echnical Memorandum NWS CR-59

HOURLY CUMULATIVE TOTALS OF RAINFALL BLACK HILLS FLASH FLOOD JUNE 9-10, 1972

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Central Region Headquarters

Scientific Services Division
Central Region Headquarters
April 1976

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UNITED STATES
DEPARTMENT OF COMMERCE
Frederick B. Dent, Secretary

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
Robert M. White, Administrator

National Weather
Service
George P. Cressman, Director

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INTRODUCTION

On the night of June 9, 1972, heavy rains over the East Central Black Hills produced flood waters that grew into the greatest natural disaster (in terms of human life) in the history of the State of South Dakota. So shattering was the tragedy that since that night (and undoubtedly for a long time to come), time in Rapid City is reckoned as "Before the Flood" or "After the Flood".

The intensity of the rainfall was unprecedented in the history of weather records in the Black Hills area. As much as 15 inches of rain fell near the village of Nemo on Box Elder Creek and 14.5 inches near Sheridan Lake, all within a period of less than five hours. Over an area of about 50 miles long and about 10 miles wide, the rainfall averaged four times the six-hour amounts that might be expected to occur once in a hundred years. This downpour produced record floods in the streams running eastward out of the Black Hills from Bear Butte Creek (Fig. 1), which flows through the City of Sturgis, to Grace Coolidge Creek, which emerges just east of the Mount Rushmore National Memorial.

Several other reports have been written concerning the tragedy, but the purpose of this paper is to provide further insight by presenting hourly increments of the storm rainfall.

The elevation of the terrain within the area of extremely heavy rainfall is, on the average, nearly 5,000 feet above sea level, but with some points rising to over 6,000 feet. To the east, elevations fall off sharply to the prairie which adjoins the Black Hills. Stream beds lower by as much as 100 feet or more per mile. It was this terrain feature, combined with the intense precipitation, that brought about the high stages and flood flow velocities.

BUCKET SURVEY

In the days following the flood, a careful and extensive bucket survey[1] was made to obtain a more detailed rainfall areas distribution than that provided by existing rainfall networks and rainfall reports from the general public. As a result of the survey, the public cooperated by providing about 300 additional reports. Recording rain gage records

[1] Bucket survey is a term applied to gathering rainfall amounts from pails, buckets, or any container which catches rainfall.

were used whenever possible. In areas not served by a recording gage, estimates were made from reports of runoff and from interviews with local residents. The results of this survey were charted for each hour in the form of isohyets of total accumulated precipitation to the hour in question (1600[2] to midnight; see Figs. 2 to 10). By midnight almost all of the rainfall had already fallen in those areas which contributed to the flooding, although rain did continue to spread out to the west, north, and south for several hours after midnight.

It is very interesting to note that all of the rainfall that contributed significantly to the seriousness of the flooding occurred in a period of less than eight hours. At any one location, the rainfall generally occurred in less than four hours.

The bucket survey made after the storm produced not only total rainfall amounts but also information on the sequence of events. The sequence cannot be completely nor fully accurately obtained from such a survey, in that gage observers read the gages at non-designated times and intervals. Consequently, the incremental rainfall amounts to fixed times have to be interpolated and interpreted by comparison with rainfall recorder records and observer reports. While there were recording rain gages in the area of concern, only six were fully used in this analysis as three were inoperative while two produced only partial recordings.

The data also included many accounts of the time of the heavy downpours as the voluntary observers read and emptied their rain gages. Both the recording rain gage data and the supplementary data have been compiled in Table 1 and provide the basis for the hourly incremental isohyetals. The reader is referred to Table 3, Pages 25 to 29 of Reference 1, for location of rainfall observations. A location map is included as Figure 1.

ISOHYETAL MAPS

The first hourly summation (Fig. 2) is for 1600 June 9, 1972. By that time, thunderstorm activity had already produced a two-inch center upstream from Sturgis on Bear Butte Creek. Very light rains were occurring in the Southern Hills, amounting by then to mostly less than 0.10 inch.

By 1700 (Fig. 3) the thunderstorm activity in the Northern Hills had increased substantially. A four-inch center can be identified, and the periphery of the activity had expanded. The separate light rain area previously in the Southern Hills had extended just into the Central Hills; however, the rain continued to be light.

By 1800 (Fig. 4) the individual rainfall areas had merged into a single area. The general pattern of rainfall had now been established eastward from a north-south axis along the ridge of the Hills. Rainfall activity over the Northern Hills had produced at least a seven-inch amount.

[2] All times are in Mountain Daylight time.

By 1900 (Fig. 5) rainfall over the Northern Hills had started to slacken and the Central Hills were receiving heavy amounts of rainfall. Rainfall intensities of at least two inches per hour were occurring there and the isohyets of accumulated precipitation indicated centers of 3 to 4 inches there.

By 2000 (Fig. 6) areas of six-inch rainfalls were quite extensive and four centers of over eight-inch accumulations were showing. The thunderstorms producing the 8-inch centers were stationary over Box Elder, Rapid, and Spring Creeks.

By 2100 (Fig. 7) torrential precipitation rates were occurring over the Central Hills and maximum rainfall intensities of 4.5 inches per hour were occurring. Over the Northern Hills the rains totaled 8 to 10 inches with the rainfall rates slackening to about one inch per hour. The Northern Hills had now experienced their maximum runoff and Bear Butte Creek was flowing at its maximum rate. In the Central Hills two centers of at least 10 inches had developed and 8 inches of precipitation had fallen over an area extending from the Northern Hills into the Southern Hills. The heaviest rainfall was then occurring over the Southern Hills while moderate rainfall was extending westward from the Northern Hills. Heavy rates of runoff were being experienced in all creeks and streams flowing eastward from the Black Hills.

At 2200 (Fig. 8) twelve-inch centers of rainfall were now showing in the Central and Southern Hills while in the Northern Hills the rain had practically stopped. Precipitation rates of 2 to 3 inches per hour were being experienced and the maximum runoff rates were being realized. These precipitation rates continued over the Central and Southern Hills to near midnight, then diminished steadily and stopped about 0200 June 10.

CONCLUSIONS

Several interesting conclusions may be drawn from the foregoing analyses. The unprecedented precipitation intensities for this area as compared with Technical Paper 40, coupled with the extended durations, produced a record rainfall. Two inches per hour is a high rainfall rate for the Black Hills area. An examination of the operation of the current NWS rainfall reporting network[3] under these severe conditions, indicates that the first reports would have come in at 1900, fully three hours after the initial rain. Had the current reporting network and the two-inch criteria been in existence, reports from the Northern Hills would have reached the National Weather Service by no later than 1700. With the new reporting criteria, which requires a report for each additional inch after the two-inch report, the incoming telephone system of the Weather Service Office would have become greatly overloaded and it would have been impossible to keep the WSO updated. Had there been a backup collection center in the immediate vicinity of Rapid City, it too would have become overloaded. However, there is little question that if the present network and criteria had been established and functioning reasonably well, sufficient data would have been available to more precisely evaluate and warn of the flood potential.

3 Immediately after the June 9 flood, the National Weather Service set up a 30-observer rain gage network in the Black Hills.

Another interesting conclusion may be derived from the use of a local warning radar network. Had an operational radar been in existence, heavy rainfall intensities would have been identified as early as 1600 over the Northern Hills. With both the intensities increasing and the durations lengthening, a warning could have been based upon radar observations. Radar observations, when supported by a reasonable rainfall network, could have kept the WSO abreast of the developing storm. Runoff in Bear Butte Creek could have been sufficient to trigger a flash flood alarm system in that creek as early as 1700. This would be about four and a half hours lead time to the crest, yet scarcely an hour ahead of the initial flooding. In either case, to minimize the effect of the death-dealing waters, only an active emergency plan which utilized the alarms as an alerting tool would have been fully effective.

Adequate communications, including teletype, telephone, and radio, should be available to interconnect the agencies responsible for dealing with such an emergency, as the present telephone system became overloaded. Radio ties are essential for moving both data and warnings; the use of the news media for mass dissemination is paramount, and the use of the teletype to communicate among NWS Offices is essential.

DISCUSSION

Certain initial steps have already been taken to improve the flash flood warning system for the Black Hills. A rain gage network of approximately 30 observers has been established. These observers report directly to the National Weather Service Office at Rapid City, with the Rapid City Police Dispatcher as an alternate. Two flash flood alarm systems have been established, one in Rapid Creek upstream from Rapid City and one in Bear Butte Creek upstream from Sturgis. A radio communications system connecting the Civil Defense, Rapid City Police, Ellsworth Air Force Radar, and the Weather Service Office, has been established. After the flood, commercial telephone lines were extensively replaced with more failsafe features. Modern teletype connects the National Weather Service Office at Rapid City to NWS Forecast Centers at Sioux Falls and Kansas City.

RECOMMENDATIONS

1. A local use radar be located at the Rapid City WSO for monitoring weather activity. This is scheduled for December 1976.

2. Other communities within the Black Hills area purchase and use flash flood alarms.

3. Self-help rainfall networks and community action plans be established at other key damage centers in the Black Hills.

4. Communities should hold drills periodically, in cooperation with the NWS, to assure operational readiness.

ACKNOWLEDGMENT

The authors wish to express their appreciation to Mr. Lawrence Hughes, Central Region Headquarters, for his editorial and technical assistance.

REFERENCES

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2. Natural Disaster Survey Report 72-1, Black Hills Flood of June 9, 1972, by U. S. Department of Commerce, National Oceanic and Atmospheric Administration

3. Technical Paper No. 40, Rainfall Frequency Atlas of the U. S., by David M. Hershfield, National Weather Service

Table 1

Black Hills Flash Flood - June 9-10, 1972
Flash Flood Network - Cumulative Precipitation Totals

Drainage	Observer	1600	1700	1800	1900	2000	2100	2200	2300	Mid-nite	Storm Total
Rapid Creek	Pfisterer	T	T	0.3	1.0	6.0	8.5	10.5	11.5	12.0	12.8
	Gunderson	T	T	0.1	1.5	2.5	4.5	5.5	5.8	6.0	6.3
	Lee	T	T	0.3	2.0	4.0	8.0	9.0	9.6	9.8	10.0
	Simpson	0.01	0.05	0.3	1.7	2.5	3.9	5.7	6.3	6.6	7.07
	Kennison	0.05	0.08	0.1	0.5	0.6	0.7	0.9	1.2	1.4	1.72
	Buskala	0	0	T	0.08	0.2	0.3	0.4	0.7	1.0	1.58
	Dwyer	0	0	T	0.1	0.2	0.3	0.6	1.0	1.8	1.8
	Scholt	0	0	0	0	T	0.1	0.3	0.6	0.9	1.3
Box Elder Creek	Merchen	T	0.2	0.6	2.4	3.2	5.8	6.1	6.2	6.4	7.5
	Nemo (Ranger Sta.)	0.1	0.1	1.5	4.0	6.0	9.5	11.5	12.5	13.5	14.0
	Salmon	T	T	T	0.2	3.5	6.2	6.3	6.8	7.5	7.5
Spring Creek	Wheel Inn	T	T	1.2	2.8	8.0	11.3	11.8	12.0	12.0	12.0
	Barker	T	T	T	1.8	3.0	5.0	5.1	5.1	5.1	5.14
	Bear Mountain	0	0	0	T	0.1	1.2	2.0	2.0	2.0	2.0
Battle & G. Coolidge Creeks	Mt. Rushmore	0	0.6	1.0	3.0	5.8	6.2	6.2	6.3	6.3	6.30
	Custer St. Park	T	0.2	0.5	1.5	2.4	3.0	3.5	3.8	3.9	3.9
	Mt. Coolidge	T	T	0.2	1.0	1.8	2.0	2.6	3.0	3.2	3.2
Southern Hills	Kistler	0	T	T	T	1.7	4.0	4.0	4.0	4.0	4.0
	*Wind Cave	0.02	0.04	0.04	0.04	0.04	0.04	0.3	2.2	2.4	2.51
	VA-Hot Springs	0	T	T	T	T	T	T	T	T	1.31
	Evans	0	0	T	T	T	0.1	0.1	0.1	0.2	1.3
	Tepee (Ranger Sta.)	0	0	0	0	0	0	T	T	T	0.96
	Cold Brook Res.	0	T	T	T	T	T	T	0.1	0.1	1.4

Note: Times are in Mountain Daylight Savings Time.

* NWS recorder

Table 1 (Cont.)
Black Hills Flash Flood - June 9-10, 1972
Flash Flood Network - Cumulative Precipitation Totals

Drainage	Observer	1600	1700	1800	1900	2000	2100	2200	2300	Mid-nite	Storm Total
Northern Hills	KDSJ Deadwood	0	0.2	0.5	1.2	1.5	1.8	1.8	1.8	1.8	2.03
	Larive	0	0.1	0.2	1.0	1.2	1.5	1.5	1.5	1.5	1.82
	Ball	0	T	T	T	T	0.1	0.1	0.2	0.4	0.5
	Stafford	0	0	0	T	T	0.1	0.1	0.1	0.5	1.0
	Lillehaug	0	0	0	T	T	0.1	0.2	0.2	0.4	1.0
	Steffen	0	0	0	0.1	0.1	0.2	0.4	0.6	0.9	1.50
	KBFS Belle Fourche	0	0	0	T	T	T	0.1	0.1	0.2	1.69
Bear Butte Creek	Herbert	0.1	1.5	4.0	5.0	7.0	7.5	7.5	7.5	8.0	8.0
	VA-Ft. Meade	0.3	0.5	0.5	1.5	1.7	1.8	2.0	3.5	4.0	4.83
Elk Creek	Lundstrom	0.1	0.4	1.0	1.8	2.0	3.8	4.5	5.0	6.5	7.0

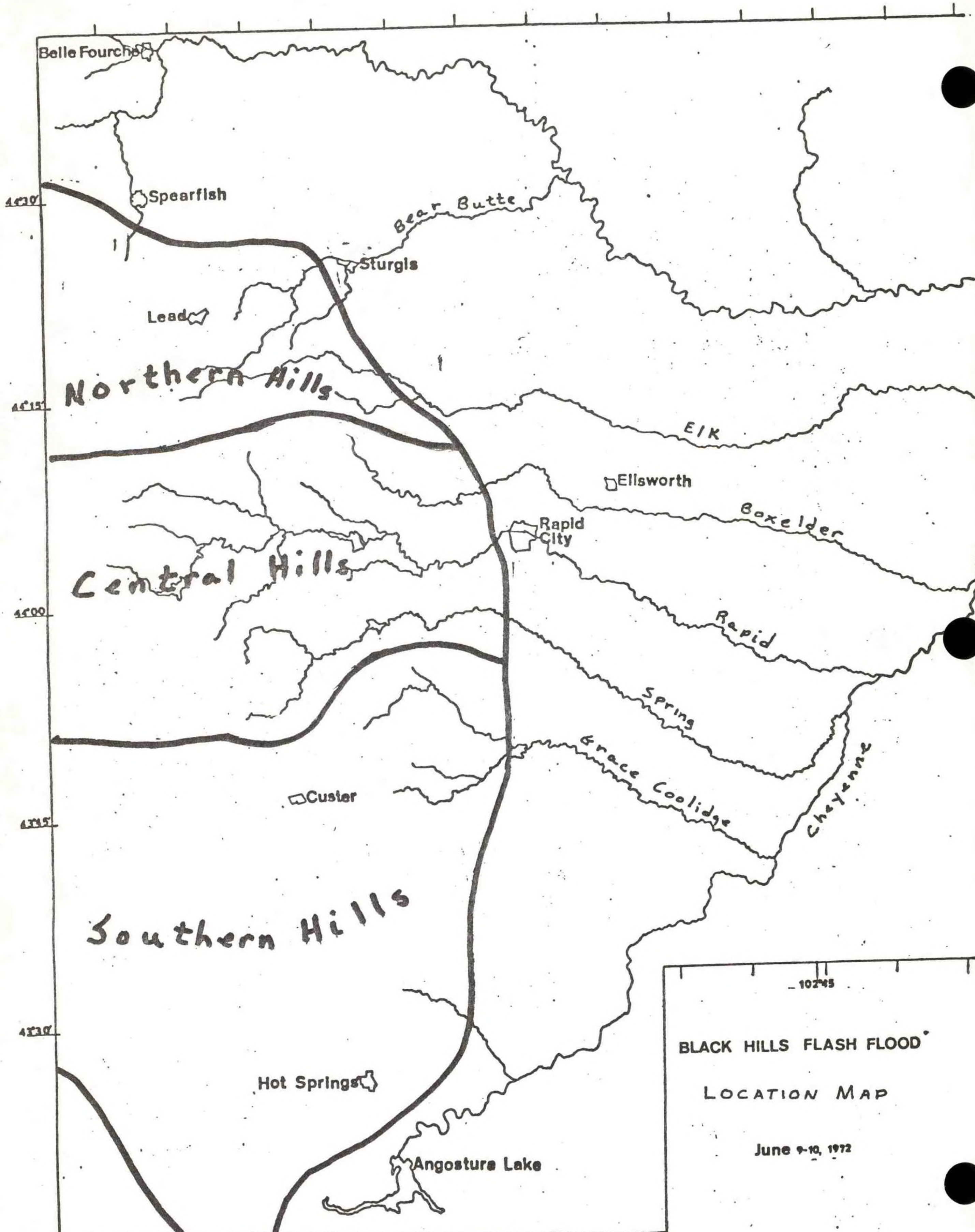

Belle Fourche
Spearfish
Bear Butte
Sturgis
Lead
Northern Hills
Elk
Central Hills
Ellsworth
Rapid City
Boxelder
Rapid
Spring
Grace Coolidge
Cheyenne
Custer
Southern Hills
Hot Springs
Angostura Lake
44°30'
44°15'
44°00'
43°45'
43°30'
103°45'
103°30'
103°15'
103°00'
102°45'
BLACK HILLS FLASH FLOOD
LOCATION MAP
June 9-10, 1972

Figure 1

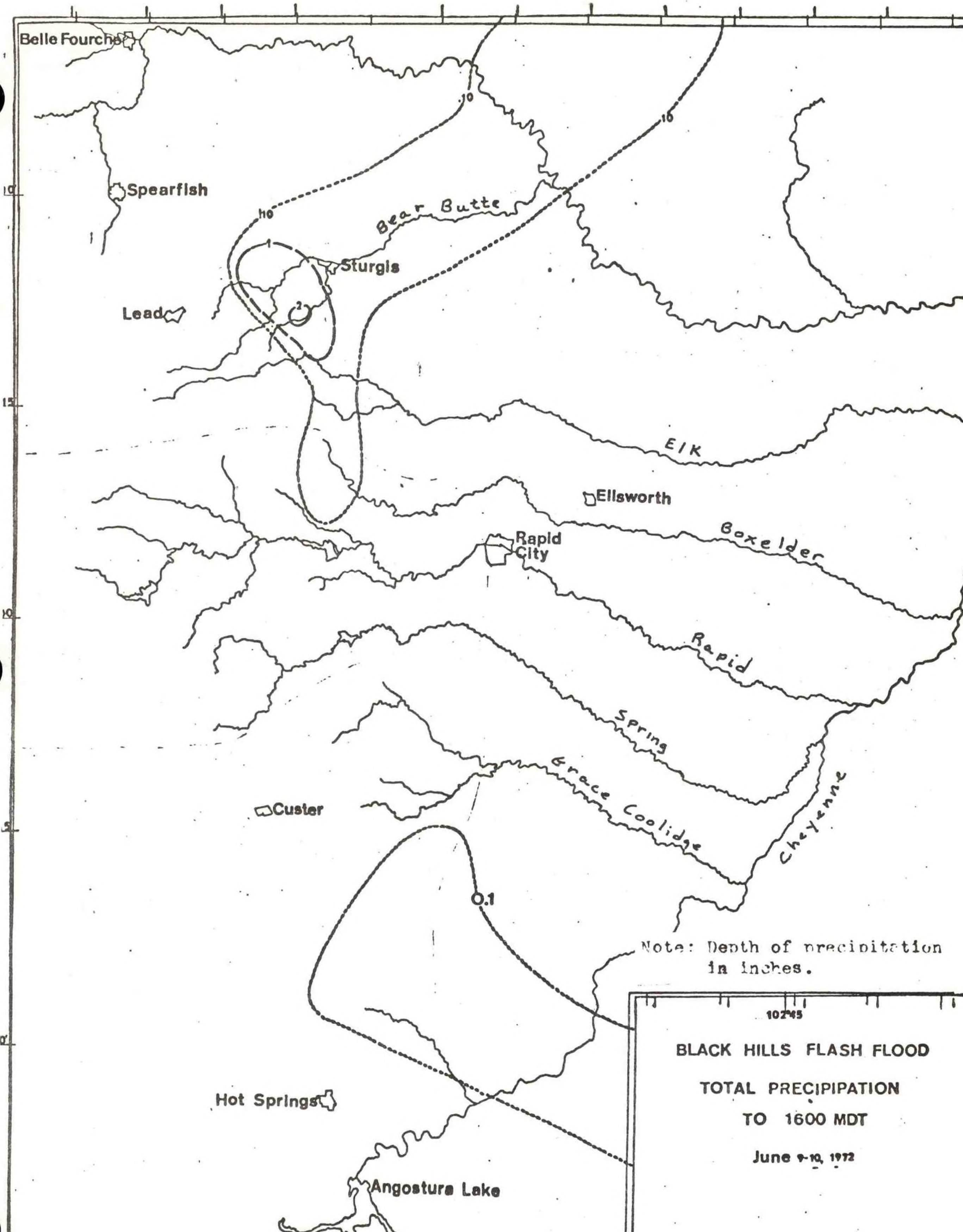
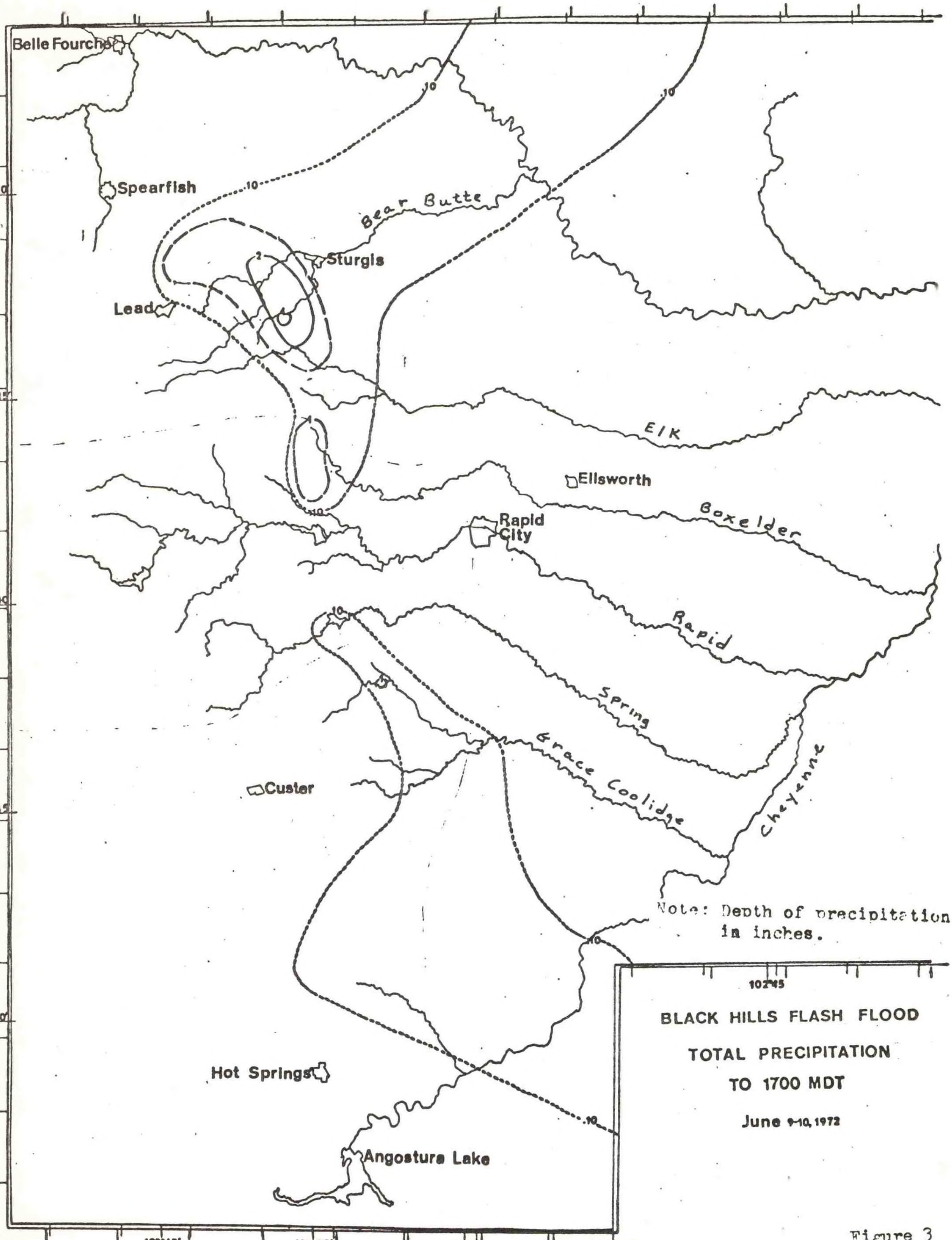

Belle Fourche
Spearfish
Bear Butte
Sturgis
Lead
Elk
Ellsworth
Rapid City
Boxelder
Rapid
Spring
Grace Coolidge
Cheyenne
Custer
0.1
Note: Depth of precipitation in inches.
Hot Springs
Angostura Lake
BLACK HILLS FLASH FLOOD
TOTAL PRECIPIPATION
TO 1600 MDT
June 9-10, 1972
103°45′
103°30′
103°15′
103°00′
102°45

Figure 2



Note: Depth of precipitation in inches.

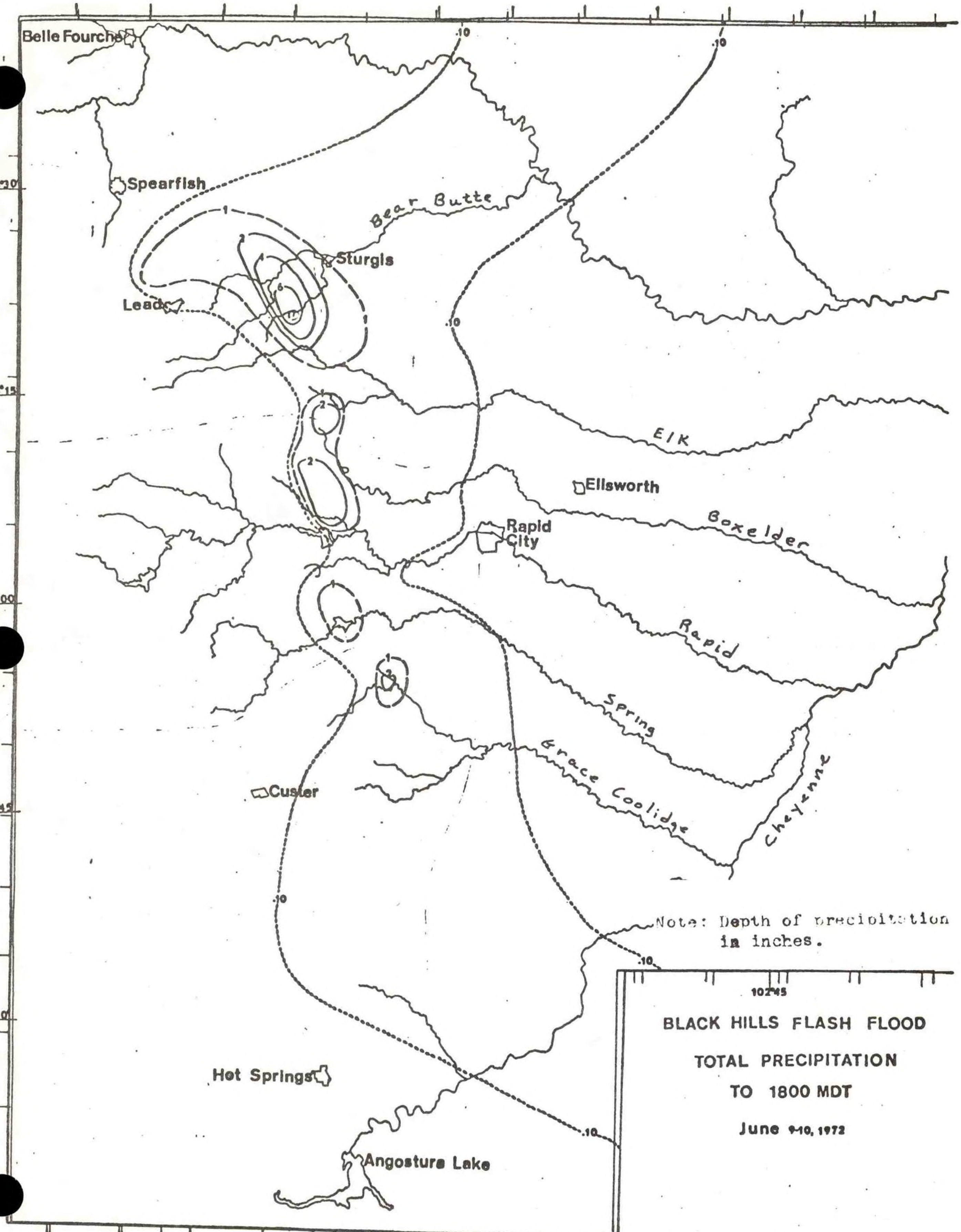
BLACK HILLS FLASH FLOOD

TOTAL PRECIPITATION

TO 1700 MDT

June 9-10, 1972

Figure 3



BLACK HILLS FLASH FLOOD

TOTAL PRECIPITATION

TO 1800 MDT

June 9-10, 1972

Figure 4

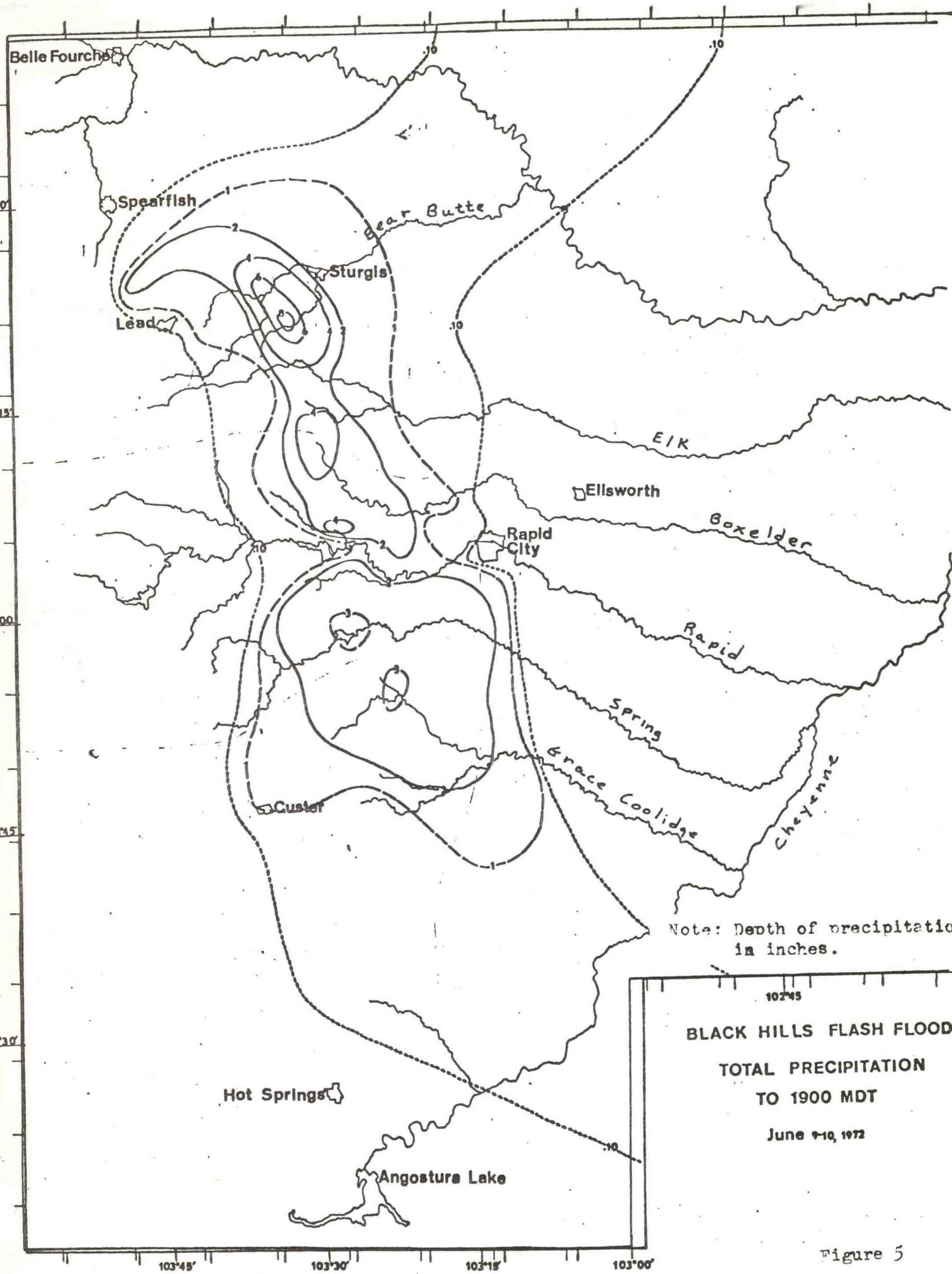
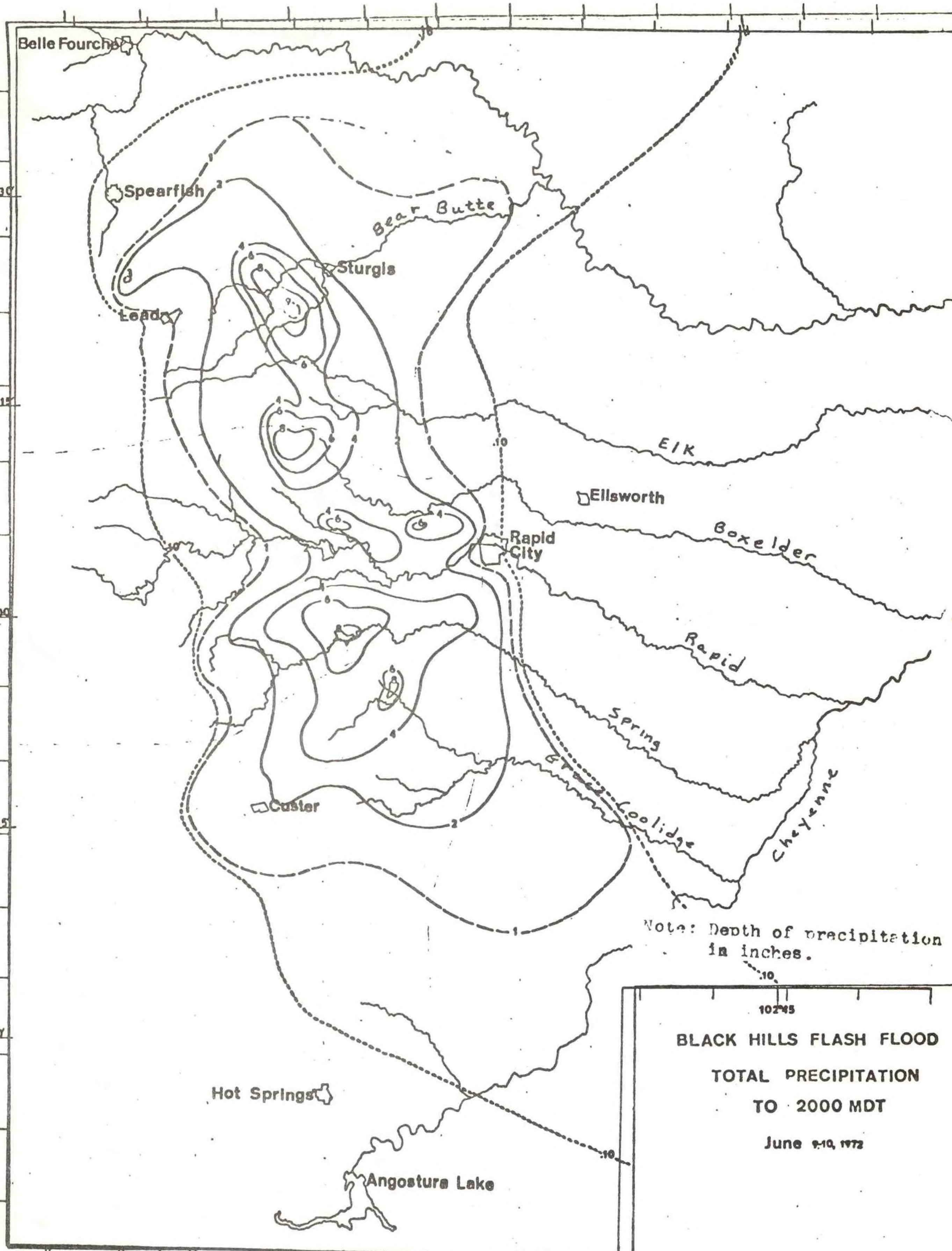

Belle Fourche
Spearfish
Bear Butte
Sturgis
Lead
Elk
Ellsworth
Boxelder
Rapid City
Rapid
Spring
Grace Coolidge
Cheyenne
Custer
Hot Springs
Angostura Lake
103°45'
103°30'
103°15'
103°00'
102°45'
Note: Depth of precipitation in inches.
BLACK HILLS FLASH FLOOD
TOTAL PRECIPITATION
TO 1900 MDT
June 9-10, 1972

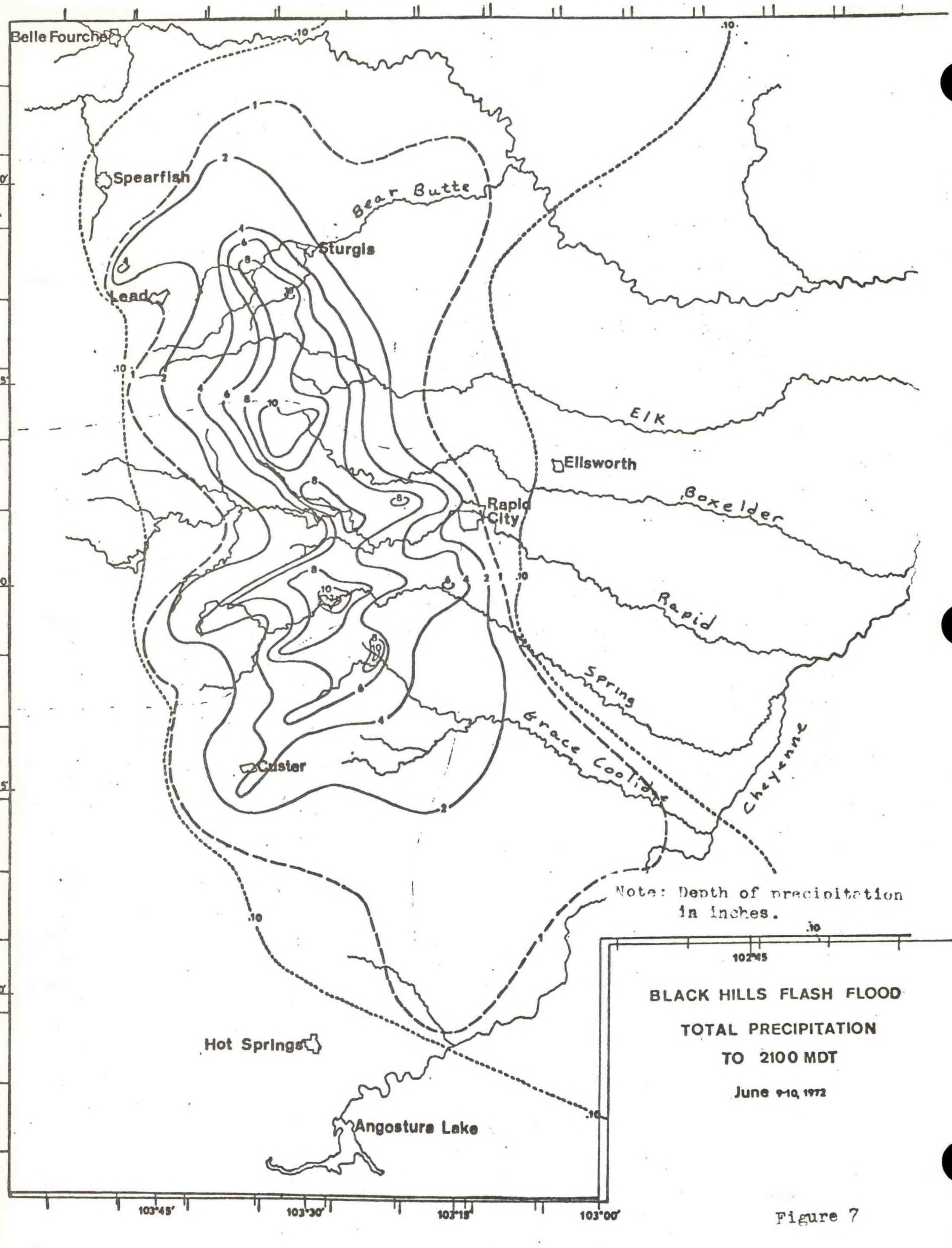
Figure 5



Note: Depth of precipitation in inches.

BLACK HILLS FLASH FLOOD
TOTAL PRECIPITATION
TO 2000 MDT
June 9-10, 1972

Figure 6



BLACK HILLS FLASH FLOOD

TOTAL PRECIPITATION

TO 2100 MDT

June 9-10, 1972

Figure 7

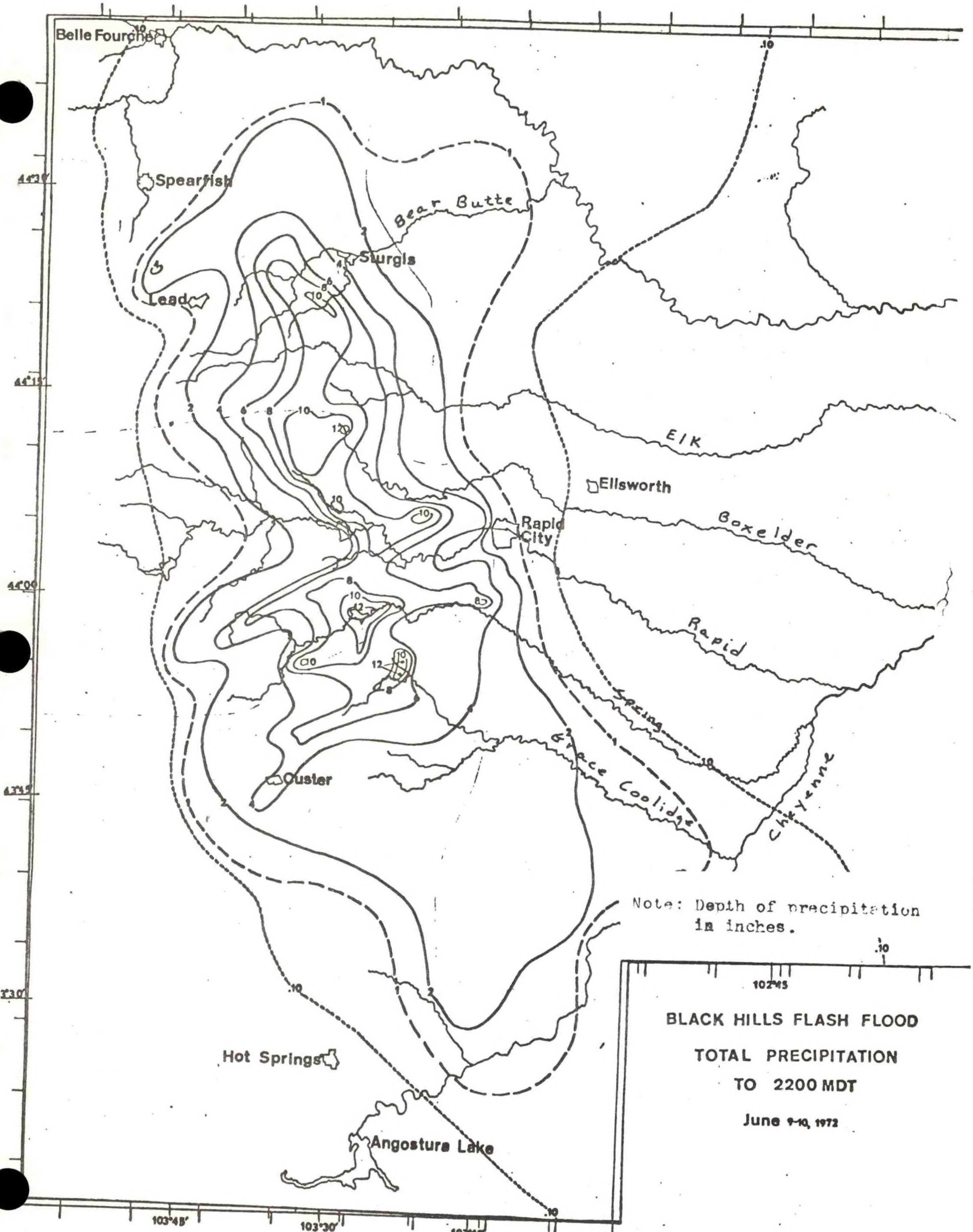
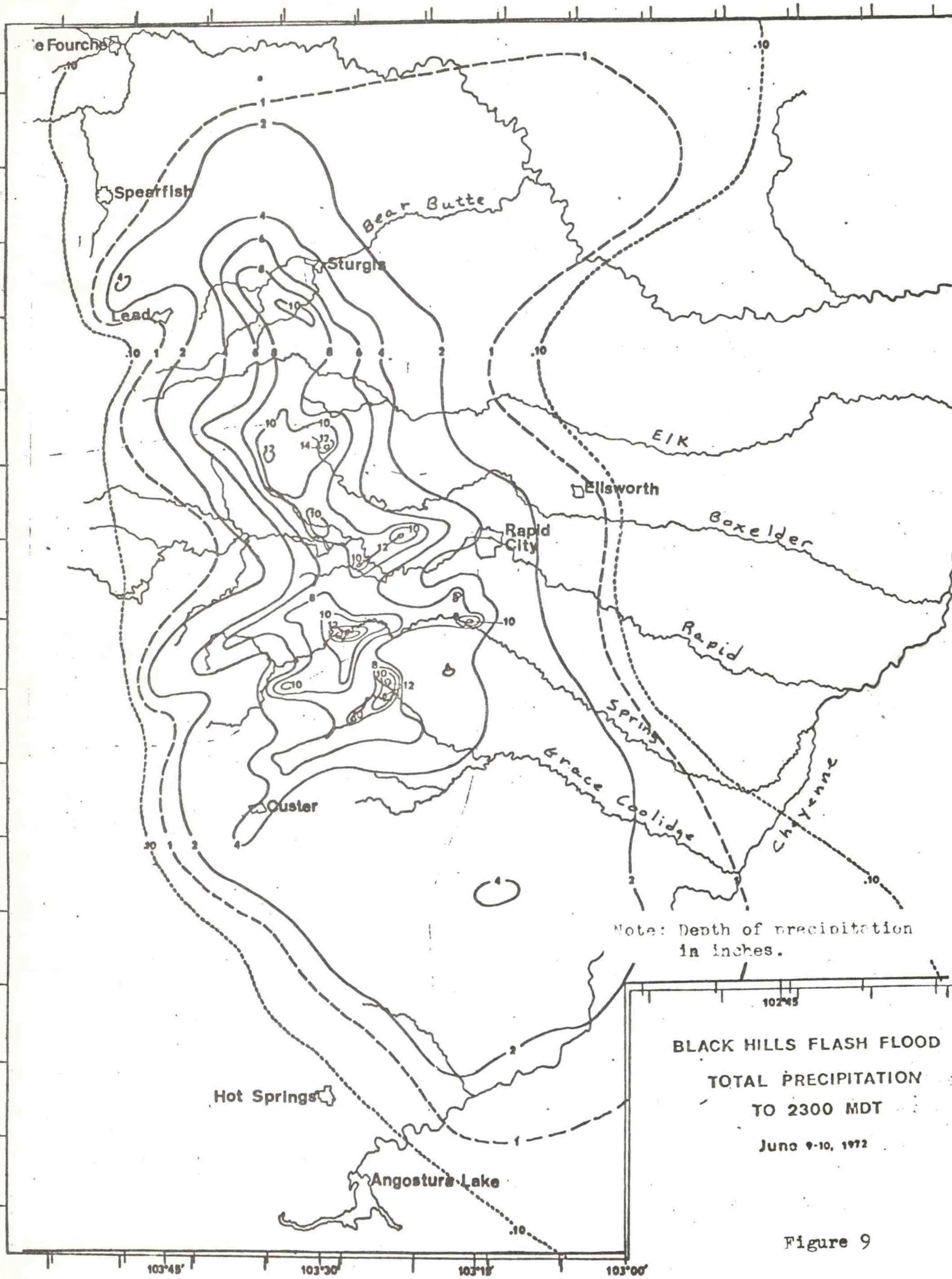

Belle Fourche
Spearfish
Bear Butte
Sturgis
Lead
Elk
Ellsworth
Rapid City
Boxelder
Rapid
Spring
Grace Coolidge
Cheyenne
Custer
Hot Springs
Angostura Lake
44°30'
44°15'
44°00'
43°45'
43°30'
103°45'
103°30'
103°15'
103°00'
102°45'
Note: Depth of precipitation in inches.
BLACK HILLS FLASH FLOOD
TOTAL PRECIPITATION
TO 2200 MDT
June 9-10, 1972

Figure 8



Note: Depth of precipitation in inches.

BLACK HILLS FLASH FLOOD
TOTAL PRECIPITATION
TO 2300 MDT
June 9-10, 1972

Figure 9

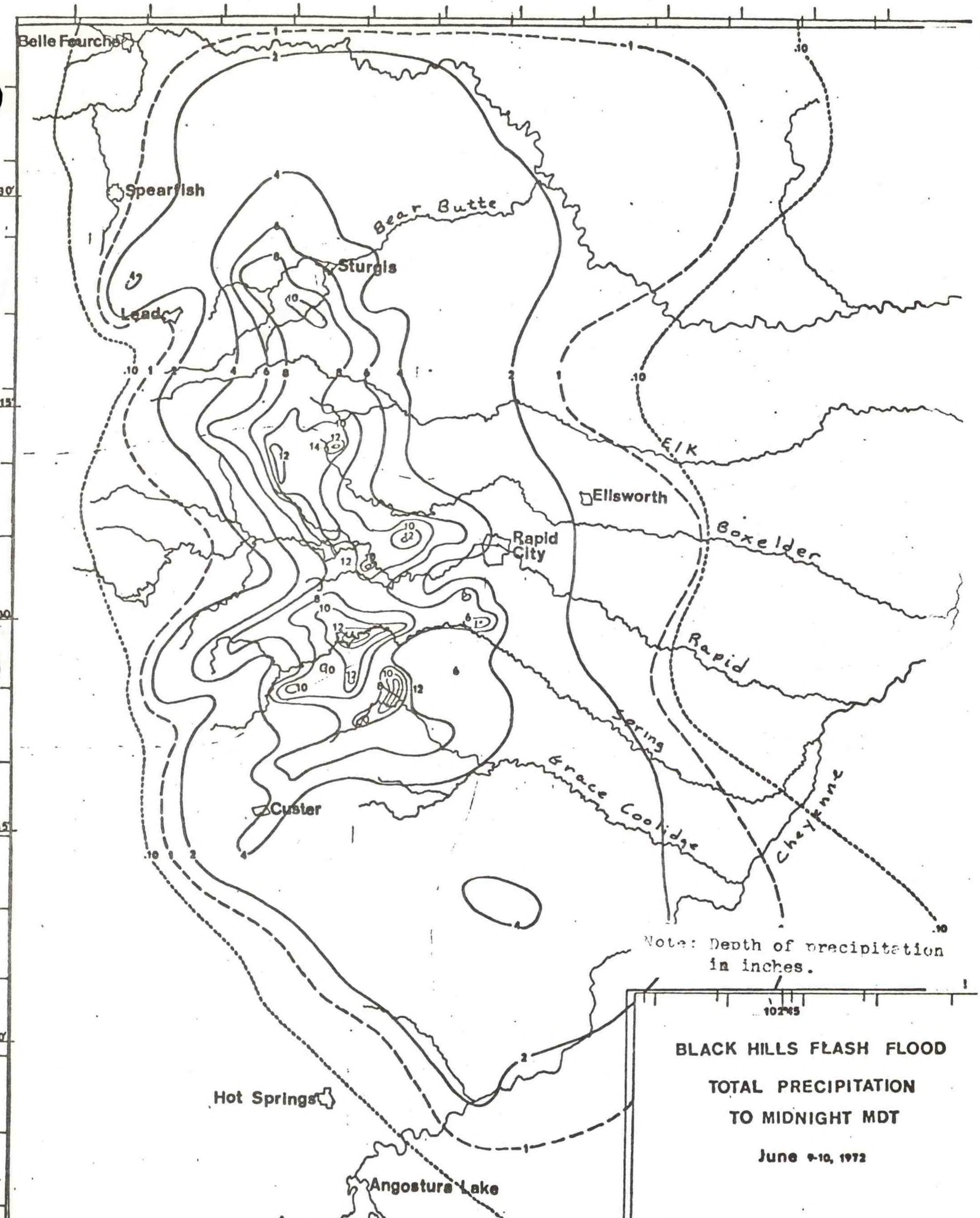

Belle Fourche
Spearfish
Bear Butte
Sturgis
Lead
Elk
Ellsworth
Rapid City
Boxelder
Rapid
Spring
Grace Coolidge
Cheyenne
Custer
Hot Springs
Angostura Lake
44°30'
44°15'
44°00'
43°45'
43°30'
103°45'
103°30'
103°15'
103°00'
102°45'
Note: Depth of precipitation in inches.
BLACK HILLS FLASH FLOOD
TOTAL PRECIPITATION
TO MIDNIGHT MDT
June 9-10, 1972

Figure 10

(continued from front inside cover)

NWS CR 48 Manual of Great Lakes Ice Forecasting. C. Robert Snider - December 1971 (COM-72-10143)

NWS CR 49 A Preliminary Transport Wind and Mixing Height Climatology St. Louis, Missouri Donald E. Wuerch, Albert J. Courtois, Carl Ewald, Gary Ernst June 1972 (COM-72-10859)

NWS CR 50 An Objective Forecast Technique for Colorado Downslope Winds Wayne E. Sangster December 1972 (COM-73-10280)

NWS CR 51 Effect on Temperature and Precipitation of Observation Site Change at Columbia, Missouri March 1973 (COM-73-10734)

NWS CR 52 Cold Air Funnels. Jack R. Cooley and Marshall E. Soderberg September 1973 (COM-73-11753)

NWS CR 53 The Frequency of Potentially Unfavorable Temperature Conditions in St. Louis, Missouri October 1973 Warren M. Wisner

NWR CR 54 Objective Probabilities of Severe Thunderstorms Using Predictors from FOUS and Observed Surface Data (COM 74-11258) Clarence L. David May 1974

NWS CR 55 Detecting and Predicting Severe Thunderstorms Using Radar and Sferics John V. Graff and Duane C. O'Malley June 1974 (COM-74-11335)

NWS CR 56 The Prediction of Daily Drying Rates Jerry D. Hill Nov. 1974 (COM-74-11806)

NWS CR 57 Summer Radar Echo Distribution Around Limon, Colorado Thomas D. Karr and Ronald L. Wooten Nov. 1974 (COM-75-10076)

NWS CR 58 Guidelines for Flash Flood and Small Tributary Flood Prediction Lawrence A. Hughes and Lawrence L. Longsdorf October 1975 (PR247569/AS)