nurse educators, and nurse leaders in other service-oriented Title IV programs affords a dynamic strategy for meeting the learning needs of the target population of MCH Project 969.

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Mortality from Flash Floods: a Review of National Weather Service Reports, 1969–81

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SYNOPSIS

Of all weather-related disasters that occur in the United States, floods are the main cause of death, and most flood-related deaths are attributed to flash floods. Whenever a weather-related disaster involves 30 or more deaths or more than $100 million in property damage, the National Weather Service (NWS) forms a survey team to investigate the disaster and write a report of findings. All NWS survey reports on flash floods issued during 1969–81 were reviewed to determine the mortality resulting from such floods, the effect of warnings on mortality, and the circumstances contributing to death.

A total of 1,185 deaths were associated with 32 flash floods, an average of 37 deaths per flash flood. The highest average number of deaths per event was associated with the four flash floods in which dams broke after heavy rains. Although there were 18 flash floods in 1977–81 and only 14 in 1969–76, the number of deaths was 2½ times greater during the earlier period. More than twice as many deaths were associated with flash floods for which the survey team considered the warnings inadequate than with those with warnings considered adequate.

Ninety-three percent of the deaths were due to drowning and 42 percent of these drownings were car related. The other drownings occurred in homes, at campsites, or when persons were crossing bridges and streams.

The need for monitoring dams during periods of heavy rainfall is highlighted.

OF ALL THE WEATHER-RELATED DISASTERS that occur in the United States, floods are the main cause of death, and most flood-related deaths are attributed to flash floods (*1*). Flash floods are due to the fast runoff of water from heavy rains in a relatively short time, and runoff is accelerated in mountainous and narrow valley terrain. For example, the runoff from heavy rainfall in a mountainous area near Tucson, Ariz., in July 1981 flooded a recreational area. Eight persons died when an 8-foot wall of water rushed down a canyon where 150 people were camping.

Limited information is available on the number of deaths that occur each year as a result of flash

floods. Recently, the National Weather Service (NWS) of the National Oceanic and Atmospheric Administration asked the Centers for Disease Control (CDC) to assist in obtaining an estimate of mortality associated with flash floods and to identify factors that increase the risk of death and injury from such events. Two sources of information on flood-related injuries and deaths are NWS survey reports and storm reports.

Whenever a weather-related disaster involves 30 or more deaths or more than $100 million in property damage, NWS forms a survey team to investigate the disaster. The survey team writes a report of findings, along with recommendations for correcting any deficiencies which may have hampered appropriate warnings to the general public.

Methods

All NWS survey reports thought to be associated with flash floods were reviewed to determine the number of events that met the NWS working definition of a flash flood (heavy rainfall within a 12-hour period that leads to the issuance of a flash flood warning). Thirty-four reports covering 1969–81 met those criteria. Using those reports, we reviewed the mortality resulting from such floods and the effect of warnings on mortality and tried to enumerate the circumstances contributing to death and injury.

Results

Of the 34 reports on events meeting the criteria of a flash flood, 32 (94 percent) gave the number of deaths associated with the flood and were the source of the data in tables 1–4. Only three reports, however, provided information on injuries. With so few reports on injuries, we could not attempt in this review to assess injuries related to flash floods.

Mortality. A total of 1,185 deaths were associated with the 32 flash floods, an average of 37 deaths per flood (table 1). Although there were 18 flash floods in the 5-year period of 1977–81 compared with 14 in the previous 8-year period of 1969–76, the number of deaths was 2½ times greater during the earlier period.

Flash flood characteristics. Descriptive information, including the number of deaths, location, circumstances, and date, for each of the 32 flash floods with fatalities reported is listed in table 2 by State. The highest number of flash floods per State occurred in Arizona, Texas, and Pennsylvania (four each). Of these States, Pennsylvania had the highest average number of deaths per flood. However, the one flood resulting in the most deaths occurred in Rapid City, S. Dak., where 236 people died after a

Table 1. Deaths associated with flash floods, by year, 1969–81 [1]

Year	Number of events	Number of deaths	Deaths per event
1969	1	100	100
1970	2	36	15
1971	2	34	15
1972	5	536	107
1973	1	13	13
1974	1	9	9
1975	1	4	4
1976	1	135	135
1977	3	136	45
1978	4	78	19
1979	5	55	11
1980	4	32	8
1981	2	21	10
Total	32	1,185	...
Average			37

[1] 2 flash flood reports were excluded because they did not provide information on deaths.

Table 2. Flash floods investigated by the National Weather Service survey team, by geographic location, 1969 to 1981 [1]

Flood location	Date	Number of deaths	Description
Alabama–2			
Gainesville, Demopolis	April 1979	5	20 inches of rain in 3 days
Mobile	September 1979	5	5–9 inches of rain in 24 hours, associated with Hurricane Frederick
Arkansas–1			
Little Rock area	September 1978	11	4.5 inches of rain in 6 hours, associated with a tropical storm
Arizona–4			
Maricopa County	September 1970	23	11.4 inches of rain in 24 hours in narrow canyon
Region not given	December 1978	10	No information
Phoenix, Oak Creek Canyon	February 1980	3	16 inches of rain in 9 days
Tucson, Tenque Verde Falls	April 1981	8	No rain in area of flash flood but in upper mountains

Table 2. Flash floods investigated by the National Weather Service survey team, by geographic location, 1969 to 1981 [1]—*Continued*

Flood location	*Date*	*Number of deaths*	*Description*
California–2			
Los Angeles Basin (San Luis Obispo, Santa Barbara)	February 1978	20	6.2 inches of rain in 12 hours followed by a dam break in canyon
Los Angeles, Orange County, San Bernardino, San Diego	February 1980	18	3 inches of rain in 9 days, associated with a tropical storm
Colorado–1			
Big Thompson	July 1976	135	12 inches of rain in 4.5 hours in river canyon
Florida–1			
Pensacola, Panama City	September 1975	4	6 inches of rain, associated with a hurricane
Georgia–1			
Toccoa	November 1977	38	5.7 inches of rain in 4 days, accompanied by a dam break
Kansas–1			
Kansas City	September 1972	25	16 inches of rain in 24 hours
Kentucky–1			
Pike County	July 1979	3	7 inches of rain in 3 hours
Maryland–1			
Baltimore, Hartford	September 1971	16	12 inches of rain in 8 hours, associated with a hurricane
Mississippi–1			
Choctaw County, Winston County, Oktibbeha County	April 1979	4	20 inches of rain in 3 days
Nevada–1			
Lake Mohave, El Dorado	September 1974	9	7 inches of rain in ½ hour in narrow channel in a recreation area
New Jersey–1			
Trenton	September 1971	4	12 inches of rain in 5 days
North Carolina–1			
Ashe County	May 1973	13	12 inches of rain in mountains
North Dakota–1			
Bismarck, Fargo	March 1979	1	Heavy rains combined with melting snow
Pennsylvania–4			
Chester	September 1971	14	12 inches of rain in 5 days
Not given	June 1972	118	19 inches of rain associated with hurricane
Johnstown, Harrisburg, Indiana, Buford, Somerset.	July 1977	76	11 inches of rain
Armstrong, Butler, Clarion	August 1980	9	5 inches of rain in 2 days in a narrow valley
Puerto Rico–1			
Not given	August 1979	37	Heavy rains associated with a hurricane and dam overflow
South Dakota–1			
Rapid City	June 1972	236	15 inches of rain in 6 hours accompanied by a dam break
Tennessee–1			
Not given	April 1977	22	15 inches of rain in 5 hours
Texas–4			
Corpus Christi	August 1970	13	Heavy rain associated with a hurricane
South Central area	May 1972	18	16.5 inches of rain in 2 hours
Hill Country, Big County	September 1978	33	28 inches of rain in 12 hours associated with a tropical storm
Austin	May 1981	13	10 inches of rain in 4 hours
Virginia–1			
St. James Basin	September 1969	100	12 inches of rain in 8 hours in mountainous area
West Virginia–2			
Buffalo Creek	February 1972	139	4 inches of rain in 2 days accompanied by a dam break
Harrison County	August 1980	2	3.5 inches of rain in 1 hour associated with a tropical storm

[1] 2 flash flood reports were excluded because they did not provide information on deaths.

dam broke. Of the 34 floods, most occurred during the summer (July-September), with September having the most floods.

Month	Number of reports
January	0
February	4
March	1
April	2
May	3
June	2
July	5
August	4
September	11
October	0
November	1
December	1
Total	34

A review of the meteorologic and topographic factors contributing to flash floods in NWS survey reports showed that most were due to heavy rainfall alone (table 3). The highest average number of deaths per event, however, was associated with the four flash floods in which dams broke after heavy rains.

Warnings. The types of warning given and the number of deaths associated with each event are shown in table 4. Although warnings were issued for heavy rains and flash flooding, no warnings were issued for potential dam failures in the four events involving dam breaks. More than twice as many deaths were associated with flash floods for which the survey team considered the warnings inadequate than with those with warnings considered adequate. Warnings deemed inadequate were largely heavy rain and flash flood warnings issued for a region within a broad time frame such as the next day rather than for a flash flood in a specific area and time frame. The 20 deaths associated with those three flash floods when no warning was given occurred in remote recreational areas where the population considered at risk was small.

Causes of death. Causes of death were given in 16 of the 32 reports. They covered only 190 (15 percent) of the deaths; all such information was incomplete. Of these 190 deaths, 177 (93 percent) were due to drowning. A large portion (42 percent) of these drownings were car related; for example, victims had been in cars that were driven into low areas, across flooded bridges, or off the road into deep water. The other drownings occurred in the home, at a campsite, or when persons were crossing bridges and streams (table 5). Only a few reports contained information on the age and sex of flash flood victims.

Table 3. Meteorologic and topographic factors contributing to flash floods surveyed, 1969–81 [1]

Meteorologic and topographic factors	Number of events	Number of deaths	Deaths per event
Heavy rainfall not associated with tropical storms, hurricanes, dam breaks	12	221	18
Heavy rain associated with hurricane or tropical storm	9	241	26
Heavy rains associated with topographical factors (canyon, mountains, arroyo)	7	297	43
Heavy rain contributed to dam break	4	426	107
Total	32	1,185	...
Average			37

[1] 2 flash flood reports were excluded because they did not provide information on deaths.

Table 4. Type of warning given and number of deaths in flash floods, 1969–81 [1]

Type of warning	Number of events	Number of deaths	Deaths per event
No warning given at all (of rain, floods, etc.)	[2]3	20	7
Warning for heavy rains without flash flood warning	1	16	16
Warning for flash flood in region, but with time-space limitations	10	448	44
Warning for flash floods in areas where flash flooding occurred	14	275	19
Warning given for heavy rain and flash flood, but no warning for dam breaks	4	426	106
Total	32	1,185	...
Average			37

[1] 2 flash flood reports were excluded because they did not provide information on deaths.
[2] These flash floods occurred in remote recreational areas where population at risk was small.

Discussion

From these data, we cannot draw conclusive inferences for all flash floods; the floods that the NWS staff surveyed are not representative of all flash floods. The lack of a systematic method for collecting data, particularly the circumstances sur-

'A review of the meteorologic and topographic factors showed that most of the flash floods were due to heavy rainfall alone.'

Table 5. Circumstances of 190 deaths described in 16 survey reports of flash floods

Circumstances of death	Number	Percent
Drownings	177	93
Car related	80	43
Swept into water (in home, at campsite, or when crossing bridge)	81	43
Rafting or sailing	4	2
Storm sewer	2	1
During evacuation (not involving car)	4	2
Performing rescue	6	3
Trauma	2	1
Heart attack	7	3
Electrocution	2	1
Buried in mud slide	2	1
Total	190	100

rounding death, also poses problems in the interpretation of the data. Nevertheless, several observations are worthy of note on the basis of those severe floods surveyed by the National Weather Service.

The decrease in deaths in the past 5 years—despite an increase in the number of flash floods—may reflect an improvement in the warning system and awareness programs concerning flash floods. There appeared to be fewer deaths when flooding occurred within the area and time frame that was predicted.

Involvement of vehicles and driving practices during flash floods should be investigated further. A large number of car-related drownings were reported in the survey reports that provided information on the circumstances of death.

The high death toll associated with dam breaks from heavy rains deserves special attention. All types of dams should be monitored during periods of heavy rainfall so that sufficient warnings of potential dam failures can be issued. The Army Corps of Engineers has identified 68,153 non-Federal dams in the United States (dams over 6 feet high, with a maximum water impounding capacity at least 25 feet high, exceeding 15 acre-feet). Thirteen percent, or 8,818, of those dams have been inspected by the Corps (*2*). According to the "National Program of Inspection of Non-Federal Dams" flood report to Congress in May 1982, 2,925 of them were evaluated as being unsafe because of various deficiencies, primarily inadequate spillway capacity. These unsafe dams pose a public health threat and therefore should be closely monitored during periods of heavy rainfall, especially those dams with large numbers of people immediately downstream.

Recently the importance of monitoring dams by personal inspection during heavy rains was demonstrated in Essex, Conn. (*3*). Several dams in the town which were considered unsafe by the Corps were kept under constant vigil during heavy rains on June 4–5, 1982. On the evening of June 5, water was observed to flow over the top of one dam. The fire department evacuated people in parts of the town that might be affected if the dams failed. Within 1 hour of the evacuation notice five dams in Essex broke. Although most of the area sustained substantial destruction, not a single life was lost.

NWS survey reports provide a unique data base for the study of factors contributing to death and injuries related to flash floods. For optimum use of these reports, information in each report should be systematically recorded. The NWS is considering changes in the format of the survey reports so that the following information can be systematically recorded:

- death or injury;
- age, sex, and race of victim;
- time of death or injury;
- geographic location;
- circumstances of death;
- place of death or injury (home, car, outdoors);
- activity in which victim was engaged;
- type of injury; and
- cause of death.

In addition to NWS survey reports, all flash floods and associated deaths and injuries should be reported systematically to the NWS through its reporting network. Information on deaths and injuries can be used to calculate mortality and morbidity rates and to identify risk factors.

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