.5	B	Ralph Rossknecht, Traile Pk-Calumet Pt on Sheridan Lake
Pennington	2S	6E	32	NW	3.6	A	Dr. R. A. Kovarik, R–53, 2.5 SW Rapid City
Pennington	1S	8E	28	NE	3.0	A	Wayne Warren

See footnotes at end of table.

TABLE 3.—*Total rainfall, June 9–10, at miscellaneous gaging stations in the Black Hills*—Continued

County	Township	Range	Section	Quarter section	Total rainfall	Type [1]	Remarks [2]
Pennington	2S	8E	19	NE	4.0	R	IAS 9001
Pennington	2N	3E	23	SE	1.72	R	Rochford
Pennington	1N	9E	17	C	2.32	R	Rapid City
Pennington	1N	5E	11	C	7.07	R	Pactola Dam
Pennington	2N	6E	32	SW	12.8	A	Observer took times
Pennington	1N	10E	24	SE ¼	1.7	A	
Pennington	1N	7E	21	NE ¼	4.0	A	
Pennington	1N	6E	36	NW ¼	5.5	B	
Pennington	1N	6E	9	CN ½	6.5	A	
Pennington	1N	6E	9	CN ½	7.9	B	
Pennington	1S	6E	8	NW ¼	6.6	B	
Pennington	1S	6E	9	NW ¼	9.75	B	
Pennington	1S	8E	15	SE ¼	3.85	B	
Pennington	1S	8E	20	NW ¼	3.50	B	
Pennington	1S	9E	12	NE ¼	1.50	A	
Pennington	1S	10E	26	SE ¼	1.72	A	
Pennington	1S	11E	26	NW ¼	1.68	B	
Pennington	2S	9E	6	C	2.5	B	
Pennington	2S	12E	11	CE ½	1.5	B	
Shannon	41N	47W	4	NW ¼	3.5	B	
Shannon	41N	47W	4	NW ¼	2.0	B	

[1] The type A refers to rain gage. Type B refers to bucket.
[2] Under remarks, all 4 digit numbers refer to School of Mines. Rain gages and numbers of the type R–55 are bucket survey reference numbers.

TABLE 4.—*Daily precipitation (inches), Black Hills and vicinity*
[T= less than measurable amount; MSG= missing data]

Station	Location		Time of observation (MDT)	June			
	Lat	Long		8	9	10	11
Buskala Ranch	44°13′	103°49′	7 p.m.	T	0.08	1.58	---
Custer	43°46′	103°46′	7 a.m.	---	---	3.45	---
Deadwood	44°23′	103°44′	7 p.m.	0.05	.30	1.73	---
Deerfield 4 NW	44°04′	103°54′	7 p.m.	.20	---	.60	---
Farmingdale 4 N	44°02′	102°54′	6 p.m.	---	---	1.68	---
Fort Meade	44°24′	103°28′	5 p.m.	---	.45	4.38	---
Hermosa 1 W	43°50′	103°13′	7 a.m.	---	---	2.81	T
Hill City	43°56′	103°34′	9 a.m.	.02	---	5.14	---
Hot Springs	43°26′	103°28′	7 p.m.	---	---	1.31	---
Lead 1 SE	44°21′	103°46′	7 p.m.	.03	.17	1.65	T
Lead 6 SSW	44°17′	103°48′	7 p.m.	T	.40	1.04	---
Mount Coolidge	43°45′	103°29′	6 p.m.	---	.05	MSG	---
Mount Rushmore National Memorial Park	43°53′	103°27′	6 p.m.	---	---	6.30	0.02
Pactola Dam	44°04′	103°29′	8 a.m.	---	---	7.16	---
Rapid City	44°04′	103°16′	6 p.m.	---	T	3.60	---
Rapid City, WSO AP	44°03′	103°04′	12 p.m.	---	2.08	.24	---
Spearfish	44°21′	103°53′	8 a.m.	---	T	1.68	.32

above Canyon Lake Reservoir, with all the flow being derived from about 51 sq mi of drainage area downstream from Pactola Reservoir. This gives a unit discharge of 612 cfs per sq mi for the peak.

The gage on Rapid Creek above Canyon Lake Reservoir was inundated by floodwater but remained intact, allowing part of the record to be salvaged. The recorder tape showed a stage of 1.65 feet, then a gradual rise in water surface beginning at 1900 MDT and continuing until 2000 MDT, when the water began a sharp but even rise until 2100 MDT, when it leveled off for 15 minutes (fig. 18). The creek had risen approximately 3 feet in 2 hours. From 2115 MDT until 2315 MDT, the creek rose another 12 feet, beginning with a rapid rise of about 3.5 feet in 15 minutes. The flood peaked at a stage of 15.77 feet, 7.69 feet higher than the previous flood of record.

The gates on the spillway at Canyon Lake Reservoir were opened to lower the lake level but were soon clogged by large amounts of floating debris. Several men were assigned to keep the debris moving through the spillway, but the task became impossible when a boat dock from the lakeshore broke loose and lodged in the spillway. After this, several boats were caught in the spillway and, along with the boat dock, blocked the exit to the lake. Shortly thereafter, water started to flow over the left end of the 500-feet-long earthfill dam. The water level of the lake continued to rise and soon overtopped the entire dam. Although the main break in the dam probably washed out fairly rapidly, it was reported that water flowed over the top of the dam for approximately 45 minutes before the dam gave way. Most reports give the time when the dam broke as 2245 MDT, which coincides fairly well with the

TABLE 5.—*Hourly precipitation (inches) in Black Hills and vicinity*

Station	Location		June 9 (MDT)										
	Lat	Long	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	0000
Edgemont 25 NNW	43°39′	103°56′	----	----	----	----	0.03	0.01	----	----	0.23	0.06	0.04
Oral	43°24′	103°16′	----	----	----	----	----	----	----	----	2.35	1.13	.07
Pactola Dam	44°04′	103°29′	----	----	0.01	0.04	.25	1.37	0.86	1.37	1.83	.57	.30
Rapid City, WSO AP	44°03′	103°04′	----	----	----	----	----	----	----	----	----	.61	1.16
Rochford	44°07′	103°43′	----	----	.05	.03	.05	.33	.12	.15	.17	.26	.20
Spearfish 1 W	44°29′	103°53′	----	----	----	----	----	.08	.02	.11	.14	.25	.31
Wind Cave	43°33′	103°29′	----	----	.02	.02	----	----	----	----	1.99	.30	.12

Station	Location		June 10 (MDT)								
	Lat	Long	0100	0200	0300	0400	0500	0600	0700	0900	1000
Edgemont 25 NNW	43°39′	103°56′	0.04	0.04	0.02	----	----	----	----	----	----
Oral	43°24′	103°16′	.03	.01	.01	----	----	----	----	----	----
Pactola Dam	44°04′	103°29′	.26	.14	.02	0.01	----	----	0.02	0.04	0.01
Rapid City, WSO AP	44°03′	103°04′	.31	.13	.09	.02	----	----	----	----	----
Rochford	44°07′	103°43′	.34	.03	.02	.02	----	----	----	----	----
Spearfish 1 W	44°29′	103°53′	.31	.26	.02	----	----	----	----	----	----
Wind Cave	43°33′	103°29′	.04	----	.01	----	----	----	----	----	----

Station	Location		June 10 (MDT)				
	Lat	Long	1500	1700	1800	1900	2000
Edgemont 25 NNW	43°39′	103°56′	----	----	----	----	----
Oral	43°24′	103°16′	----	----	----	----	----
Pactola Dam	44°04′	103°29′	----	----	----	----	----
Rapid City, WSO AP	44°03′	103°04′	----	----	----	----	----
Rochford	44°07′	103°43′	----	----	----	----	----
Spearfish 1 W	44°29′	103°53′	----	0.01	0.01	0.14	0.06
Wind Cave	43°33′	103°29′	----	----	----	----	----

Notes:
1. No precipitation on June 8 or 11 at these stations.
2. Other usually unpublished hourly data shown as mass curves, fig. 16.

timing of the flood crest flowing out of Cleghorn Canyon and entering Rapid Creek immediately upstream from Canyon Lake. (See fig. 19.)

The effect of the failure of the dam at Canyon Lake Reservoir on the subsequent flood wave and on the total damage is difficult to assess. Lacking actual recorded measurements of the flood wave, several indirect measurements have been computed for Rapid Creek. Each of these indirect measurements is based on a reconstruction of the water-surface profiles and on the shape and roughness of the channel, but each is subject to some error. The extreme nature of the flood and the associated floating debris (houses, trees, cars, and trailers) may affect the relation between measured high-water marks and actual discharge. By adding together the 31,200 cfs peak discharge measured on Rapid Creek above Canyon Lake Reservoir and the 12,600 cfs peak discharge that poured from Cleghorn Canyon into Rapid Creek, some 43,000 cfs, or 86 percent, of the peak discharge of 50,000 cfs determined to have been carried by Rapid Creek through Rapid City at midnight on June 9 (fig. 20*A*) can be accounted for.

On the basis of computations of discharge, because of the relatively small size of Canyon Lake Reservoir, and because the dam did not give way abruptly, the failure of the dam does not appear to have been a major contributor to the peak discharge of Rapid Creek at Rapid City. The vast amount of water coming down Rapid Creek and the several streams contributing to the flow of Rapid Creek far overshadowed the amount of water in the small reservoir.

After moving through the city, the flood peak on Rapid Creek passed into the Great Plains, where it spread out over a wide area; much of the water was stored in the wider flood plain. By the time the flood peak reached the gaging station at Farmingdale, the the peak discharge had attenuated to 7,320 cfs. This gives a unit discharge of 26 cfs per sq mi for the 283 sq mi drainage below Pactola Dam (fig. 20*B*). This peak discharge was only about one-seventh the peak discharge measured in Rapid City but was still a peak of record at that site. The flood peak traveled the 65 river miles from Deer Creek near Pactola Reservoir to Farmingdale in about 17 hours, or an average speed of 3.8 miles per hour (fig. 21). Coming off the slopes of the Black Hills, the flood peak had traveled at about twice that speed, covering the approximately 22 river miles between Deer Creek and Rapid City in about 3½ hours.

After the flood, high-water marks were surveyed along the banks of Rapid Creek through Rapid City. From this survey and the resulting flood profiles, a map was prepared for an earlier report showing areas of the city inundated by floodwaters (Larimer, 1973).

BOXELDER CREEK

The headwaters of Boxelder Creek are located in an area where up to 12 inches of rain fell during the night; as a result, this creek experienced very

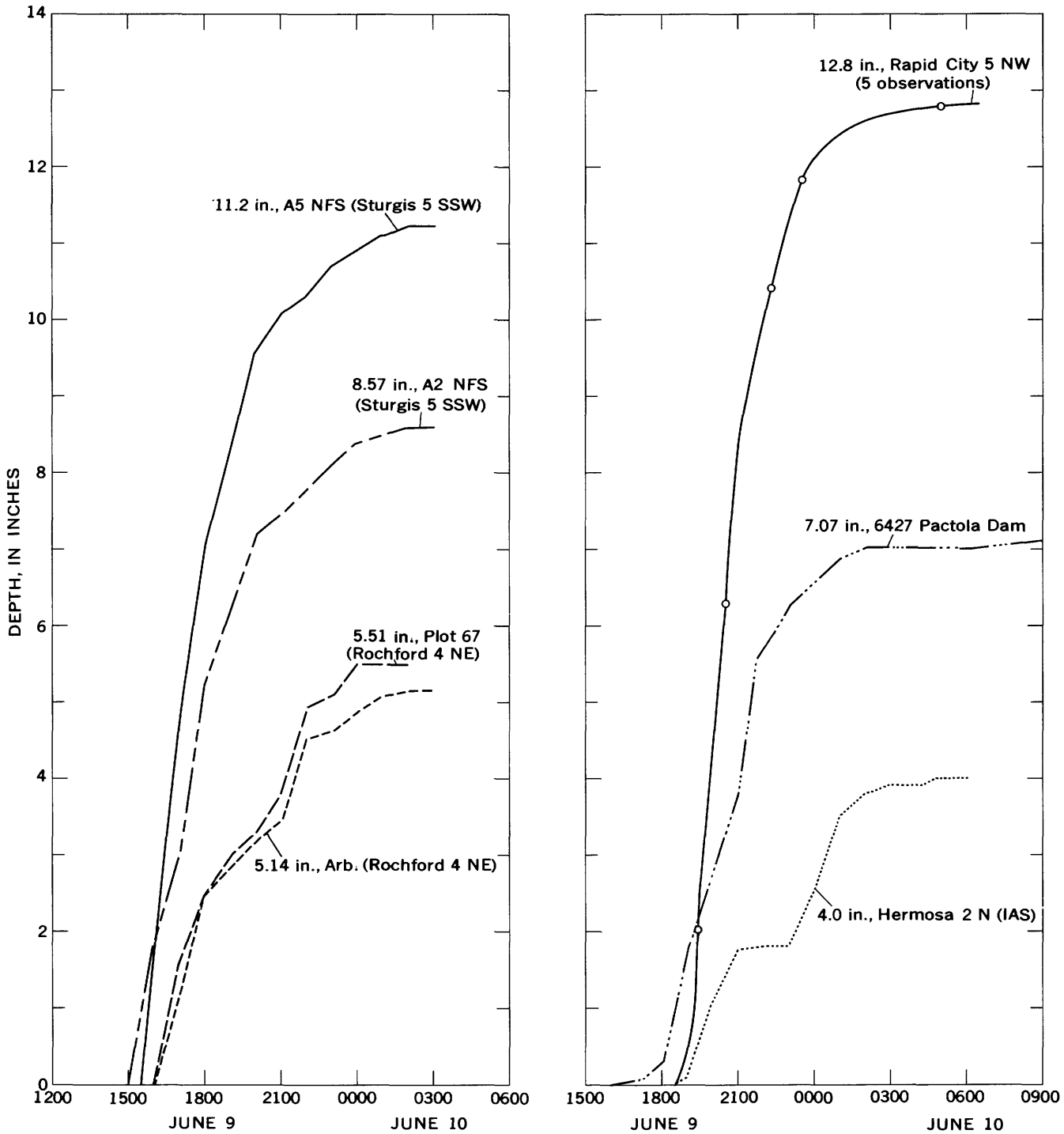


FIGURE 16.—Mass rainfall curves for selected stations where rainfall exceeded 4.0 inches.

high flooding. Although flooding was extreme, total damage was fairly low compared to that along Rapid Creek, because of the area's low level of development. Significant damage was done to one of the bridges on Interstate 90 between Rapid City and Sturgis as a result of stream scour; damage was also done to other roads and ranches.

Peak discharge of Boxelder Creek was computed at several locations. At the gaging station on Boxelder Creek near Nemo, the discharge was determined to be 30,100 cfs from a drainage area of 96 sq mi, or a unit discharge of 314 cfs per sq mi. The gaging station was so completely destroyed that no remnants of the gaging station could be found.

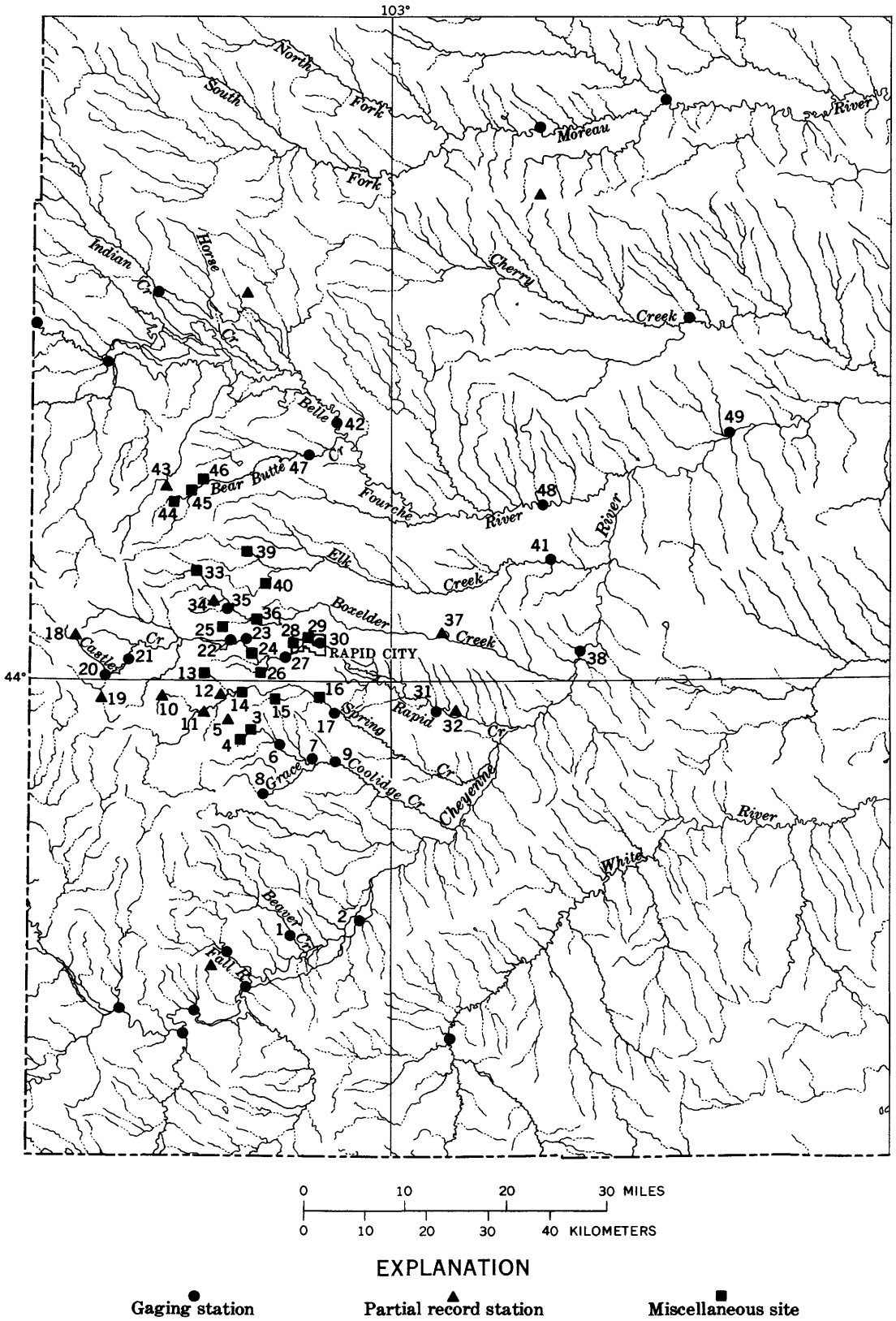


FIGURE 17.—Stream-gaging stations and miscellaneous measurement sites in the Rapid City area.

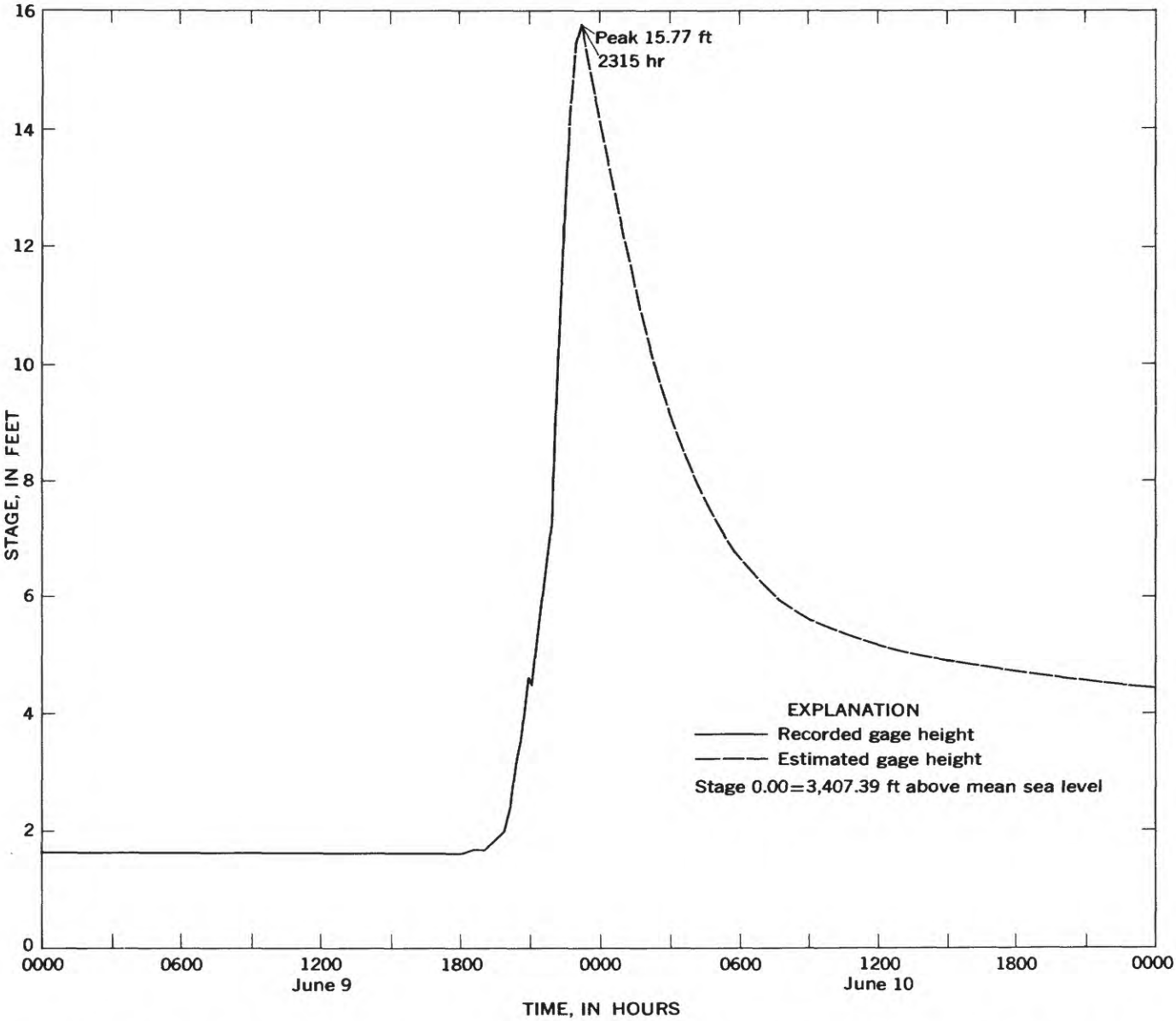


FIGURE 18.—At the gaging station above Canyon Lake Reservoir, Rapid Creek began rising slowly at 1900 MDT on June 9. By 2000 MDT, the stream started rising faster, finally peaking some 14 feet above the 1900 MDT level at a discharge of 31,200 cfs by 2315 MDT.

The North Fork, Middle Fork, and South Fork of Boxelder Creek all cross Highway 385 about 4 to 6 miles upstream from Nemo, and all three of these sites were noted to have had very little flow during the storm. From Nemo Road, 7 miles northwest of Nemo, there was practically no flow into Reausau Lake, which is on a tributary to Boxelder Creek. Rainfall, and therefore runoff, was not unusually heavy upstream from this point. This moderate rainfall in effect eliminated approximately 45 sq mi of contributing drainage area above the gage on Boxelder Creek near Nemo, raising the unit discharge at Nemo to about 590 cfs per sq mi for the contributing area.

A discharge of 1,180 cfs was determined on Boxelder Creek at Benchmark, near Nemo. Total drainage area above this point is 37.2 sq mi; however, only about half of the drainage area contributed to this runoff because rainfall was light on the headwaters.

Another indirect measurement was made at a stream-gaging station on Estes Creek near Nemo, a tributary to Boxelder Creek. The gage was washed out and destroyed, and the hydrograph record was lost. This creek had a peak discharge of 6,620 cfs

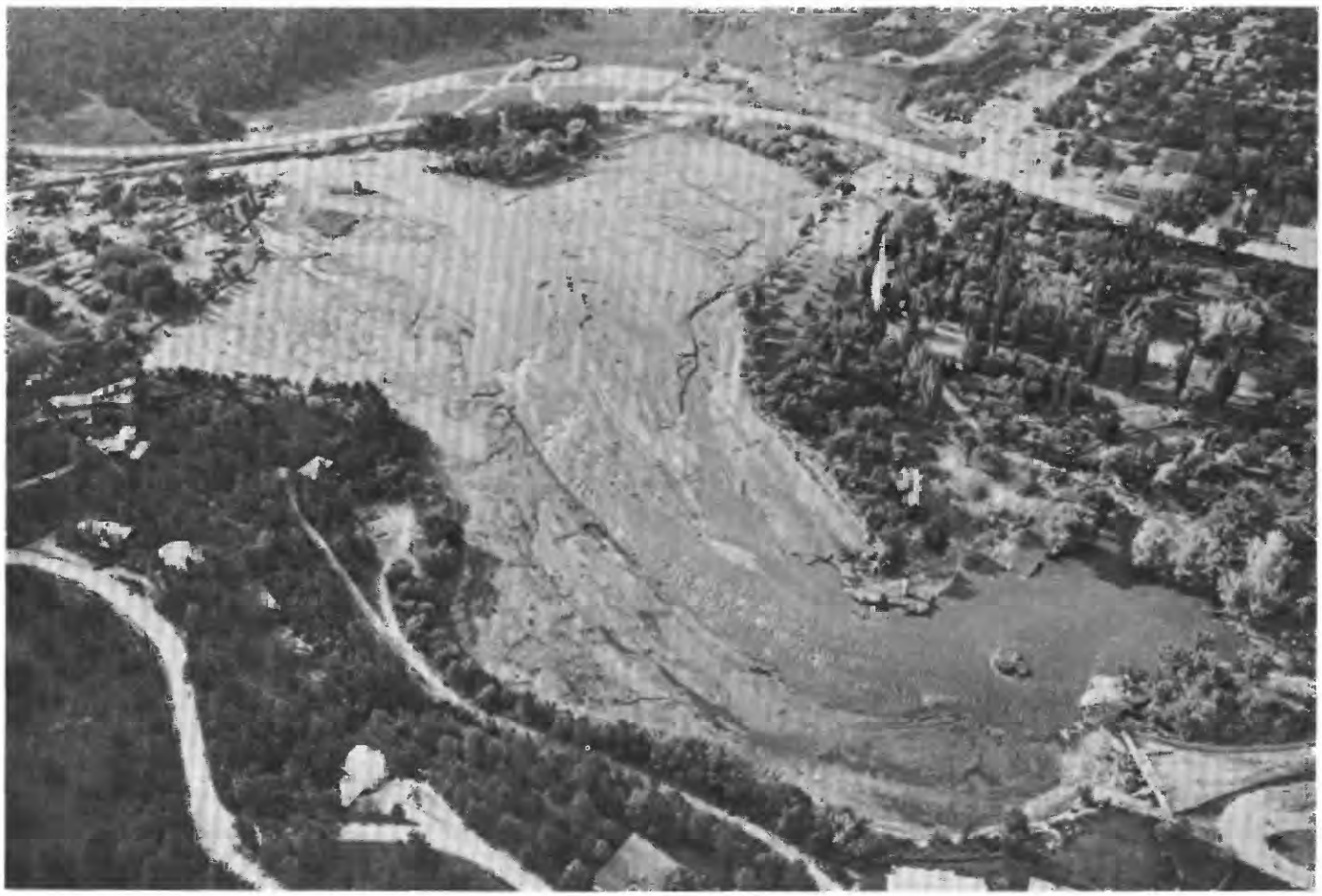


FIGURE 19.—View of Canyon Lake Reservoir following the collapse of the dam. Jackson Boulevard is visible at the top. (American Red Cross photograph.)

from a drainage area of 6.14 sq mi, a unit discharge of 1,080 cfs per sq mi.

A third measurement was made on the main stem of Boxelder Creek at the point where the creek leaves the mountains and flows onto the plains. At this point, a peak discharge was computed to be 51,600 cfs from a drainage area of 117 sq mi, or a unit discharge of 442 cfs per sq mi.

BATTLE CREEK

Battle Creek and its tributaries were in the area of some of the most intense rainfall; extreme flooding was found all along the stream. Eight people were killed in the small town of Keystone, built on the banks of Battle Creek in a little canyon near Mount Rushmore National Memorial. Much of the town was washed away.

Peak discharges were determined at six points in the basin; on a small tributary to Battle Creek; on Battle Creek upstream from Keystone; on Grizzly Bear Creek near its junction with Battle Creek, at Keystone; at the gaging station downstream from Keystone; at the canyon mouth where Battle Creek empties into the plains; and on the plains near Hermosa. The measurement on the small tributary to Battle Creek was made specifically to get information on discharge in small drainage areas. This measurement was made at a crest-stage gage 2.8 miles northwest of Keystone, with a drainage area of 0.88 square miles. Discharge at the peak was 1,330 cfs. This represents a unit discharge of 1,510 cfs per sq mi. Battle Creek upstream from Keystone had a peak discharge of 10,800 cfs, and Grizzly Bear Creek peaked at 6,230 cfs. Unit discharges were 794 and 676 cfs per sq mi, respectively.

The U.S. Geological Survey has maintained a gage on Battle Creek downstream and 4.5 miles southeast of Keystone for the past 11 years. The peak discharge at this site was 26,200 cfs from a drainage area of 66 sq mi, giving a unit runoff of 400 cfs per sq mi. The discharge of Battle Creek at the canyon mouth was 44,100 cfs from a drainage area of 110

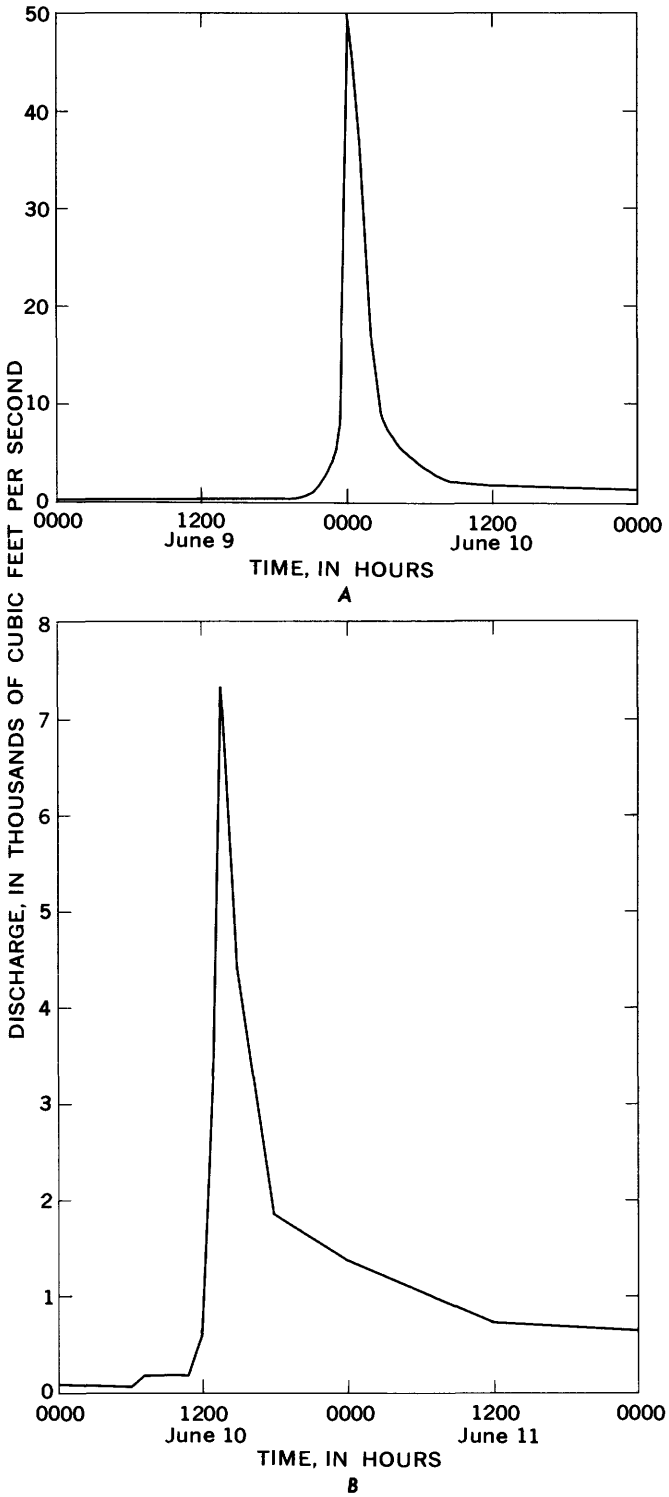


FIGURE 20.—Peak discharges on Rapid Creek. *A*, At midnight on June 9, a peak discharge of about 50,000 cfs was carried through Rapid City by Rapid Creek. By contrast, the average discharge for June 9 was 1,050 cfs, and for June 10, 5,600 cfs. *B*, Around 1330 MDT on June 10, the flood peak reached the gaging station on Rapid Creek near Farmingdale. Peak discharge at this point was 7,320 cfs.

sq mi. This represents a unit discharge of 400 cfs per sq mi.

One more gage is located on Battle Creek near Hermosa, 18 miles south of Rapid City on the plains. Here the peak discharge was 21,400 cfs from a drainage area of 178 sq mi. The reduction in peak discharge between the canyon mouth and Hermosa demonstrates how quickly discharge attenuated after reaching the plains area.

GRACE COOLIDGE CREEK

Grace Coolidge Creek basin is located to the south of the heavy rainfall area and discharges into Battle Creek upstream from Hermosa. Grace Coolidge Creek did not experience heavy flooding; the peak discharge at the gaging station near Custer was only 709 cfs from a drainage area of 25.3 sq mi.

SPRING CREEK

In the upper Spring Creek basin there was very little runoff in streams west of Hill City. The peak discharge of Newton Fork, 3.9 miles northwest of Hill City, was only 21 cfs. There was, however, high runoff from tributaries in the lower Spring Creek basin. Because of the variability within the basin, the discharge was determined in several places so that the origin and amount of water could be documented.

High runoff appeared between Hill City and the Sheridan Lake area. Measurements were made on Palmer Creek near Hill City and on Spring Creek and Horse Creek near their entries into Sheridan Lake to determine the runoff from the headwaters area. Palmer Creek, 3 miles east of Hill City, peaked at 4,370 cfs from a drainage area of 8.24 sq mi, a unit discharge of 530 cfs per sq mi. At Sheridan Lake, where the drainage is 58.0 sq mi, Spring Creek had a peak discharge of 5,630 cfs, a unit discharge of 97 cfs per sq mi. Horse Creek, another major tributary to Sheridan Lake, produced a peak discharge of 1,830 cfs, or a unit discharge of 181 cfs per sq mi. Sheridan Lake stored some water for a short time and slightly reduced the flood peaks downstream.

Rockerville Gulch near Rockerville is a small tributary to Spring Creek and is located near the center of heavy rainfall. The discharge obtained from a drainage area of 1.79 sq mi was 1,560 cfs, or a unit discharge of 870 cfs per sq mi.

The flow of Spring Creek was also determined where it crosses Highway 328. Representing the runoff from a drainage area of 88.9 sq mi, the peak

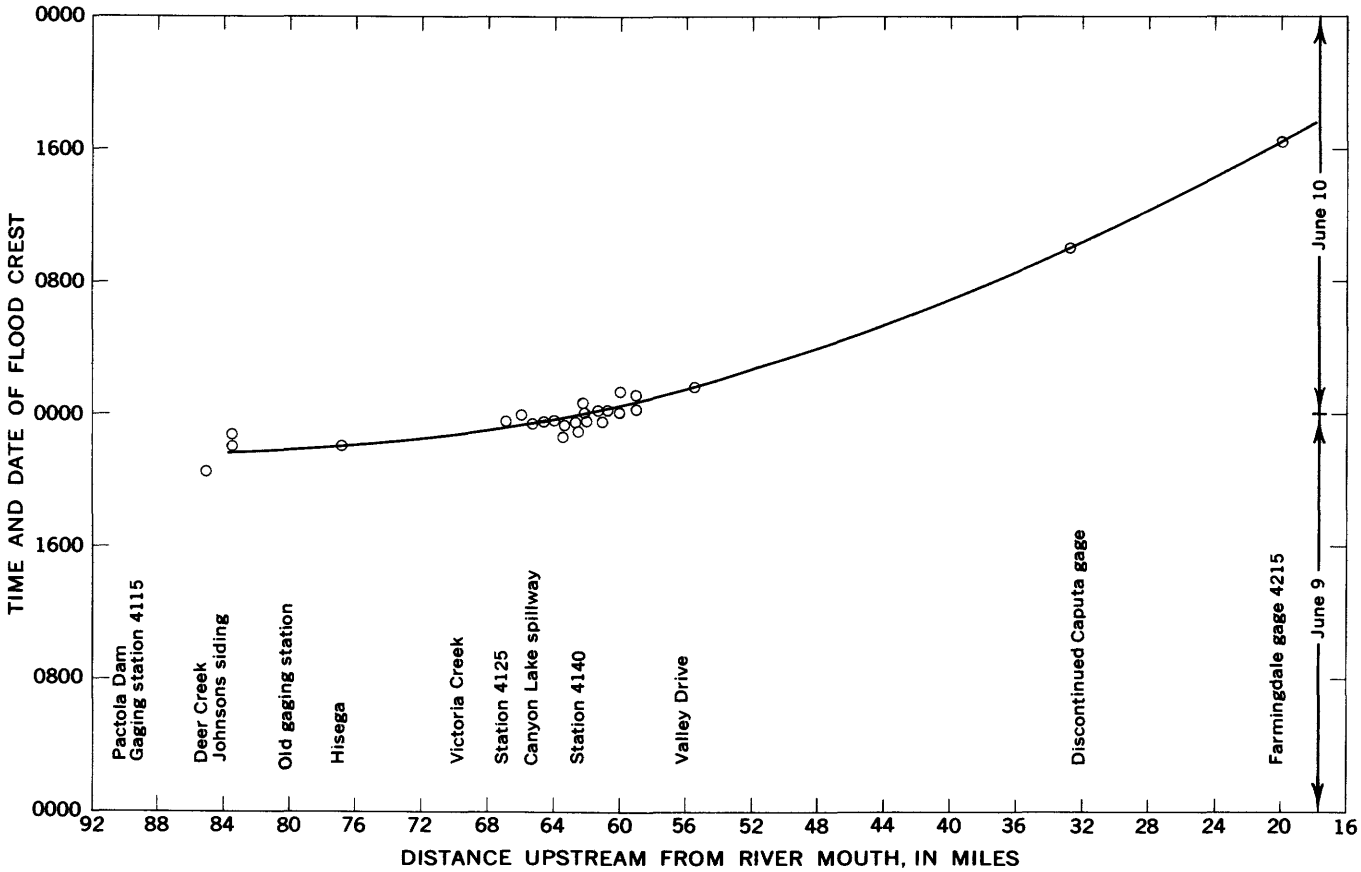


FIGURE 21.—Timing of flood peak down Rapid Creek.

discharge was 14,900 cfs, or a unit discharge of 168 cfs per sq mi.

At the point where the creek crosses Highway 16, Spring Creek had a peak discharge of 21,800 cfs from a drainage area of 103 sq mi, or a unit discharge of 212 cfs per sq mi. At the gaging station near Hermosa, Spring Creek had spread out into the plains area. Here the stream has a drainage area of 199 sq mi and the discharge had attenuated to 13,400 cfs, a unit discharge of 67 cfs per sq mi.

ELK CREEK BASIN

The Elk Creek basin, draining eastward from the Black Hills, is one of the larger basins in the flood area. The basin did not receive the heaviest rainfall and consequently did not have as much runoff as some of the streams farther south. Flooding in this basin was significant, however, damaging creek beds, roads, bridges, and a few ranches. Because only a few people inhabit the basin, property damage was relatively slight. At the point where it leaves the hills, Elk Creek produced a peak discharge of 11,600 cfs. This is a unit discharge of 256 cfs per sq mi. About 15 miles upstream from this site, Elk Creek crosses Highway 385 and was noted to have had practically no flow at the time of the peak. By the time Elk Creek reached Elm Springs, some 40 miles east on the plains, the peak discharge had attenuated to 1,880 cfs (fig. 22).

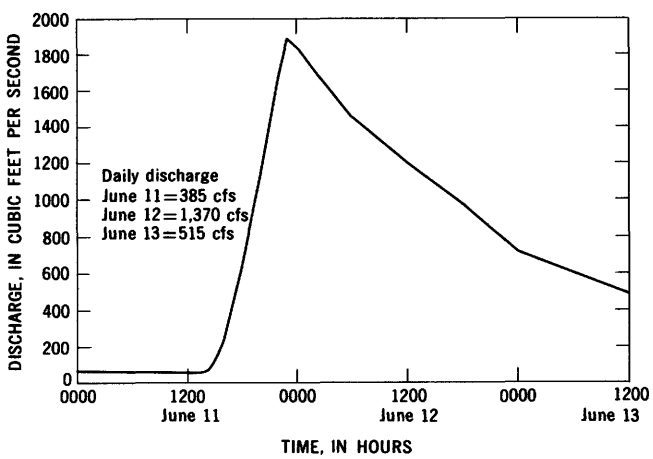


FIGURE 22.—The peak discharge of Elk Creek at Elm Springs, some 40 miles east of the Black Hills, was 1,880 cfs on June 11.

BEAR BUTTE CREEK

The Bear Butte Creek basin, a tributary to the Belle Forche River, was on the northern fringe of the storm area and not in the area of most intense rainfall. A discharge of 19,000 cfs was computed for Bear Butte Creek at a discontinued gaging-station site near Galena, 4 miles southwest of Sturgis. This represents a unit discharge of 398 cfs per sq mi from the 47.6 sq mi basin. A peak discharge of 19,500 cfs was measured at a miscellaneous site just upstream from Sturgis. This represents a unit discharge of 368 cfs per sq mi from 53.0 sq mi. At the Bear Butte gage site downstream from and 12.5 miles northeast of Sturgis, the discharge was only 7,220 cfs (fig. 23). This latter site includes the flow of Deadman Gulch.

Deadman Gulch, tributary to Bear Butte Creek at Sturgis, carried considerable runoff—enough to overflow its banks in the city and to discharge water down many of the streets of Sturgis. Basements were flooded in a few houses. A discharge of 4,740 cfs was measured in Deadman Gulch just upstream from Sturgis, giving a unit discharge of 797 cfs per sq mi from 5.95 sq mi. The fill under the bridge of the interstate highway scoured badly but traffic was not interrupted and the bridge structure was not damaged. Elsewhere in Sturgis, traffic was delayed for a few hours in places, but no major damage was done. In the same vicinity, Vanocker Creek had significant runoff but was not as high as Bear Butte Creek.

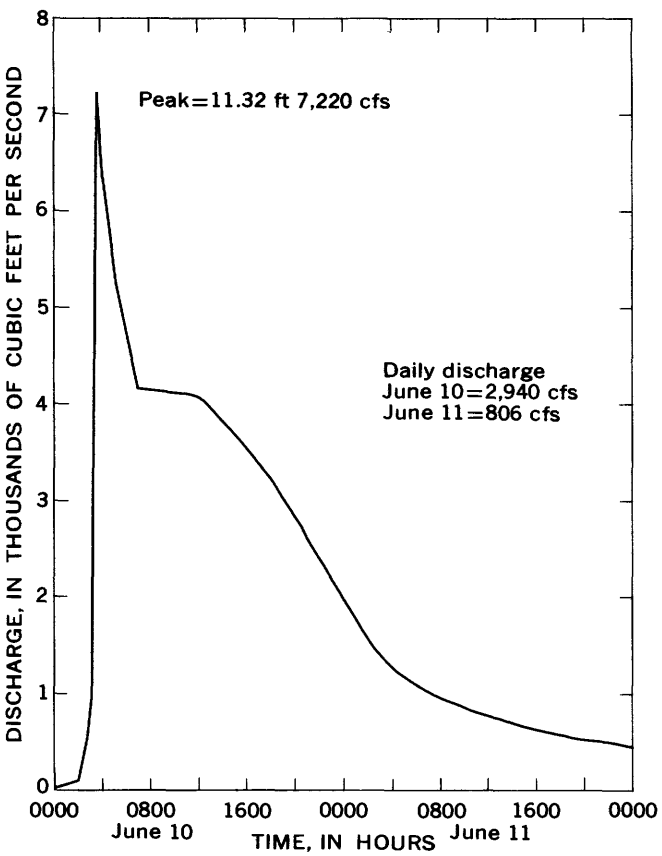


FIGURE 23.—At the gaging station 12.5 miles northeast of Sturgis, the peak discharge of Bear Butte Creek had attenuated to 7,220 cfs about equal to a 40-year flood.

CHEYENNE RIVER

All the flooding covered in this report lies within the Cheyenne River basin, and all discharge from the flood, except for losses through evaporation and seepage, eventually ended up in the Cheyenne River. The water was stored in vast overflow areas as it reached the plains, however, and the peaks were diminished considerably. As a result, the peak discharge of the Cheyenne River at the gaging station near Wasta, S. Dak., 43 miles east of Rapid City, was only 11,800 cfs (fig. 24). Furthermore, the peak was broad, hardly pushing the Cheyenne River out of the main channel banks at the peak stage.

FLOOD VOLUMES

The floods in the Rapid City area struck quickly and viciously but did not last long. Flood peaks were sharp. The stage and discharge of Rapid Creek at Rapid City rose quickly, and the water overtopped

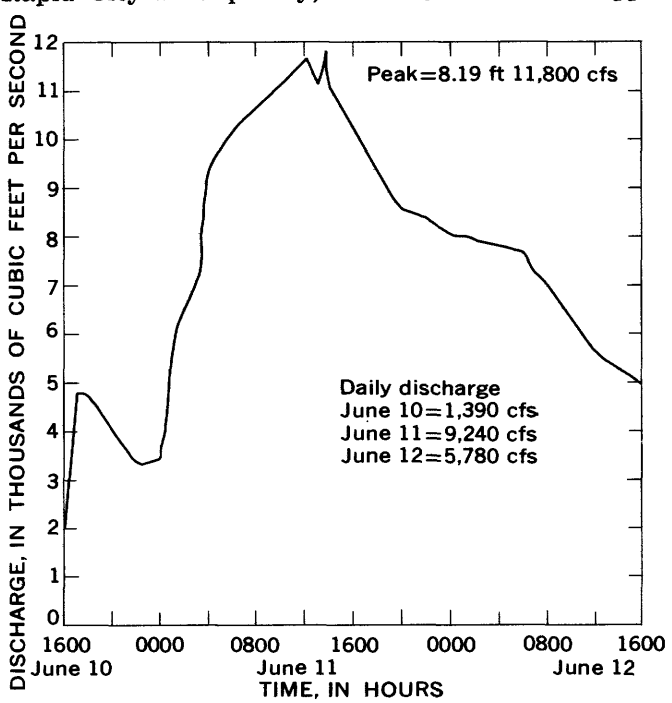


FIGURE 24.—By the time it reached Wasta, the Cheyenne River had received peak discharges from most of the streams in the flood area. Yet, because of attenuation, the peak discharge on the Cheyenne was only 11,800 cfs, about equal to the 2-year flood.

its banks at about 2215 to 2230 MDT on the 9th. By 0400 MDT to 0500 MDT the next morning, the water was back within the banks of the stream. Because of the short duration of the peak, the total volume of water in the flood was relatively small. For example, total flow in the Rapid Creek above Canyon Lake was a little more than 9,000 acre-feet during the 2-day period June 9, 10. Total flow for Rapid Creek at Rapid City was a little more than 13,000 acre-feet during the same 2-day period, and Boxelder Creek near Nemo flowed a little more than 19,000 acre-feet. As a basis for comparison, Pactola Reservoir was about half full and contained some 60,000 acre-feet of water at the time of the flood—about four times the total floodflow of Rapid Creek at Rapid City.

After the floodwater flowed downstream from Rapid City, it spread out over a broad flood plain. Because the flood event came and left quite rapidly, ground-water levels were not raised significantly. Instead, the water was temporarily stored in the flood-plain alluvium. Thus the major effect was to sustain discharges at a higher than normal level. For example, the flow of Rapid Creek at Rapid City 1 week after the flood was about 500 percent higher than the flow 1 week before the flood; 2 weeks after the flood, the flow was still about 400 percent higher.

RELATIVE MAGNITUDE

Flood stages and discharges for the June floods are summarized for the Rapid City area in table 6. The table also shows previous peaks of record for selected sites. Although the 1972 floods generally exceeded previous peaks of record in the stricken area, floods of greater relative magnitudes have been experienced in the United States (fig. 25). Figure 26 shows the comparison between the 1972 Black Hills floods and previous maximum floods experienced in South Dakota.

TABLE 6.—*Flood stages and discharges in the Rapid City area during the June 1972 flood and during previous maximum floods*

[The first column under "Maximum floods previously known" shows the period of known floods before June 1972. This period may be longer than the actual period of record, because records of historical floods may have been obtained. The last column contains the recurrence interval in years of the June 1972 peak discharge]

No.	Station No.	Stream and place of determination	Drainage area (sq mi)	Maximum floods previously known: Prior to June 1972: Period	Maximum floods previously known: Prior to June 1972: Year	Maximum floods previously known: Gage height (ft)	Maximum floods previously known: Discharge: Cubic feet per second	Maximum floods previously known: Discharge: Recurrence interval[1] (yrs)	Maximum June 9–10, 1972: Day	Maximum June 9–10, 1972: Hour (MDT)	Maximum June 9–10, 1972: Gage height (ft)	Maximum June 9–10, 1972: Discharge: Cubic feet per second	Maximum June 9–10, 1972: Discharge: Recurrence interval[1] (yrs)
1	4025	Beaver Creek near Buffalo Gap (4.5 mi upstream from mouth).	130	1937–72	1938 1927	16.46 18.0	11,700 -----	>100	10	0100	7.09	829	4
2	4026	Cheyenne River near Buffalo Gap (12 mi east of Buffalo Gap).	9,810	1968–72	1971	11.44	17,600	10	10	0700	7.24	2,670	<2
3	----	Battle Creek at Keystone ---------	13.6	-------	----	----	-----	---	9	2130	----	10,800	>100
4	----	Grizzly Bear Creek near Keystone (tributary to Battle Creek).	9.22	-------	----	----	-----	---	9	2130	----	6,230	>100
5	4038	Battle Creek tributary near Keystone (2.8 mi northwest of Keystone).	.88	1956–72	1967	5.41	16	---	9	2100	18.8	1,330	>100
6	4040	Battle Creek near Keystone (15 mi southwest of Rapid City).	66	1945–47 1961–72	1965	3.71	718	4.5	9	2200	14.5	26,200	>100
7	----	Battle Creek at canyon mouth near Hermosa (2.2 mi southwest of Hermosa).	110	-------	----	----	-----	---	9	2245	----	44,100	>100
8	4050	Grace Coolidge Creek near Custer (11.5 mi east of Custer).	25.3	1945–47 1967–72	1947	4.50	206	2.0	10	0245	3.64	709	7
9	4060	Battle Creek at Hermosa (0.8 mi south of Hermosa).	178	1949–72	1952	14.00	2,950	12	9	2300	17.72	21,400	>100
10	4068	Newton Fork near Hill City (3.9 mi northwest of Hill City).	[2] 8.25	1969–72	1971	3.62	25	2	9	2145	3.51	21	2
11	4069	Palmer Creek at Hill City (3 mi east of Hill City).	8.24	1956–72	1962	7.55	[2] 350	>100	9	----	17.06	4,370	>100
12	----	Spring Creek at entrance to Sheridan Lake.	58.0	-------	----	----	-----	---	9	2400	----	5,630	>100
13	4069.5	Horse Creek at entrance to Sheridan Lake.	10.1	-------	----	----	-----	---	9	2400	6.65	1,830	>100
14	----	Spring Creek below Sheridan Lake at Highway 328.	88.9	-------	----	----	-----	---	10	0033	----	14,900	>100
15	----	Rockerville Gulch at Rockerville ----	1.79	-------	----	----	-----	---	9	2300	----	1,560	>100
16	----	Spring Creek at Highway 16 near Rockerville (8 mi south of Rapid City).	103	-------	----	----	-----	---	10	0200	----	21,800	>100
17	4085	Spring Creek near Hermosa (17 mi south of Rapid City).	199	1949–72	1967	5.49	772	6.2	10	0300	13.12	13,400	>100
18	4088.5	Silver Creek near Rochford (1.1 mi east of Rochford).	[2] 6.20	1969–72	1969	4.17	13	2	10	0645	3.49	[2] 3.3	<2
19	4089	Heeley Creek near Hill City (13.5 mi northwest of Hill City).	4.86	1969–72	1969	----	15	2	10	0700	2.96	1	<2
20	4090	Castle Creek above Deerfield Reservoir near Hill City (30 mi west of Rapid City).	83	1948–72	1952	5.81	1,120	45	10	0430	2.14	19	<2
21	4100	Castle Creek below Deerfield Dam (28 mi west of Rapid City).	96	1946–72	1952	3.87	200 (daily)	---	10	----	----	18 (daily)	<2
22	4105	Rapid Creek above Pactola Reservoir at Silver City (17 mi west of Rapid City).	292	1953–72	1965	10.44	2,060	20	10	0905	5.74	228	<2
23	4115	Rapid Creek below Pactola Dam (13 mi west of Rapid City).	[3] 1	1928–32 1946–72	1952	[4] 6.74	2,170	---	9	2030	8.62	378	---
24	----	Rapid Creek at Highway 40 (8 mi west from Rapid City).	8.35	-------	----	----	-----	---	9	2245	----	5,750	>100

See footnotes at end of table.

TABLE 6.—*Flood stages and discharges in the Rapid City, South Dakota, area during the June 1972 flood and during previous maximum floods*—Continued

No.	Station No.	Stream and place of determination	Drainage area (sq mi)	Maximum floods previously known: Prior to June 1972 Period	Year	Gage height (ft)	Discharge: Cubic feet per second	Recurrence interval[1] (yrs)	Maximum June 9–10, 1972: Day	Hour (MDT)	Gage height (ft)	Discharge: Cubic feet per second	Recurrence interval[1] (yrs)
25	----	Deer Creek at Deer Creek campground (8 mi west of Rapid City).	4.28	-------	----	----	-----	---	9	2030	----	3,530	>100
26	----	Victoria Creek at Victoria Dam near Rapid City.	6.71	-------	----	----	-----	---	9	2100	----	6,860	>100
27	4125	Rapid Creek above Canyon Lake near Rapid City.	[3] 52	1946–72	1952	8.08	2,600	24	9	2315	15.77	31,200	>100
28	----	Cleghorn Canyon at Rapid City (one-half mi from mouth).	6.95	-------	1962	----	2,920	>100	9	2200	----	12,600	>100
29	----	Lime Creek at 36th and West Main in Rapid City.	2.51	-------	----	----	-----	---	9	2300	----	481	>100
30	4140	Rapid Creek at Rapid City --------	[3] 91	1903–06 1942–72	1962 1920	8.37 13.6	3,300 -----	36	9	2400	15.45	50,000	>100
31	4215	Rapid Creek near Farmingdale (20 mi southeast of Rapid City).	[3] 283	1946–72	1947	8.4	2,640	12	10	1330	11.85	7,320	>100
32	4217.5	Rapid Creek tributary near Farmingdale (3.8 mi southeast of Farmingdale).	1.51	1970–72	1970	3.87	35	[2] 10	10	----	----	1	<2
33	4223.95	Boxelder Creek at Benchmark near Nemo (3½ mi northwest of Nemo).	37.2	-------	----	----	-----	---	9	2100	----	1,180	7
34	4224	Estes Creek near Nemo (1.6 mi southeast of Nemo).	6.14	1969–72	1970	5.41	([5])	---	9	2200	([6])	6,620	>100
35	4225	Boxelder Creek near Nemo (12 mi northwest of Rapid City).	96	1945–47 1966–72	1946 1911	[4] 5.75 14	1,180 -----	4	9	2230	20.4	30,100	>100
36	----	Boxelder Creek at Nemo road near Rapid City (3 mi northwest of Rapid City).	117	-------	----	----	-----	---	10	0030	----	51,600	>100
37	4232.5	Boxelder Creek tributary at New Underwood (0.1 mi west of New Underwood).	.14	1970–72	----	----	1	---	10	----	----	3	<2
38	4235	Cheyenne River near Wasta (43 mi east of Rapid City).	12,800	1914–15 1928–32 1934–72	1932 1915 1920	12.28 13.5 17	46,300 ----- -----	20	11	1330	8.19	11,800	2
39	----	Elk Creek at canyon mouth near Piedmont (4 mi northwest of Piedmont).	45.5	-------	----	----	-----	---	9	2400	----	11,600	>100
40	----	Stagebarn Canyon near Piedmont (2 mi southeast of Piedmont).	16.8	-------	----	----	-----	---	10	1245	----	4,100	>100
41	4255	Elk Creek near Elm Springs (38 mi northeast of Rapid City).	540	1949–72	1952 1962 1920	[4] 10.61 11.0 [4] 17	8,540 ----- -----	12	11	1100	8.70	1,880	2
42	4370	Belle Fourche River near Sturgis (20 mi northeast of Sturgis).	5,870	1945–72	1946 1962	13.86 14.32	17,900 -----	8	10	1700	10.56	7,060	<2
43	4371	Boulder Creek near Deadwood (3.5 mi east of Deadwood).	1.69	1956–72	1962	8.46	210	15	9	2215	5.59	59	<2
44	4372	Bear Butte Creek near Galena (discontinued gaging station, 4 mi southwest of Sturgis).	47.6	1965–69	1965	8.61	4,950	>100	9		11.78	19,000	>100
45	----	Bear Butte Creek at Interstate 90 at Sturgis.	53.0	-------	----	----	-----	---	9		----	19,500	>100
46	----	Deadman Gulch at Interstate 90 at Sturgis.	5.95	-------	----	----	-----	---	9		----	4,740	>100
47	4375	Bear Butte Creek near Sturgis (28 mi north of Rapid City).	192	1945–72	1962	[4] 12.45	12,700	>100	10	0330	11.32	7,220	40
48	4380	Belle Fourche River near Elm Springs (4.3 mi northwest of Elm Springs).	7,210	1928–32 1934–72	1964 1927 1933	15.90 21.8 20	45,100 ----- -----	45	11	0600	8.62	9,810	3
49	4385	Cheyenne River near Plainview (10 mi southeast of Plainview).	21,600	1950–72	1957 1965 1920 1927	---- 11.68 17.5 14	41,700 ----- ----- -----	([7])	11	2230	9.44	14,600	<2

[1] From Patterson (1966) and Hardison (1973).
[2] Approximate.
[3] Contributing area downstream from Pactola Dam.
[4] Datum then in use.
[5] Discharge not determined.
[6] Datum destroyed by flood.
[7] Regulated.

THE DESTRUCTION

Just as we have tried to describe the storm and flood in terms of physical facts and numbers, we can try to add another dimension to the flood by describing the death and destruction inflicted in the Rapid City area the night of June 9, 1972. To the scientific facts that describe the magnitude and rarity of this natural disaster, we can add the human effect of the flood: the number of deaths and the destruction, the words of the witnesses, and photographs of the aftermath.

THE VICTIMS

According to the American Red Cross, 237 people died in the Black Hills floods. Another 3,057 people were injured, including 118 who needed hospital care. Perhaps more startling, 6 months after the flood, eight people were still listed as missing.

Based on incomplete newspaper descriptions, the dead ranged in age from 3 months to 94 years. About 25 percent of the victims were over 60 years old, 15 percent were under 13, and 30 percent were under 30. Some 10 percent of those who died in the flood

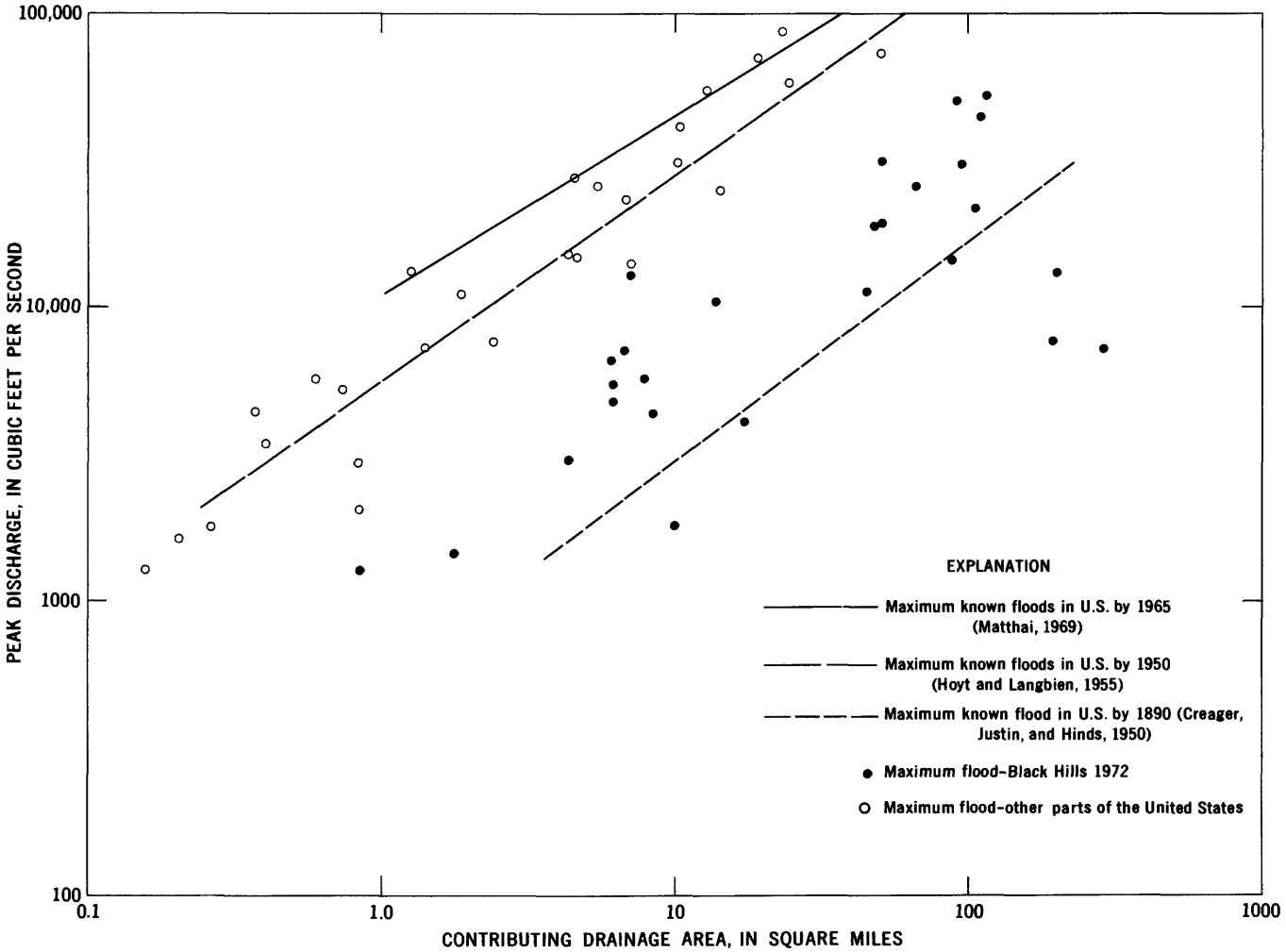


FIGURE 25.—Comparison of the Black Hills floods with maximum floods previously determined in the United States.

were tourists from 13 States and from France enjoying the wild beauty of the Black Hills.

THE DAMAGE

Total damage in the Black Hills flood is estimated (written commun., U.S. Army Corps of Engineers) to exceed $160 million (table 7). The National Flood Insurance Association reported that 29 flood insurance policies were in effect in the area, covering less than $300,000 in damage, or about one-half of 1 percent of the damage to homes and businesses. The Red Cross counted an overall total of 770 permanent homes and 565 mobile homes destroyed in the flood; an additional 2,035 permanent homes and 785 mobile homes suffered major damage (fig. 27).

The Soil Conservation Service estimates 5,000 automobiles were destroyed in the flood, and the Federal Highway Administration reports that highway damage was severe. Within the Federally aided highway system, major repairs were required at about 160 locations, including the replacement of washed-out bridges and the removal of accumulations of debris. (See fig. 28.)

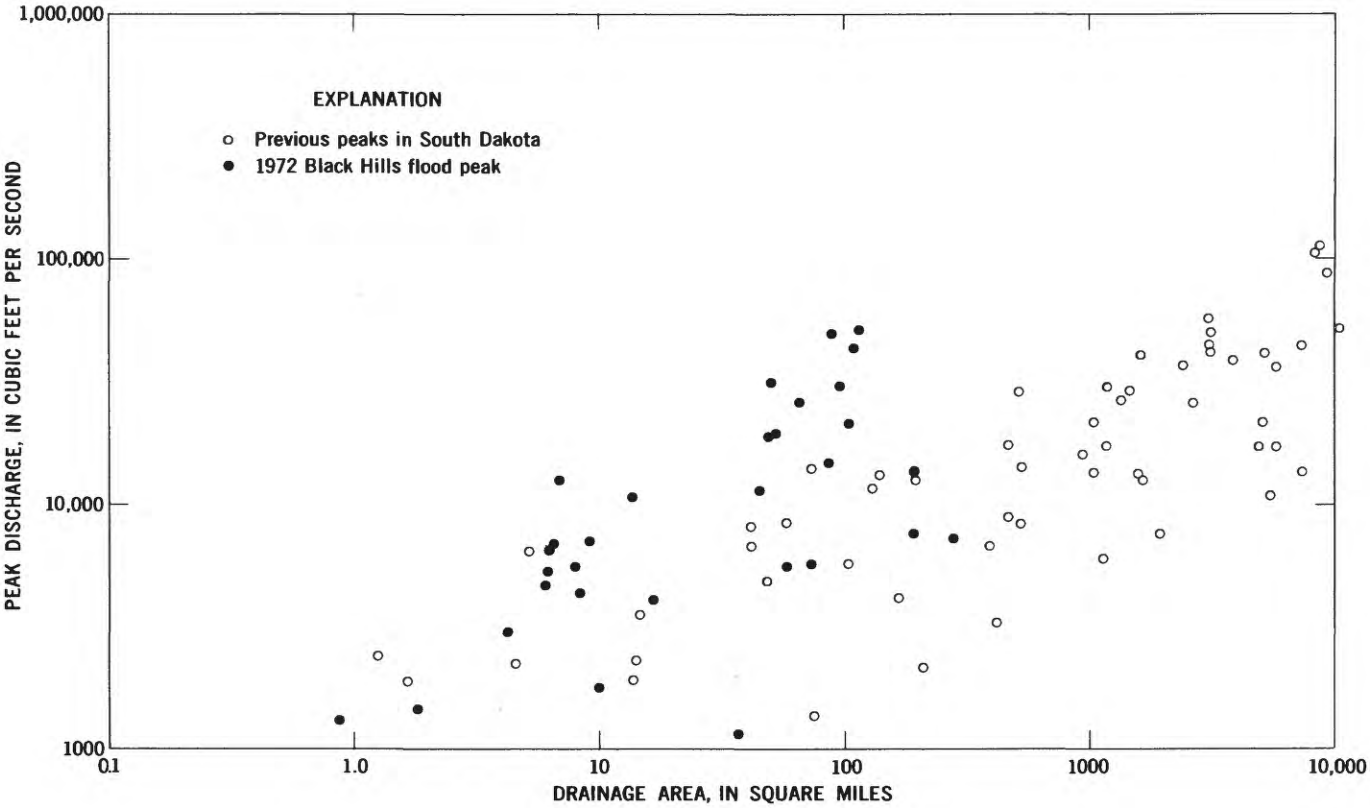


FIGURE 26.—Comparison of the Black Hills flood peaks with maximum floods previously determined in South Dakota.

TABLE 7.—*Damage estimates for the Black Hills flood*

[Furnished by the U.S. Army Corps of Engineers]

Urban damages:		
Residential damage:		
Rapid City	$ 35,095,000	
Boxelder	1,158,000	
Sturgis	1,247,000	
Keystone	137,000	
		$ 37,637,000
Commercial and industrial damage:		
Rapid City	$ 30,881,000	
Boxelder	75,000	
Sturgis	213,000	
Keystone	1,499,000	
		$ 32,668,000
Utilities		$ 10,338,000
Associated economic losses		6,341,600
Total urban damages		$ 86,984,600
Rural damages		$ 6,217,800
Transportation damages		$ 35,380,400
Secondary economic losses:		
Estimated loss in tourist income	$ 30,000,000	
Estimated interest costs for reconstruction losses	6,364,000	
Total secondary economic losses		$ 36,364,000
Estimated total losses		$164,946,800

THE WITNESSES

Hundreds of stories of horror and devastation were related by witnesses who survived the floods. Most of the following quotes were first reported by the "Rapid City Journal" as that paper recorded eyewitness accounts of the destruction of the community.

Some of the eyewitnesses had been warned by friends and officials of the flood danger and had escaped to higher ground. Many others heard the warnings but did not heed them:

When we heard the warning, we thought he (the Mayor) was kidding. We just sat there, and pretty soon this big bunch of water came down the creek. We ran next door and suddenly the water was up to my neck. The top of a house came floating by and we grabbed on to that. A little way downstream we got off and climbed on the roof of a neighbor's house. We stayed there until the flood began to fall on Saturday.

Some were swept away, trying to struggle to safety; others were more fortunate:

The people were crying and screaming for help. And you could just see the people floating around, just before your eyes. Some going under . . . some floating in a car or in a house . . . it's just terrible. A car floated down the main street where we live, so we tried to make it on foot toward a hill and couldn't make it. My husband almost floated away, but

FIGURE 27.—One of 770 permanent homes and one of 565 mobile homes destroyed in the flood. The homes have been searched (S) for victims and condemned (X). (American Red Cross photographs.)

FIGURE 28.—The roads, the bridges, and the cars they served suffered much of the damage caused by the Black Hills floods. Chapel Lane, now bridgeless, ends suddenly at the entrance to Canyon Lake. The cars were stacked by the force of the water as it pushed through Rapid City. ("Rapid City Journal" photograhs.) (Continued on following page.)

the children grabbed him. We went back to the house and the water came up to our necks. We just stood there until the water came down to our waists and we were rescued.

Many of the victims, campers in the Black Hills area near the streams, were taken by surprise by the sudden increase in discharge and were swept away in their sleep or before they could reach high ground:

A little before 11 p.m., Tom heard water coming in the cabin. He woke us all up. We couldn't open the cabin door to get out because of water outside. I kicked out a window and right then a car smashed into it. We all grabbed a mattress in the one room in the cabin and floated in the water—it was four or five feet deep—and the cabin started floating downstream. It went at least a mile and then one wall of the cabin broke away from the rest of it. I'd given myself up for dead, I thought this was it.

And for three of the six companions of this boy, it was.

Many people were found the next morning hanging onto trees, poles, wires, or anything else that they could grab:

I looked out the window and I saw him in the flashes of lightning. He was caught in a tree over there. He was a brave youngster, only about 10. I kept hollering at him to hold on and climb higher.

He was saved several hours later.

Miraculous and sad tales were told of how invalids were saved or lost. One 71-year-old lady kept her invalid granddaughter alive by holding her on a mattress that floated on the water in the room:

When the water reached my chest, I thought "if it goes any higher, this will be it." I was so afraid she would tip and roll off, so I stood right beside the mattress, balancing *** it was all so slimy.

Vicki simply couldn't do it (climb up on the roof). Besides, I didn't think taking her up on the roof in the dark and the pouring rain would be any safer for her.

This is but one of many heroic deeds performed this unforgettable night. Many stories were yet to be told, and just as many would never be told (fig. 29).

Figure 28.—Continued

FIGURE 29.—Ironically, one of the major problems that faced the survivors of the Rapid City flood was a lack of adequate drinking water. Truly a case of "water, water everywhere, but not a drop to drink." (American Red Cross photograph.)

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