THE BLACK HILLS (South Dakota) FLOOD OF JUNE 1972: IMPACTS AND IMPLICATIONS

by Howard K. Orr

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Abstract

Rains of 12 inches or more in 6 hours fell on the east slopes of the Black Hills the night of June 9, 1972. Resulting flash floods exacted a disastrous toll in human life and property. Rainfall and discharge so greatly exceeded previous records that recurrence intervals have been presented in terms of multiples of the estimated 50- or 100-year event. Quick runoff was produced in the heaviest rainfall areas regardless of hydrologic condition. Flood sources included all major geologic and soil types and practically all land uses in the Black Hills. The highest measured peak runoff per unit area came from a 7-square-mile drainage, all on sedimentary formations, the upper portion of which burned over in 1936, but which is now well vegetated, apparently stable, and in good hydrologic condition. Greatest damage occurred where man-origin debris piled up against bridges, highways, homes, and other improvements.

Keywords: Floods, watershed management, hydrologic data, flash floods, storm runoff, record rainfall.

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The Black Hills (South Dakota) Flood of June 1972: Impacts and Implications

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[1]*Research reported here was conducted at Station's Research Work Unit at Rapid City, in cooperation with South Dakota School of Mines and Technology; central headquarters is maintained at Fort Collins in cooperation with Colorado State University.*

Contents

	Page
The Storm	1
Hydrologic Condition	2
Antecedent Rainfall and Moisture Conditions	3
Flood Peaks	3
Experimental Watershed Response	8
Summary and Conclusions	12
Literature Cited	12

The Black Hills (South Dakota) Flood of June 1972: Impacts and Implications

Howard K. Orr

The Black Hills storm and flash floods of June 9, 1972 will long be remembered — not only for the tragic loss of life and property but also as a hydrologic event of such magnitude and rarity that the recurrence interval is more than ordinarily problematical. It also has provided a unique opportunity for land managers and researchers to study and observe environmental and land management responses and implications under the stress of a rare storm event.

The purpose of this report is to examine and describe physical factors and relationships involved in the production of excessive flood flows from a number of Black Hills drainages on June 9, including the Sturgis Experimental Watersheds, and to postulate supporting theory.

The Storm

The storm was concentrated in an area about 40 miles long by 20 miles wide. The area includes downstream portions of nearly all the watersheds draining east out of the Black Hills from Bear Butte Creek on the north to Iron Creek (tributary to Battle Creek) on the south (fig. 1).

According to recording gages on the Sturgis Experimental Watersheds (in the northern part of storm area, fig. 1), precipitation began at about 1450 (m.s.t.), and gradually built up to a maximum intensity of nearly 6 inches per hour about 1630. Rain continued steadily but at gradually declining intensity until between 0200 and 0230 on June 10.

At the Black Hills Experimental Forest, about 15 miles south and slightly west, the storm began between 1600 and 1615. Less rain fell (total was 5.82 inches in one gage) than either to the northeast or southeast, but rainfall ended at about the same time (by 0230 on June 10). At Rochford, about 5 miles further southwest, total storm precipitation was only 1.77 inches.

At Pactola Dam, about 12 airline miles east of the Experimental Forest and slightly further south (about halfway along the north to south axis of the storm but still slightly west of the approximate north-south line of heaviest precipitation cells), light rainfall started between 1400 and 1500. Maximum rain fell between 2000 and

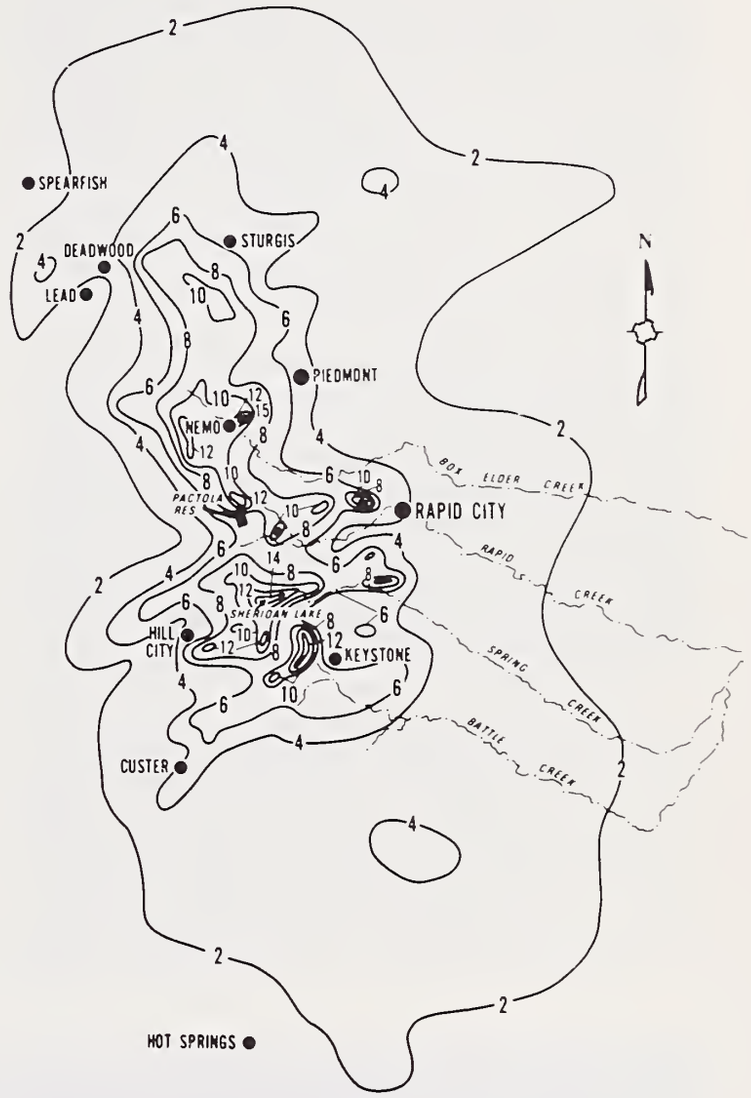

Figure 1.--Total rainfall during evening of June 9 into morning of June 10, 1972 (U. S. Department of Commerce 1972).

2100 (1.83 inches) and by midnight 6.86 inches had accumulated. The maximum 6-hour precipitation, 6.30 inches, fell between 1700 and 2300. The storm ended there between 0200 and 0300, after 7.03 inches of rain fell.

The best available information from locations further east, and nearer the apparent center of heavy precipitation cells in the Rapid Creek drainage, indicates rainfall started about 1900 and accumulated to 13 inches by 0700 on

June 10. Nearly 12 inches of rain fell in 6 hours (about 1930 June 9 to 0130 June 10).

Putting these facts together, the heavy rainfall obviously started earliest in the northern Hills. As separate cells fed in on strong east and southeast winds, the storm built to larger and larger proportions as it spread southward.

H. J. Thompson, Office of Hydrology, National Weather Service, described the general meteorological circumstances in which the storm developed (Thompson 1972, p. 163). Strong low-level winds from the east forced moist air upslope on the east side of the Hills. Sustained orographic effect helped force the air to rise and cool as it fed in from the east. At the same time, midlevel moisture was impinging from the south. Another especially significant contributing factor was the unusually light wind at higher atmospheric levels which did not disperse the moisture or move the thunderstorms eastward as rapidly as usual. The result was repeating thunderstorms in an apparently unusual combination of meteorological conditions. Under "reverse shear" conditions (St. Amand et al. 1972), an almost continuous line of thunderstorms formed and remained quasi-stationary over the eastern Hills for as long as 6 to 8 hours, whereas the more ordinary thunderstorm moves out in 1 to 2 hours.

Thompson (1972) asserts that the recurrence interval of such an extraordinary event cannot be computed with any degree of accuracy, but adds in effect that the measured rainfall was in an amount **unlikely** to occur more than once in several thousand years. In a report from the National Oceanic and Atmospheric Administration, (U.S. Department of Commerce 1972) it is stated that the 6-hour rainfall averaged about four times the amount to be expected once every 100 years.

Hydrologic Condition

In all of the most heavily flooded watersheds examined, there was consistent evidence of surface runoff from slope areas even where there were no clearly visible drainage patterns, and further upslope than in the case of more ordinary storms. The consistency of this kind of evidence, irrespective of site, is a key factor in analyzing the production of the flood flow. Surface runoff occurred from all types of areas, including dense forest and well-grassed slopes. In other words, classification in "good" hydrologic condition did not in this case preclude the production of excessive surface runoff. Surface runoff is here differentiated from overland flow in the sense that surface runoff was evident in shallow depressions of microtopography not ordinarily observed, but there was little evidence of sheet movement of water that resulted in sheet movement of soil or its protective cover of litter and humus. This is a generalization that applied across forest types and densities, other vegetation types, slopes, topography, parent materials, geology, and soils. Thick forest floor, where present, apparently acted as an efficient water conveyance system, but without displacement except where water was diverted or concentrated by stones, roots, or other obstacles (fig. 2). The storm and runoff produced were obviously of a magnitude that plays a major role in shaping topography as we see it today.

Figure 2.--Water apparently flowed through this thick forest floor without disturbance until it was diverted or ponded by stones. When this happened, the litter floated and moved downslope (right to left), leaving a small spot of bare mineral soil. Many such spots could be seen on some slopes.

Antecedent Rainfall and Moisture Conditions

Precipitation had not been excessive, January through May, at any of the continuous measuring stations in the Hills. Distributions by months were near average, and totals for representative stations varied from slightly below to slightly above average (table 1). Temperatures had not been extreme. In short, there were no apparent clues leading up to the extreme storm and flood event of June 9-10. Apparently it was a random event, neither preceded nor followed by distinctive extremes.

On the other hand, the topography and location of the Black Hills in relation to the nature and movement of major weather systems would appear to make the area a more likely prospect for development of the kind of storm that occurred on June 9 than most parts of the continental United States. In other words, atypical behavior of meteorological elements, such as the low-velocity winds aloft which occurred over the Hills on June 9, might, in combination with other factors, be expected to evoke a more violent reaction than in other areas.

By June 9 evapotranspiration usually exceeds precipitation input, and soil moisture storage deficit is increasing. Before the end of May, soon after the start of the growing season, streamflow is usually declining while precipitation increases to maximum in June. Precipitation and flow were, in general, following the usual patterns up to June of 1972. Some stations received practically no precipitation in the week preceding June 9, while others (Pactola Dam in table 1) received relatively large amounts as late as June 4.

Flooding occurred from watersheds in all of the major geologic types in the Hills. Though the nature of flooding was clearly influenced by soils and geology, precipitation amounts and intensities were the primary factor. Type of vegetation and biomass per unit area (relative evapotranspiration) no doubt also had less effect than they would have had later in the growing season. Effects of differential evapotranspiration would not yet have accumulated to as great a degree.

Flood Peaks

Peak unit area discharges (as computed from USGS measurements)[2] do not coincide with ranking of mean area rainfall (table 2). The highest mean area rainfall (of the watersheds computed) occurred on Este Creek, a 6-square-mile tributary of Boxelder Creek. Parent material is primarily metamorphic. Though the unit area discharge is no doubt among record highs for watersheds of comparable size in the entire United States, it was not the highest measured.

[2]*Data obtained from Rapid City Subdistrict Office, Water Resources Division, U. S. Geological Survey.*

Table 1.--Precipitation at selected stations (from January 1, 1972), prior to the June 9, 1972 Black Hills storm and flood, in comparison with average

Time period	Sturgis No. 2	Experiment Forest Arboretum	Pactola Dam	Rapid City
	Inches			
January	1.37	0.96	0.21	0.34
February	1.01	.76	.31	.41
March	1.32	1.07	.67	.52
April	4.11	2.62	2.24	2.45
May	5.48	4.24	2.89	3.19
June 1-8	.13	.93	3.91	.34
Sum through May 1972	13.29	9.65	6.32	6.91
Long-term average through May	14.56	11.12	8.14	6.48
Sum through June 8, 1972	13.42	10.58	10.23	7.25

Peak unit area discharge was practically the same from Victoria Creek (tributary to Rapid Creek) as from Este Creek, but the recurrence interval is much greater, although parent material is also metamorphic and computed mean rainfall was considerably less. Reasons are not apparent, although they may be related to the method used by U.S. Geological Survey (USGS) to calculate estimated 50-year discharge (Patterson 1966). The recurrence intervals in table 2 are expressed in terms of multiples of the 50-year peak discharge as computed by USGS.

The highest per-unit-area discharge, and by far the greatest recurrence interval, occurred from Cleghorn Canyon (Wild Irishman Creek), tributary to Rapid Creek at the west edge of Rapid City (table 2). Area average rainfall was not the highest, though as much as 13 inches reportedly fell in the middle to lower reaches of the watershed. One distinctively different physical characteristic of the watershed (compared with others listed) is that it is almost entirely on sedimentary formations, Deadwood sandstone and Pahasapa limestone in upper reaches to sandstones with interbedded limestones and red shales of the Minnelusa formation at the junction with Rapid Creek. Also, the upper portion of the watershed burned in September 1936 (the 760-acre Johnston fire).

Much of this old burn has not come back to pine (figs. 3, 4, 5). Aspen and birch are now abundant on the more moist slopes and in stream bottoms. Most of the remaining area is well vegetated with herbaceous species and shrubs. There is considerable private land and residential development in the lower reaches (Cleghorn Canyon). There was evidence of runoff from all types of areas, but slope damage was minimal, even on the kind of steep south-facing slope shown in figure 3. This is one of the slopes bared in the 1936 fire. Figure 6 is a closeup of the left portion of this same slope. Pine reproduction is sparse, but the site is well stabilized by herbaceous vegetation. One landslide, visible in figure 3 and shown closeup in figure 7, occurred on this slope. The slide was not large, about 32-35 feet long and about half as wide, and apparently resulted from a combination of water concentration from up-

Table 2.--Peak discharge and area average precipitation of selected Black Hills watersheds, flood of June 9, 1972 (in order of area average rainfall as computed by Rocky Mountain Forest and Range Experiment Station)

Drainage	Peak discharge		Recurrence interval[2]	Area average rainfall	Area
	C.f.s.[1]	C.s.m.		Inches	Sq.Mi.
Este Creek (near Nemo)	6,620	1,078	6.0	10.69	6.14
Deer Creek at campground 8 miles west of Rapid City	3,530	825	23	9.96	4.28
Gordon Gulch (near Sheridan Lake)	([3])			9.42	[4]3.15
Horse Creek (at Sheridan Lake)	1,830	181	6.7	9.09	10.1
Deadman Creek (at Sturgis)	4,740	797	4.5	8.78	5.95
Battle Creek (at Keystone)	10,800	794	8.8	8.34	13.6
Little Elk Creek (at Elk Creek)	([3])			8.04	[4]19.7
Cleghorn Canyon (Wild Irishman Creek)	12,600	1,813	61	7.87	6.95
Prairie Creek (at Rapid Creek)	([3])			7.21	14.0
Grizzly Bear Creek (near Keystone)	6,230	676	6.4	7.11	9.22
Victoria Creek	6,860	1,022	35	7.10	12.8
Iron Creek	([3])			6.68	16.3

[1] From USGS measurement by slope-area method.
[2] Multiple of 50-year peak discharge as computed by USGS.
[3] Not measured by USGS but flooding severe.
[4] Measurement from Rocky Mountain Forest and Range Experiment Station.

Figure 3.--A south-facing slope in the upper reaches of Wild Irishman Creek (Cleghorn Canyon). The area burned over 36 years ago, and much of it has not come back to pine forest. The rock outcrop is Pahasapa limestone, with darker Deadwood sandstone outcrop (D) about 1/4 of the way downslope. Vegetation is well established and the soils are stable. S indicates slide area closeup in figure 7.

Figure 5.--Valley bottoms in the old 1936 Johnston Fire (760 acres) were invaded by aspen and birch. These species also invaded on the more moist north-facing slopes, as shown in figure 4. This view is from the top of the ridge in figure 3, looking almost directly east toward Rapid City in the far background.

Figure 4.--Looking back southwest from high on the slope in figure 3. One of the main tributary channels of Wild Irishman shows in the lower portion of the photo, and flood-deposited material is visible (arrow), together with an old road.

Figure 6.--Looking mostly west (left) across the left portion of the slope in figure 3. Vegetation is a well-established mixture of grasses and forbs. Soils are stable for the most part.

Figure 7.--To the right of the area in figure 6 is this small flow slide about 30 to 35 feet long and about half as wide. It was the only visible area on the entire slope where any appreciable amount of soil was displaced.

slope and liquefaction of shallow, stony soil on bedrock (possibly upper Deadwood sandstone) which was near but did not intersect the slope plane. The flow slide material moved all the way downslope to the main channel, and was no doubt the source of some of the water-deposited material in the lower portion of figure 4. Vegetation was not stripped from the slope in the slide path, however.

Some additional channel cutting and deposition, associated mainly with old roads, was evident in upper reaches. Practically all of that debris was intercepted and filtered out by shrub and herbaceous vegetation in open meadow areas such as that shown in figure 4. Severe channel cutting and erosion became increasingly evident further downstream in the narrower, more constricted lower canyon.

Much debris (including tree branches, limbs, and roots) lodged on the upstream side of trees (fig. 8). Several such deposits were examined closely. None of the debris originated as logging slash, as was at first thought. No axe or saw cuts were visible. The debris obviously came from trees close enough to the channel that record high flow literally tore them out and stripped them of limbs and foliage. Ring counts of some of the trees deposited in debris piles indicate they were 80-85 years old. In other words not since at least 1890 had any combination of storms, fire, timber stand conditions, grazing, or other land use produced such large floods. In Boxelder, and undoubtedly in other drainages, trees were downed that had been in place more than 100 years—long before settlement by white man.

Figure 8.--Woods debris 8 to 10 feet high against the upstream side of trees in Wild Irishman (Cleghorn Canyon), downstream from the areas shown in figures 3 to 7. Here the channel has broadened and there is less gradient, but it steepens and narrows again before joining Rapid Creek at the west edge of Rapid City.

This conclusive evidence negates serious speculation that this rare flood event may indicate general environmental degradation. Severity of consequences of the flooding, though none the less tragic, were in direct proportion to man's encroachment on stream channels and floodways. Also, man-origin debris no doubt caused more environmental deterioration or damage than any **a priori** upstream land use or management. Similar consequences, though less spectacular and without the great loss of life, occurred in 1962 and earlier.

Another watershed of particular interest is Grizzly Bear Creek, which drains from a research natural Area on the Precambrian granite of the Harney Range (fig. 9). This area has had little disturbance of any kind in many years. Yet the stream flooded inside as well as outside the boundary of the Natural Area, enough to drastically erode and alter some channel sections. Litter piles and associated upslope bare spots again attested to the production of significant surface runoff from a microtopography that would not ordinarily be noticed. There is evidence, however, that watersheds in this general area have low storage capacity due to coarse-textured parent material, and an obvious history of flooding, even during much lesser storms.

A large proportion of the most heavily flooded watersheds was in areas of metamorphic parent material of the general type shown in figure 10. Material of this type characteristically breaks down to loamy soils, often quite stony. The kind of erosion shown in figure 11 is typical of what happened to cut slopes in residual soil. Fines were washed out, leaving stones protruding. Slumping of steep road cuts was not uncommon in this kind of situation.

Figure 9.--Channels eroded severely, even in areas that have received little use in many years. Shown here is Grizzly Bear Creek, draining out of the Pine Creek Natural Area in the Harney Range. Parent rock is granite, which here weathers to a coarse-textured shallow soil with low storage capacity.

Figure 10.--Characteristic metamorphic parent material in part of storm area that received some of the heaviest rainfall. Flooding from a drainage no more than 1 mile long caused this channel damage, which was on the outside of a turn.

Experimental Watershed Response

The best quality overall precipitation and flow records that we know of are from the three Sturgis Experimental Watersheds—217, 89, 190 acres—in the northeastern Black Hills. These records are used to illustrate flow timing and distribution in relation to precipitation. The total volumes of flood flow cannot be determined, however, because of debris accumulations which practically covered the stations during recession (figs. 12, 13, 14). Accumulation apparently started at about the same time as the peaks occurred or soon after. The stations were not structurally damaged, however, despite the force of debris and peak flow about twice the design discharges computed for 1.87 inches of rain in 1 hour (table 3). Hence, the flume hydrographs are available from start of rise to the approximate peaks at all three stations.

Table 3.--Rainfall by individual gages at the Sturgis Experimental Watersheds, June 9, 1972

Gage	Total precipitation	Maximum 6-hour precipitation	
	Inches	Inches	Hours
A-1	8.68		
A-2	11.64	10.47	1500-2100
A-3	10.49		
A-4	9.57		
A-5	8.86	7.76	1450-2050
A-6	10.01		
A-7	10.96	[1]9.72	([1])

[1] By proportion, from gages A-2 and A-5; distribution record lost, only total depth available.

Figure 11.--An old road cut through residual soil, metamorphic parent material, after the June 9 flood. Fines were washed out. Platy rock was then either left protruding or it fell out and into an accumulation at the base of the slope. This sort of thing did not happen on newer back-sloped roads.

Figure 12.--Watershed 1 gaging station nearly covered over with stone and other debris, and completely inoperable after the June 9 flood. →

← Figure 13.--Watershed 2 gaging station after June 9 flood. San Dimas flume and channel is full of stone and other debris at left (upstream from headwall). Weir pond is completely obscured. Station was intact but inoperable.

Figure 14.--Watershed 3 gaging station after June 9 flood. The station continued in operation despite the debris pileup. Nearly 400 man-hours of labor were required to return all three gaging stations to temporary standby operation. →

Watershed 3 (WS3) flume functioned through the entire storm, but flow figures are not reliable after debris started to pile up following the peak, and because some water crossed over from WS2 to WS3 just upstream from the gaging stations. At least up to the peak the WS3 record is judged the best.

Rainfall started at almost precisely 1450 (m.s.t.) in all three recording gages at the watershed. The main streams started to rise almost immediately in all three watersheds, but the rise was relatively slow until between 1600 and 1700, when the heaviest sustained rainfall began. Flow then accelerated very rapidly.

Time at which flow started to accelerate most rapidly in WS3 coincided almost precisely with the start of a second period of high-intensity rain (at 1630) at rain gage A-2 in the upper reaches of the watershed. Over 3 inches of rain had already fallen—apparently enough to fill available soil storage capacity and cause the flow to respond almost immediately to additional high-intensity rain. From 1630 to 1820 the discharge increased steadily from 6 to 80 c.f.s. Maximum 1-hour rainfall occurred in this time interval—3.25 inches at rain gage A-2 (1630 to 1730) in the head of WS2, and 2.12 inches at rain gage A-5 (1645 to 1745) on the east boundary of WS1.

The watersheds behaved about as would be expected. WS2 apparently received most rainfall (fig. 15), and produced the highest unit area peak runoff (table 4). WS3 received second largest amount of rain, produced the second highest unit area peak runoff, and the second largest total area depth of runoff to the hydrograph peak. WS1, the most easterly of the watersheds, received the least rain, produced the lowest unit area peak flow, and the least depth to peak.

Maximum peaks (fig. 16) were less clearly recorded in WS1 and WS2 than in WS3. Nevertheless the peaks, as well as amounts already presented, are reasonable. WS1 hydrograph did not start maximum acceleration until about 1 hour after WS3, which is not surprising considering the fact that by the time of peak in WS3, 2 inches more rain had fallen there than in WS1.

Reasons for the two recorded peaks at WS1 are not clearly apparent. It may be that landslides (several occurred in WS1 and WS2, fig. 17) temporarily blocked flow. The debris dams then washed out, probably releasing enough surge of water to cause another peak at the gaging station. Several such slides may also have been one reason why the hydrograph in WS2 lagged behind both WS1 and WS3, particularly if the slides occurred at about the same time. Response times were opposite what might have been expected considering the fact that, in calculating design discharges, the concentration times were 12.6, 9.0, and 16.2 minutes for WS1, WS2, and WS3, respectively.

The slides themselves are of interest. Most of the ones adjacent to stream channels appear

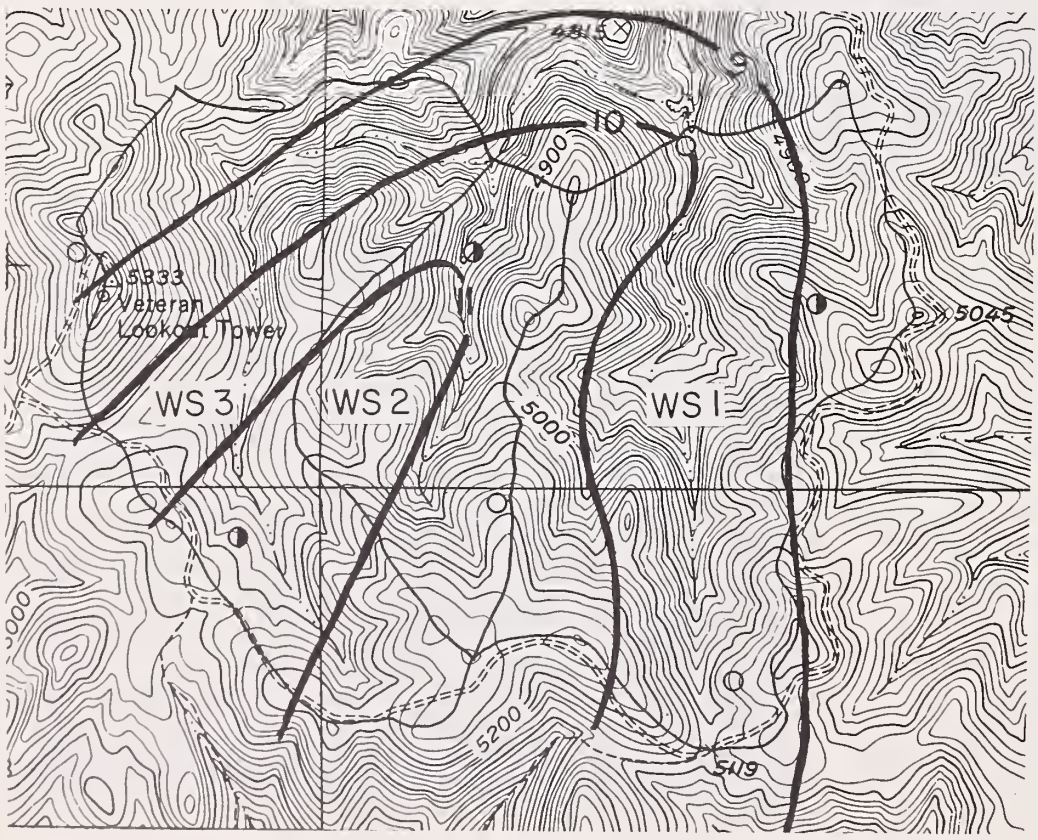

Figure 15.--Isohyetal map of the June 9, 1972 flood-producing storm on the Sturgis Experimental Watersheds: Left, watershed 3; Center, watershed 2; Right (east) watershed 1.

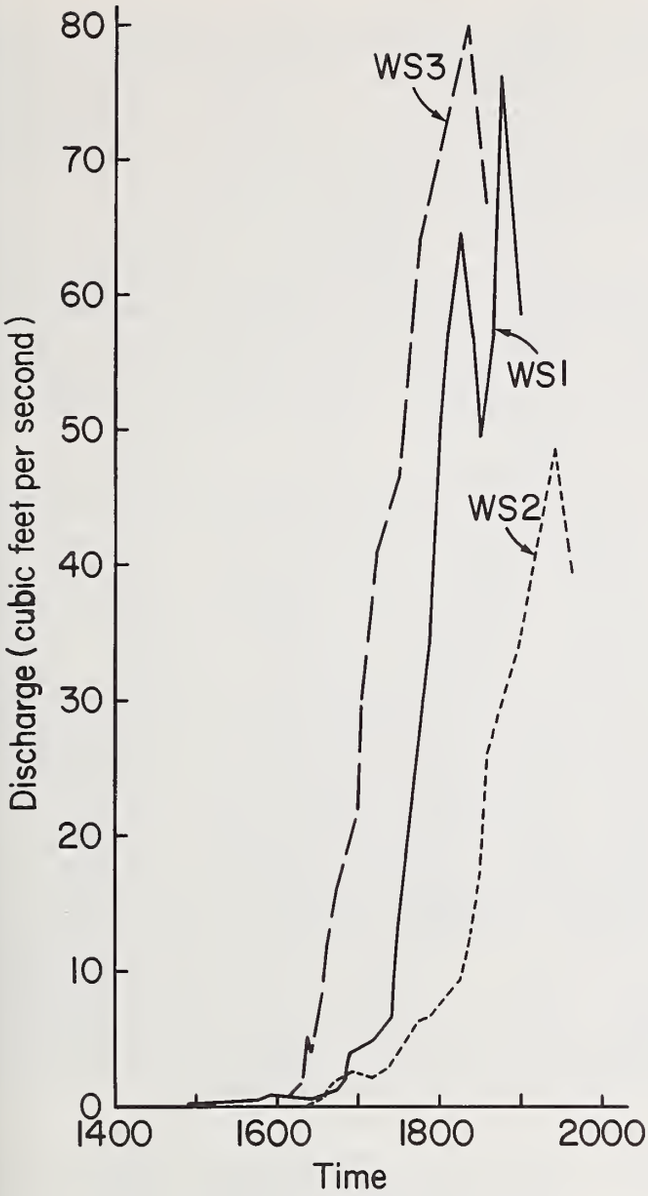

Table 4.--Area rainfall and storm discharge, Sturgis Experimental Watersheds, June 9-10, 1972

Item	Watersheds 1	2	3
Average precipitation (inches):			
Thiessen	9.28	10.83	10.47
Isohyetal	9.59	10.86	10.16
Recorded hydrograph:			
Approximate start of rise (m.s.t.)	1450	1514	1450
Time of peak (m.s.t.)	1840	1930	1832
Time to peak (hrs.& min.)	3:50	4:16	3:42
Discharge:			
Peak (c.f.s.)	76	49	80
Peak (c.s.m.)	225	349	269
Depth to peak(area inches)	.28	.47	.44
Computed 25-year design discharge (c.f.s.)	45	20	37
1972 multiple of 25-year	1.7	2.4	2.2

Figure 16.--June 9, 1972 storm flow hydrographs to about time of peaks. Debris deposits caused loss of the remainder of the hydrographs.

Figure 17.--Flow slide from channel bank in Sturgis WS1. A number of such slides blocked channels until enough water accumulated to overtop and cut through the debris. Debris in foreground is on near side of channel, which extends from right to left where man is standing.

to have occurred as the result of liquefaction of the toe of a slope by water flowing more than channel deep. Most of the slides were of the flow type (versus the rotary type). None we have seen within the watersheds were large, but there were enough of them to no doubt contribute a substantial portion of the bedload that choked the gaging stations and deposited in water supply reservoirs downstream. Several larger flow slides occurred on talus slopes along the main access road, which appear to have started as moisture accumulated to low tension along a road cut. Debris flow appears to have started at the cut face and progressed upslope —to near the ridge crest in several cases. Several such slides blocked the main access road.

Timber was harvested from WS3 in 1970 and 1971 (132 acres, 73 percent of total area). Some temporary haul road was constructed, but most was well up on a slope and away from main channels. Harvesting activity does not appear to have accelerated either the runoff or channel erosion. Haul roads and skid trails suffered minor damage, and little, if any debris reached major channels.

Summary and Conclusions

An unusual combination of atmospheric conditions triggered thunderstorms of unprecedented depth and duration from midafternoon on June 9, 1972 to early morning June 10, along the east slope of the Black Hills. Flash floods resulted in great loss of life, particularly in heavily populated areas along Rapid Creek, and property damages estimated at more than $100 million in Rapid City alone.

The storm was of such magnitude that recurrence interval is more than ordinarily problematical. Six-hour amounts ranged as high as 12 inches. Recurrence is variously estimated as four times the amount expected once in 100 years on the average (U.S. Department of Commerce 1972) to once in several thousand years (Thompson 1972). Flood flow peaks ranged as high as 62 times the once in-50-year discharge as estimated by the United States Geological Survey.

Portions of all of the major geologic types of the Black Hills were present in the torrent area. All major land uses ranging from commercial forest and agriculture, to intensive urban development were also present. All types of areas produced runoff of unprecedented proportions. Some areas yielded channel flow where long-time residents never before saw surface flow. The obvious conclusion is that runoff was produced regardless of how good the hydrologic condition. For example, surface runoff occurred under forest with thick protective litter, and concentrated in drainageways of microtopography that would not ordinarily be seen. The event was apparently so rare that the flash flooding cannot be taken as indication of general environmental degradation.

The land, regardless of condition or use, obviously could not receive and transmit the amount of rain that fell without changes in the face of the land itself. Part of these changes were the inevitable result of natural processes. In this framework, classification as "damage" is problematical.

On the other hand, damage was unprecedented where there was loss of life and the works of man were involved. A lesson to be relearned from this disaster is that encroachment on natural flow channels will inevitably result in damaging floods — some time. Flood damage in 1962 and earlier was also greatly compounded by man-origin debris, and, although cause and effect were both well documented, they were soon forgotten. All the major drainages in this 1972 flood have some known history of flooding, and they will flood again — some time. Extent of future damages will depend on sophistication of engineering works designed to **control and meter flood flows**, thus permitting continued occupancy of flood plain, or it will be necessary to **withdraw** from the most flood-susceptible areas. The final action, if man does not again forget too soon, will no doubt be a combination of the two.

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Rains of 12 inches or more in 6 hours fell on the east slopes of the Black Hills the night of June 9, 1972. Resulting flash floods exacted a disastrous toll in human life and property. Rainfall and discharge so greatly exceeded previous records that recurrence intervals have been presented in terms of multiples of the estimated 50- or 100-year event. Quick runoff was produced in the heaviest rainfall areas regardless of hydrologic condition. Flood sources included all major geologic and soil types and practically all land uses in the Black Hills. The highest measured peak runoff per unit area came from a 7-square-mile drainage, all on sedimentary formations, the upper portion of which burned over in 1936, but which is now well vegetated, apparently stable, and in good hydrologic condition. Greatest damage occurred where man-origin debris piled up against bridges, highways, homes, and other improvements.

Keywords: Floods, watershed management, hydrologic data, flash floods, storm runoff, record rainfall.

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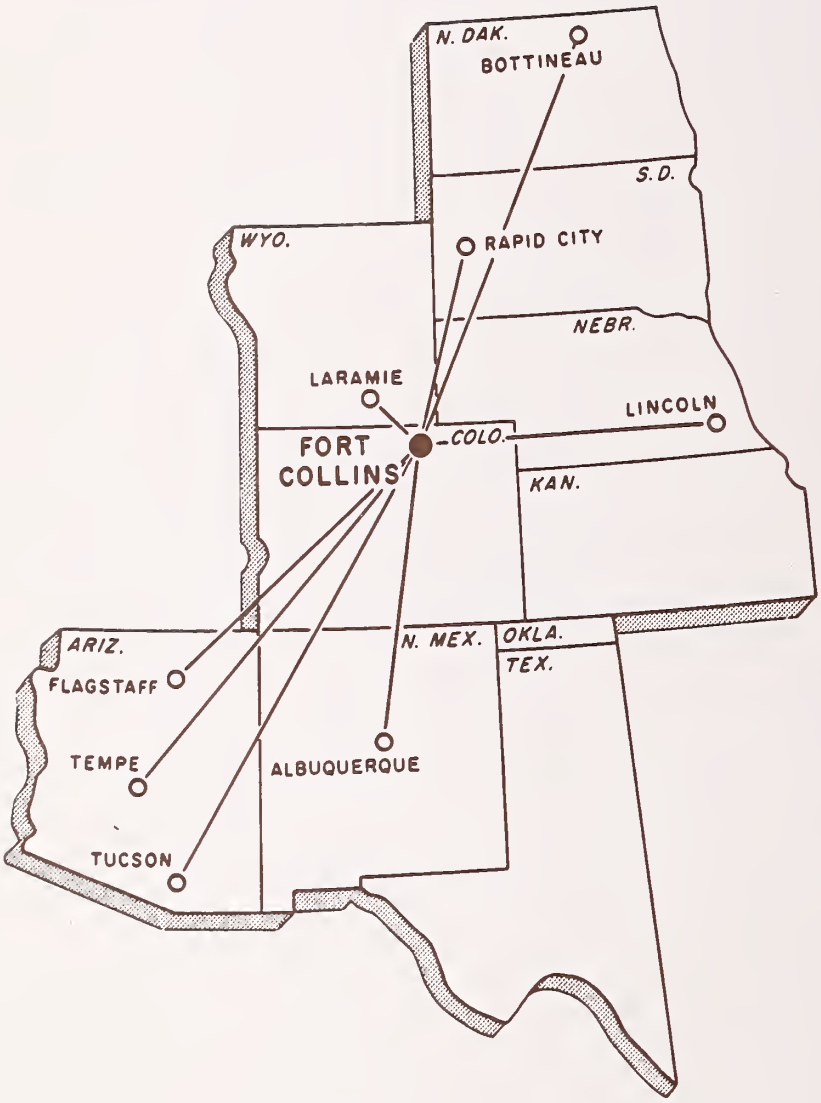
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