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Understanding Natural Disaster or Weather-Related Drowning Deaths Among Children

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Abstract

OBJECTIVES: Drowning is the leading cause of death during flood disasters. Little is known about these deaths. Child death review teams review details of child deaths to understand circumstances and risk factors to inform prevention.

METHODS: Using data entered in 2005 to 2021 for children ages 0 to 17 years from the National Fatality Review-Case Reporting System, we identified 130 drowning deaths directly attributed to natural disaster or weather incidents, and 14 deaths indirectly attributed to these incidents. Frequencies, proportions, and χ^2 statistics were used to describe selected measures and compare with other drowning deaths.

RESULTS: Children who drowned as a direct result of a natural disaster- or weather-related incident were more likely to be aged >4 years (81% vs 40%, $P < .001$) and located in a rural or frontier setting (63% vs 30%, $P < .001$). They were more likely to be supervised at the time of the incident (61% vs 38%, $P < .001$), and it was more likely for additional children (35% vs 5%, $P < .001$) or adults (33% vs 3%, $P < .001$) to have perished. The indirect deaths were commonly a result of damage to protective barriers.

CONCLUSIONS: The characteristics of natural disaster- or weather-related drowning deaths among children differ from other drowning deaths. Natural disaster- or weather-related drowning may warrant tailored drowning prevention strategies. Improved surveillance of all water-related deaths may be a proactive action leading to the development of these prevention strategies, whereas poststorm remediation of protective barriers can be used as a reactive prevention after a storm has passed.

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Natural disasters- and weather-related incidents are associated with excess mortality in the United States, with ~2000 US residents dying annually from weather-related causes during 2006 to 2010.[1] Among weather-related deaths, storms and floods account for the third largest proportion of deaths after cold and heat emergencies.[2] Floods are the most frequent natural disaster globally, and account for the highest death rate among natural disasters.[3] Drowning accounts for the most deaths during floods.[4] Common causes of drowning during floods and storms include attempting to drive across flooded roadways and bridges, attempting to rescue another person, drowning in a flooded residential location, or while boating.[4,5] In addition to deaths that are directly caused by natural disasters and weather-related incidents, indirectly related deaths occur when a disaster results in unsafe conditions that contribute to a death.[6] Directly related drowning could include a child who was swept away in flood waters. Indirectly related drowning deaths could include a child drowning in a pool after a fence was damaged by hurricane winds.[7]

Understanding the causes and circumstances of direct and indirect natural disaster- and weather-related drowning deaths is critical for the development of both proactive and reactive prevention strategies. Children have unique vulnerabilities during natural disasters and extreme weather-related incidents, and high-mortality risk during floods,[8] yet few studies have investigated the causes and circumstances of these natural disaster- and weather-related drowning deaths among children.

This study uses National Fatality Review-Case Reporting System (NFR-CRS)[9] data to describe natural disaster- and weather-related drowning among children in the United States. Data from child death review (CDR) can improve understanding of fatal drowning among children and youth. CDR teams review deaths of children within their jurisdictions to better understand factors that contribute to a child's death, as well as to inform future fatality prevention efforts. The National Center for Fatality Review and Prevention (National Center) provides resources and assistance to CDR teams across the country and maintains the NFR-CRS.[9] NFR-CRS data are robust in their ability to describe characteristics of deaths of children and encompass information unavailable through other sources, including information on supervision, the child's ability to swim, and if a child's death was related to a natural disaster or weather incident.

The goal of this study is to describe the characteristics and unique factors of natural disaster- and weather-related drowning deaths (hereafter referred to as disaster/weather-related drowning) compared with drowning deaths that did not occur during a natural disaster- or weather-related incident. Describing these characteristics and factors can inform prevention and preparedness strategies to protect children during natural disaster or weather incidents.

METHODS

Data Source

We used data from the NFR-CRS, a Web-based application that collects standardized, case-specific data on circumstances of child deaths reviewed by CDR teams. Detailed information on the scope and limitations of the database have been previously described.[10]

Case Selection

From 2005 to 2021, there were 203 869 deaths collected in the NFR-CRS among children ages 0 to 17 years. A multi-step process, detailed in Fig 1, was used to identify the disaster/weather-related drowning deaths. First, text fields and narratives for all deaths that were attributed to a natural disaster- or weather-related incident were searched for "warning," wind, storm, or flood, and 26 cases were identified. However, this question has only been part of the NFR-CRS since 2018, so it has not been asked for all deaths entered.

Second, text fields for motor vehicle crash deaths with an incident type of "child in/on vehicle that ran off the road" or "other event" were searched to identify vehicles driving into waters or being swept away (using terms flood, drown, water, rain, and storm) and were only included if related to a natural disaster or weather incident ($n = 16$). The drowning location and type of water were then recoded on the basis of details provided in text fields.

Third, text fields describing location, last activity, and narrative were searched for flood, warning, storm, weather, heavy, rain, wash, monsoon, hurricane, swollen, fast, and swept in any drowning deaths. In these 86 identified deaths, we recoded the drowning location for instances when users chose "other, specify" for drowning location, but the location was available as an existing response option ($n = 30$).

Fourth, fatalities from a cause of death of electrocution caused by lightning or other source were reviewed by 1 author for mention of drowning as a contributing cause of death. Finally, deaths that were attributed to an exposure to water hazards were reviewed by 1 author to identify any deaths not previously included in the above categories. No additional deaths were identified in these efforts.

Some of the above searches identified indirect deaths, but narratives from all drowning deaths, including those in pools, hot tubs, and bathtubs, were searched using key words flood, storm, weather, heavy, rain, wash, monsoon, hurricane, swollen, fast, and swept to identify all deaths indirectly attributable to a natural disaster/weather-related incident.

In total, we identified 130 directly attributed disaster/weather-related drowning deaths and 14 more that were indirectly attributed to such incidents. In instances where the NFR-CRS user selected motor vehicle crash as the primary cause of death or other for drowning location, this limited what additional data about the drowning were collected. Denominators vary in the results for this reason.

Data Analysis

Frequencies and proportions were calculated to summarize the characteristics of the study cohort. The demographics and characteristics of the direct disaster/weather-related drowning group were compared with all other drowning not directly related to a disaster- or weather-related incident entered into the NFR-CRS (hereafter referred to as other drowning, $n = 7488$). A separate descriptive analysis was conducted for 14 deaths that were indirectly related to a natural disaster- or weather-related incident.

Statistically significant differences between a disaster/weather-related drowning and other drowning deaths were identified using Pearson's χ^2 tests. Statistical significance was deemed $P < .05$. All analyses were carried out using the Statistical Package for Social Sciences, Version 29.

RESULTS

Demographics and Death Scene Investigation

In the disaster/weather-related drowning cohort of 130 deaths, more than one-third were children ages 5 to 9 years old (35%) (Table 1). The largest proportion of decedents were white (71%), non-Hispanic (85%), and male (61%) (Table 1). Age distributions differed between the cohorts (Table 1), with older children representing a greater proportion of the 130 disaster/weather-related drowning deaths compared with the 7488 other drowning deaths (ages 5–9: 35% vs 15%; ages 10–14: 23% vs 11%; ages 15–17: 22% vs 15%, $P < .001$). Although infants and children ages 0 to 4 years old accounted for the highest number of deaths among the 7488 other drowning deaths (59%), this age group accounted for the smallest number of the 130 disaster/weather-related drowning deaths (19%, $P < .001$). Hispanic ethnicity was less common among the 130 disaster/weather-related drowning deaths (13% vs 19%, $P = .007$). Counts of disaster/weather-related drowning for type of disability were too small to report ($n < 6$) per NFR-CRS guidelines; however, all disabilities identified were either physical or cognitive/intellectual. Death scene investigations were conducted in 94% of the 130 disaster/weather-related drowning deaths, compared with 83% of the 7488 other drowning deaths ($P = .008$) (Table 1).

Location

Comparing the 130 disaster/weather-related drowning and 7488 other drowning deaths, there were significant differences in incident location of the child's home (7% vs 35%, $P < .001$), as well as incident location being a roadway (22% vs 1%, $P < .001$) (Table 1). All 130 (100%) disaster/weather-related drowning deaths occurring in sources of open water. The most frequent type of open water in the 130 disaster/weather-related drowning deaths were creeks (32%), followed by rivers (28%) (Table 2). There were significant differences in geographic locations, with 63% of the 130 disaster/weather-related drowning deaths taking place in rural or frontier locations compared with 30% of the 7488 other drowning deaths ($P < .001$) (Table 1).

Supervision

Sixty-one percent of the 130 children who died in a disaster/weather-related drowning were supervised at the time of the incident compared with 38% of the 7488 other drowning ($P < .001$) (Table 1). Although differences between the frequency of rescue attempts in these incidents was not significant (62% vs 58%, $P = .167$), there was a significant difference in the incidence of an attempted rescuer also drowning in a disaster/weather-related drowning death (13% vs 3%, $P < .001$).

Multiple-Casualty Incidents

Thirty-five percent of the disaster/weather-related drowning deaths reported 2 or more children dying in the incident compared with 5% of the other drowning ($P < .001$) (Table 1); and 33% reported 1 or more adults perishing in the same drowning incident, compared with 3% of other drowning ($P < .001$) (Table 1). On the basis of information in text fields, 41 (32%) of disaster/weather-related drowning deaths were attributed to 14 unique incidents.

Warnings, Evacuations, and Risk-Taking

In some instances, text fields from the disaster/weather-related drowning deaths indicated that the child or their household was in the process of evacuating at the time of the incident. This count was too small to report ($n < 6$). In 28 disaster/weather-related drowning deaths (22%), text fields mentioned that warnings (such as road closed barriers, closures of schools because of weather, or weather service bulletins) were disregarded. Additionally, there were 7 instances (5%) where text fields indicated that areas with atypical water levels were sought out for viewing or recreation.

Indirect Deaths

Unlike the disaster/weather-related drowning cohort, the majority (79%) of the deaths indirectly attributed to a natural disaster- or weather-related incident ($n = 14$) were among younger children (ages 0–4 years old) and the water source was most frequently a pool (86%). The most frequent manner of indirect death was when a storm such as a hurricane damaged fencing or gates, allowing the decedent to access the pool. Eight of the indirect deaths (57%) occurred in pools that were not part of the child's residence.

DISCUSSION

Children are especially vulnerable during natural disaster- and weather-related incidents, but little is known about details surrounding disaster/weather-related drowning deaths among this group. The findings from this research are unique in using CDR data to more closely investigate circumstances of child drowning during natural disaster- and weather-related incidents in the United States.

Multiple deaths occurred in multicasualty incidents, including deaths of individuals attempting to rescue a child. The higher proportion of rescuers drowning in disaster/weather-related drowning deaths indicates that supervisors or bystanders may have ignored dangerous conditions to attempt a rescue. The smaller proportion of disaster/weather-related drowning deaths among the youngest group (ages 0–4 years) may reflect that increased supervision during natural disasters and weather-related incidents is protective for children in this age group and less so for older children.

Previous research in Australia identified peak risk for children dying in flood-related drowning among 10- to 14-year-olds and described behavioral factors contributing to risk, including older adolescents swimming in flood waters or driving into flooded remote areas.[11,12] On the basis of narratives in this study, there were multiple instances when either children or supervisors sought out flooded areas to see or experience the excess water

leading to a larger proportion of deaths among children ages 5 years or older compared with other drowning. A supervisor leading children to water during a natural disaster or weather-related incident for recreating adds a more complicated layer to the problem, because it may suggest to the child that it is safe to visit these areas.

Approximately 1 in 5 (22%) disaster/weather-related drowning deaths expressly mentioned warnings such as road closures, closures of schools because of weather, or weather service bulletins being disregarded by the child or supervisor. This disregard for safety was also reflected in the motor vehicle specific data where the child was a passenger and not the driver in a majority of instances. This phenomenon has been seen in previous research, which identified that initial responses to emergency alerts often involve skepticism, disbelief, and denial, leading people to ignore warnings.[13]

Rural and frontier drowning locations were more common in the disaster/weather-related drowning cohort. Discouraging people from driving through floodwaters may be particularly challenging in rural areas and in instances where people are attempting to evacuate a natural disaster or weather-related incident.[12] In an Australian survey, 36% of people self-reported having driven through flood waters, with people living in rural areas even more likely to report having done so.[12] Findings suggest prioritizing tailoring emergency alert strategies to frontier areas with limited infrastructure.

Several indirectly related disaster/weather-related drowning deaths occurred during storm recovery when broken pool fences or other layers of protection were compromised. It may be that replacing these barriers was not prioritized in the wake of a hurricane or other storm when the broad damage to property was overwhelming. Prioritizing repair of barriers and layers of protection around pools and other residential bodies of water may prevent indirectly related drowning deaths of children after disasters.

The findings of this study have implications for pediatric and family medicine providers, public health practitioners, and preparedness professionals who work with children, youth, and families. Professionals can ensure that preparedness messages are tailored to adolescents and their caregivers. Messaging to adolescents and caregivers could emphasize avoiding flooded areas and swift moving water in natural disasters and weather-related incidents. Despite the fact that pediatric providers have many things to do and cover in relatively brief clinical encounters, they are uniquely positioned to educate families about emergency preparedness, including drowning, as part of routine preventive health care as recommended by the American Academy of Pediatrics,[14] in addition to any other drowning prevention guidance they share, such as that from the Centers for Disease Control and Prevention.[15] Their ability to address these and other issues are challenged by workforce shortages, particularly in rural areas where these deaths commonly occur.[16]

The impact of climate change should not be understated. Data from the past century show a rise in extreme precipitation events in the United States[17] and climate modeling studies predict an increase in the frequency and intensity of extreme precipitation events, hurricanes,[18] and floods[19] as a result of global warming.[20] Increasing climate-related changes that may increase flooding and drowning risk underscores the need for

disaster/weather-related drowning specific prevention strategies that include monitoring and mitigating environmental risk factors.

Better data drives more effective prevention strategies. Resources and funding dedicated to comprehensive standardized death scene investigations in disaster/weather-related drowning deaths could improve reporting on the circumstances of these deaths and development of tailored prevention. Standardized tools and investigation protocols could guide practice for death certifiers in making death determinations.[6,21]

Given the findings of this study, future research could inform understanding of the role of supervision in natural disasters and weather-related incidents, including its relationship to age. Rigorous testing that is informed by behavioral science could identify what types of prevention messages effectively resonate with families, adolescents, and rural residents in particular. A broad assessment of homeowner insurance policies may shed light on timelines for repair of fences and other barriers that limit access to residential pools after natural disasters and weather-related incidents. Finally, a nationally representative case registry for all drowning deaths could enable the collection of detailed demographic and circumstance data to inform prevention strategies.

This study was limited by small numbers. Additionally, jurisdictions have different case selection criteria for reviewing deaths in CDR and differences in data they share, so although data from the NFR-CRS can meaningfully inform prevention strategies, they are not population-level and cannot be used for population-level surveillance. Additionally, this analysis included a significant amount of text and qualitative analysis from many different CDR teams, so there were frequent inconsistencies that required recoding when possible. Keyword searches may not have identified all relevant case summaries because of differences in data entry such as misspellings of words or colloquial terms. There were instances where text narrative described more child deaths taking place in a single incident than were identified from the NFR-CRS.

Defining a natural disaster or weather-related incident on a national scale was difficult because there can be regional variation in average rainfall. A disastrous amount of rain in 1 location may be a normal amount in others. Efforts were made in qualitative analysis of text fields to distinguish disaster-level flooding, rain, or storms from a day with average rain when determining cohort inclusion. In light of this, retention ponds, storm drains, and canals were especially challenging to assess and could have been missed in the case selection. The consistency and quality of what was written in narrative fields can differ between jurisdictions, so the true count of deaths from natural disaster or weather-related incidents could be greater.

Given the descriptive nature of this study, we did not attempt to identify or control for potential confounding variables. Because of high proportions of missing or unknown data for both insurance status and whether caregivers were recipients of social services, this study was not able to describe socioeconomic status among the disaster/weather-related incident drowning cohort.

CONCLUSIONS

Disaster/weather-related drowning deaths have unique characteristics that may require tailored prevention strategies. With the addition of a new variable in 2018 to more reliably track disaster-related deaths, including those from natural disasters and weather-related incidents, the NFR-CRS may be a more informative data source to describe deaths before and after natural disaster- and weather-related incidents in years to come. Improving data quality around disaster/weather-related deaths may inform more effective prevention and preparedness planning at organizational, community, and family levels.

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ABBREVIATIONS

CDR	child death review
NFR-CRS	National Fatality Review Case Reporting System

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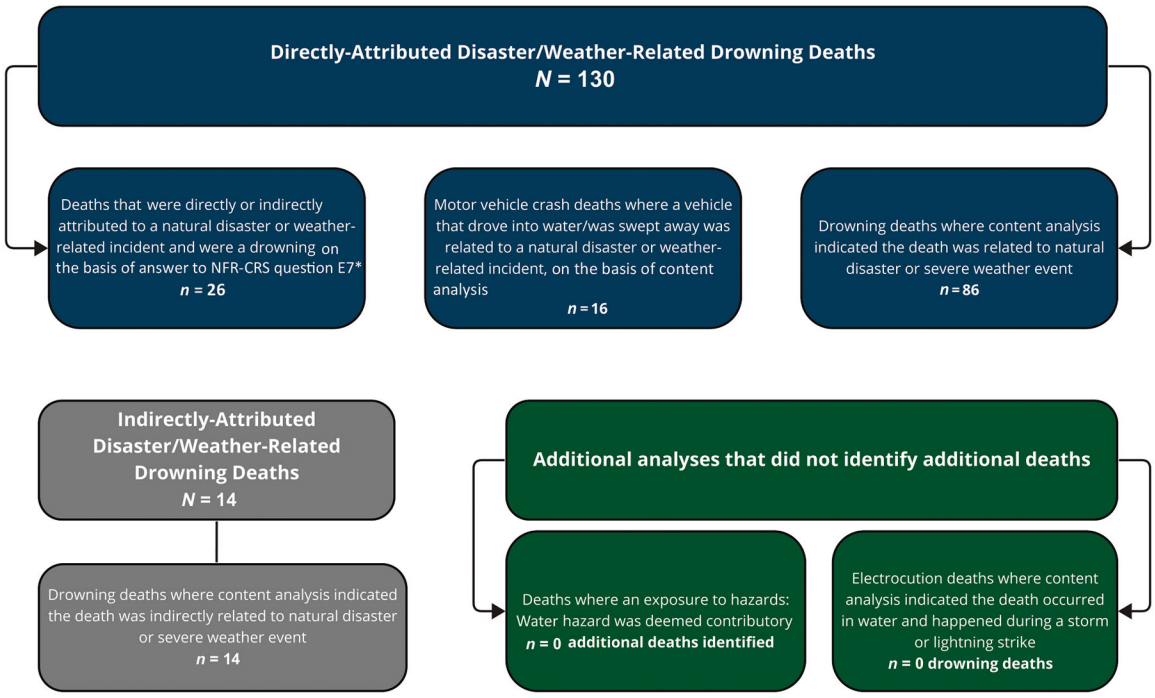

FIGURE 1.

Case selection criteria for disaster/weather-related drowning deaths, National Fatality Review-Case Reporting System, 2005 to 2021.

* Question E7 asks: “Was the death attributed (either directly or indirectly) to an extreme weather event, emergency medical situation, natural disaster, or mass shooting?” This variable was not added to NFR-CRS until 2018.

TABLE 1

Details of Disaster/Weather-Related Drowning Deaths Compared With Other Drowning Among Children 0–17 Years Old Entered Into the NFR-CRS From 2005 to 2021

Age *n* (%)	Disaster/Weather-Related Drowning, *N* = 130	Other Drowning, *N* = 7488	*P*
0–4 y	25 (19)	4341 (59)	<.001
5–9 y	46 (35)	1099 (15)	
10–14 y	30 (23)	838 (11)	
15–17 y	29 (22)	1080 (15)	
Race			
Black	25 (19)	1663 (23)	.373
Multiracial	3 (2)	145 (2)	
White	92 (71)	4680 (64)	
Additional groups[a]	7 (5)	390 (5)	
Missing	3 (2)	439 (6)	
Ethnicity			
Hispanic	17 (13)	1372 (19)	.007
Non-Hispanic	110 (85)	5341 (73)	
Missing	3 (2)	267 (3)	
Unknown	0 (0)	378 (5)	
Sex			
Female	51 (39)	2225 (30)	.142
Male	79 (61)	5092 (69)	
Missing	0 (0)	28 (0)	
Unknown	0 (0)	13 (0)	
Disabilities/chronic conditions			
Yes	9 (7)	917 (13)	.001
No	72 (55)	4319 (59)	
Missing	13 (10)	956 (13)	
Unknown	36 (28)	1166 (16)	

Age *n* (%)	**Disaster/Weather-Related Drowning, *N* = 130**	**Other Drowning, *N* = 7488**	***P***
Death investigation conducted			
Yes	122 (94)	6113 (83)	.008
No	1 (1)	236 (3)	
Missing	3 (2)	729 (10)	
Unknown	4 (3)	280 (4)	
Child history of maltreatment			
Yes	19 (15)	1004 (14)	.130
No	57 (44)	3568 (49)	
Missing	22 (17)	1523 (21)	
Unknown	32 (25)	1263 (17)	
Supervision at time of incident			
Yes	79 (61)	2771 (38)	<.001
No, not needed	30 (23)	1023 (14)	
No, but needed	15 (12)	2853 (39)	
Missing	3 (2)	378 (5)	
Unable to determine	3 (2)	333 (5)	
Supervisor type in children needing supervision[b]	Disaster/weather-related drowning, *N* = 100	Other drowning, *N* = 6335	*P*
Biological parent	71 (71)	3755 (64)	.430
Immediate relative[c]	8 (8)	757 (13)	
Other relative	7 (7)	353 (6)	
Other[d]	5 (5)	704 (11)	
Missing	9 (9)	676 (12)	
Unknown	0 (0)	90 (1)	
Place of incident	Disaster/weather-related drowning, *N* = 130	Other drowning, *N* = 7488	*P*
Child’s home	9 (7)	2582 (35)	<.001
Roadway	28 (22)	49 (1)	
Other recreation area	20 (15)	1110 (15)	
>1 place	25 (19)	605 (8)	
Other[e]	47 (36)	2717 (36)	

Age *n* (%)	**Disaster/Weather-Related Drowning, *N* = 130**	**Other Drowning, *N* = 7488**	***P***
Missing	1 (1)	229 (3)	
Type of area			
Frontier	6 (5)	49 (1)	<.001
Rural	76 (59)	2184 (30)	
Suburban	21 (16)	2138 (30)	
Urban	19 (15)	1755 (29)	
Missing	3 (2)	827 (11)	
Unknown	5 (4)	405 (6)	
Was child able to swim?	Disaster/weather drowning, *N* = 114	Other drowning, *N* = 7488	*P*
Yes	24 (21)	793 (11)	<.001
No	17 (15)	3317 (45)	
Not applicable	7 (6)	130 (2)	
Missing	11 (10)	1759 (24)	
Unknown	55 (48)	1359 (19)	
Was a rescue attempt made?	Disaster/weather-related drowning, *N* = 114	Other drowning, *N* = 7488	*P*
Yes	71 (62)	4272 (58)	.167
No	18 (16)	861 (12)	
Not applicable	6 (1)	843 (12)	
Missing	10 (9)	841 (11)	
Unknown	9 (8)	541 (7)	
If a rescue attempt was made, did rescuer also drown?	Disaster/weather-related drowning, *N* = 71	Other drowning, *N* = 4272	*P*
Yes	9 (13)	110 (3)	<.001
No	62 (87)	4116 (96)	
Missing	0 (0)	33 (1)	
Unknown	0 (0)	13 (0)	
Number of child fatalities in incident	Disaster/weather-related drowning, *N* = 130	Other drowning, *N* = 7488	*P*
1	82 (63)	6377 (87)	<.001
2	17 (13)	300 (4)	
3	13 (10)	34 (1)	

Age *n* (%)	Disaster/Weather-Related Drowning, *N* = 130	Other Drowning, *N* = 7488	*P*
5	10 (8)	5 (0)	
10	5 (4)	1 (0)	
Missing	3 (2)	634 (9)	
Number of adult fatalities in incident			
0	46 (35)	3188 (43)	<.001
1	26 (20)	182 (3)	
2 – 3	7 (5)	20 (0)	
4+	10 (8)	0 (0)	
Missing	42 (32)	3968 (54)	

[a]Combined American Indian/Alaska Native and Asian American because of small numbers.

[b]This is determined at the discretion of the person entering information into the NFR-CRS but is typically determined by age or physical condition of the child.

[c]Combined adoptive parent, stepparent, grandparent, and sibling because of small numbers.

[d]Other includes self, foster parent, parent's partner, friend, acquaintance, hospital staff, institutional staff, babysitter, licensed child care worker, and other.

[e]Other includes relative's home, friend's home, licensed foster care home, relative foster care home, licensed group home, licensed day care center, licensed day care home, unlicensed day care home, farm, school, American Indian reservation, military installation, sidewalk, driveway, other parking area, hospital, and other.

TABLE 2

Details of Incident Location for Disaster/Weather-Related Drowning

Drowning Location	Sample Frequency *N* = 130	Percent
Open water	130	100
Open water type		
Canal/drainage ditch	17	13
Creek	41	32
Lake	13	10
River	36	28
Wash/roadway	21	16
Other	2	2