Flood

A flood occurs within the U.S. resulting in direct economic losses greater than $100 Million.

Data Summary

Table 1 shows the minimum, average, and maximum values for frequencies and impacts of national level floods. Note that the low and high likelihoods do not correspond to the low and high impacts. In addition, low and high impacts are not necessarily correlated with each other between different impact categories.

Table 1

Category	Description	Metric	Low	Best	High
Health and Safety	Fatalities	Number of Fatalities[1]	0	3	25
	Injuries and Illnesses	Number of Injuries or Illnesses[1]	0	95	4,520
Economic	Direct Economic Loss	U.S. Dollars (2011)[1]	$104 Million	$740 Million	$16 Billion
Social	Social Displacement	People Displaced from Home ≥ 2 Days[2]	150	29,000	200,000
Psychological	Psychological Distress	Qualitative Bins	See text		
Environmental	Environmental Impact	Qualitative Bins[3]	Moderate[4]		
LIKELIHOOD	Frequency of Events	Number of Events per Year[5]	0.5	4	10

Event Background

Floods are one of the most common hazards in the United States. Their effects can be local, impacting a neighborhood or community, or large, affecting entire river basins and multiple states.[6] For the purpose of the SNRA, a national-level flood is defined as a flood producing direct economic loss in excess of $100 million dollars. Economic loss reported here is a combination of property and crop damage. A 13 year time period, from Jan-1-1993 to Dec-31-2005, was used to estimate the interarrival rates/frequencies and impacts for floods exceeding the $100 million threshold. A full list of aggregated flood events used for this report is located in Table 2. Table 1 reports the maximum, average, and minimum frequency with which such floods occurred in the

[1] Low, best, and high estimates for fatalities, injuries and illnesses, and direct economic loss are the historical minimum, average, and maximum for each impact type in the event set. Extremal events for one impact type may but generally do not correspond to those for other impact types.
[2] Low, average, and high reported "total affected" for floods causing greater than $100M in economic damage as recorded in the EM-DAT database during the time period 1970-2011. See Social Displacement section in this summary sheet for details.
[3] The United States Environmental Protection Agency (EPA) convened an ad hoc group of environmental experts representing the fields of environmental science, ecological risk, toxicology, and disaster field operations management to estimate environmental impacts for this event. The comments and rankings presented in this Risk Summary Sheet have not undergone review by the EPA and only represent the opinions of the group. Estimates pertain to the potential for adverse effects on living organisms associated with pollution of the environment; they are grouped into high, moderate, low, and de minimus (none) categories. Experts provided both first and second choice categories, allowing the experts to express uncertainty in their judgments as well as reflect the range of potential effects that might result depending on the specifics of the event. The first choice represents the 'best' estimate.
[4] Floods were given a best estimate of 'Moderate'. The experts assessed that flooding of agricultural areas is a typical impact. The severity of the impact depends upon whether there is release of contaminants from urban areas.
[5] Historical lowest, average, and maximum number of events per year (calculated from interarrival times).
[6] FEMA.gov: Flood, March 2011. http://www.fema.gov/hazard/flood/.

United States, and the maximum, average and minimum impacts for fatalities, injuries, and direct economic losses associated with floods in the set.

This flood risk summary is based on aggregating flood losses reported by NOAA's National Climactic Data Center (NCDC).[7] Modern flood reporting by NOAA relies on many individual reports that assess damages in a specific area of responsibility. A large scale flood, for example, can result in dozens or hundreds of damage entries that assess damages for specific geographic regions. The reason for this is that damage estimates are recorded by individuals with specific areas of responsibility. As flooding passes down the Mississippi, for example, the affected areas can pass from region to region. To capture the transient and distributed nature of flood events, individual flood loss estimates were aggregated based on proximity and time. Flood damage reports that occur within 100 miles of one another and within plus or minus one calendar day are aggregated into composite flood events. The composite flood events above the $100 million threshold are used for reporting of national level event statistics in Tables 1 and 2 of this report. All hurricanes were removed from flood events to avoid over reporting flooding captured in the hurricane risk summary sheet.

Low, average and high impact estimates were developed in the following manner. For fatalities, injuries and economic loss, the low estimate is the smallest impact for events that exceed $100 million. For event frequency, the low estimate is the lowest number of events recorded in a year. The average frequency is the expected number of events in a given year. Similarly, the average for fatalities, injuries/illness, and economic damage are the expected value for each given the occurrence of a national level flood. The maximum frequency is the maximum number of national-level floods recorded in a single year. The maximum for fatalities, injuries/illness, and economic damage is the greatest value produced by a single storm in each impact category.

It is important to note that the frequency estimates reported here differ from probabilities. The frequency of a national-level flood can be greater than one, while a probability cannot. Additionally, while the average estimates for impacts and frequency are correlated and approximate the average annual loss when multiplied together, the maximum and minimum historical values for impact and frequency are uncorrelated and do not have meaning when multiplied together.

Economic flood damages were inflated to a 2011 dollar value using average changes in the Consumer Price Index. The historical maximum for fatalities was the Great October Flood of 1998 in West Texas with an estimated 25 deaths. Several floods within the time period exceeded $100 million in economic damages without any reported loss of life or injury. In total, 37 floods exceeding the $100 million threshold are aggregated in the findings of this report. For economic loss, $104 million[8] is the smallest historic loss that meets the $100 million threshold. Twenty three historic events exceeding the economic threshold did not record any fatalities. The greatest gap between flood events occurs between 1998 and 2000. This two year time lapse between national level events results in an interarrival frequency of 0.5, or $1/t_{max}$.

Social Displacement

For the purposes of the SNRA, social displacement was defined as the number of people forced to leave home for a period of two days or longer. Note that there are limitations to this measure

[7] NOAA NCDC Storm Events Database, available by ftp from http://www.ncdc.noaa.gov/stormevents/ftp.jsp (current URL: database downloaded by SNRA project team from NCDC for analysis September 2011, URL updated 3/16/2013).
[8] 5/8/1993: Heavy rain in parts of Oklahoma, Arkansas, and Texas.

of social displacement, as the significant differences between temporary evacuations and permanent displacement due to property destruction are not captured.

To estimate social displacement for the SNRA, U.S. flood event data from EM-DAT was used to approximate the number of people forced to leave home for two days or greater. EM-DAT, an Emergency Events Database maintained by the World Health Organization Collaborating Centre for Research on the Epidemiology of Disasters with support from USAID,[9] provides estimates of the "total number affected" by disaster events. Data on "total number affected" for U.S. flood events from 1970-2011 listed in EM-DAT as causing $100M or greater in damages are listed in Table 3. This data covers a longer historic time period than the flood data used for the economic analysis and the EM-DAT events listed may not match the events listed in Table 2 exactly due to differences in damage reporting between the two databases.[10] The low, high, and average of the "total affected" data in Table 3 are used as the social displacement estimates for floods in the SNRA.

The "total affected" measure includes the number of people needing immediate assistance, which can include displacements and evacuations; the number of people needing immediate assistance for shelter; and the number of people injured. Because EM-DAT includes injuries in the "total affected" measure, there is potential for double-counting between the SNRA injury and displacement estimates for this event. However, displacement due to floods is typically significantly greater than the number of injuries, so using EM-DAT's "total affected" measure was judged to provide an estimate of social displacement of sufficient precision for the SNRA. Note that the low estimate may be biased low due to incomplete reporting of displacement and evacuations in EM-DAT.

Psychological Distress

Psychological impacts for the SNRA focus on *significant distress* and *prolonged distress*, which can encompass a variety of outcomes serious enough to impair daily role functioning and quality of life. An index for significant distress was created that reflected empirical findings that the scope and severity of an event is more important than the type of event. The equation for this index uses the fatalities, injuries, and displacement associated with an event as primary inputs; a factor elicited from subject matter experts weights the index for differing psychological impact based on the type of event, but as a secondary input.[11] The numerical outputs of this index

[9] EM-DAT: The OFDA/CRED International Disaster Database – www.emdat.be, Université Catholique de Louvain, Brussels (Belgium) [official citation]. EM-DAT is maintained by the Centre for Research on the Epidemiology of Disasters (CRED) at the School of Public Health of the Université Catholique de Louvain located in Brussels, Belgium (http://www.emdat.be/frequently-asked-questions), and is supported by the Office of U.S. Foreign Disaster Assistance (OFDA) of USAID (http://transition.usaid.gov/our_work/humanitarian_assistance/disaster_assistance/). See Criteria and Definition, http://www.emdat.be/criteria-and-definition, EMDAT Data Entry Procedures, at http://www.emdat.be/source-entry , and EMDAT Glossary, at http://www.emdat.be/glossary/ for details of criteria, thresholds, and methodology for the EM-DAT database.

[10] The historical flood incidents in Table 4 were paired with corresponding historical incidents in Table 3 for the purpose of determining a unique set of records with all impact numbers, where available, for the SNRA core data set (Appendix K). However, this identification occurred after 2011, and Table K2 was not included in the SNRA data or documentation reviewed by FEMA and the interagency, or in classified versions of the SNRA Technical Report.

[11] The Significant Distress Index is calculated from these inputs using a formula proposed by subject matter experts consulted for the SNRA project: $N_{SD} = C_{EF} \times (5\ Fat + Inj + ½\ D)$, where N_{SD} represents the number of persons significantly distressed, C_{EF} is the expert assessed Event Familiarity Factor, *Fat* is the number of fatalities, *Inj* is the number of injuries and/or illnesses, and *D* is the number of persons displaced (Social Displacement). In words, this formula suggests that there are 5 significantly distressed persons for each life lost; 1 for each person injured; and 1 for each 2 people displaced. This formula was constructed to reflect the empirical finding that the most severe stressor of a disaster is losing a loved one, followed by injury, followed by displacement. Uncertainty was captured by applying the index formula to the low, best, and high estimates of these three human impact metrics.

The Event Familiarity Factor is intended to capture the extent to which the event entails an ongoing threat with uncertainty regarding long term effects, is unfamiliar, or that people dread, exacerbating psychological impacts. This factor, ranging from 1.0 for familiar events to 1.3 for unfamiliar events, was provided by subject matter experts for each national-level event included in the SNRA: floods were given a C_{EF} of 1.0.

The numerical estimates calculated from this formula are reported in Appendix G. The semi-quantitative risk matrix is discussed in the Findings (Psychological Distress Risk).

formula were used to assign events to bins of a risk matrix for a semi-quantitative analysis of psychological risk in the SNRA.

Environmental Impact

The United States Environmental Protection Agency (EPA) convened an ad hoc group of environmental experts representing the fields of environmental science, ecological risk, toxicology, and disaster field operations management to estimate environmental impacts for this event. Estimates are based on the following assumptions:

- Experts were elicited to provide estimates in the environmental impact category based on assumptions. Actual environmental/ecological harm that occurs as a result of the events described in a given scenario may vary considerably, and will depend on numerous variables (e.g., chemical or biological agent, contamination extent, persistence, toxicity—both chronic and acute toxicity—and infectivity).
- EPA defined environmental consequence (impact)[12] as the potential for adverse effects on living organisms associated with pollution of the environment by effluents, emissions, wastes, or accidental chemical releases; energy use; or the depletion of natural resources.
- Experts identified the best estimate for environmental impacts as "moderate." Flooding of agricultural areas is a typical impact of large scale flooding. The severity of the impact depends upon whether there is release of contaminants from urban areas.

Potential Mitigating Factors

Flood risk is typically based on history, combined with a number of factors such as rainfall, river-flow and tidal-surge data, topography, flood control measures, and changes due to building and development.

Assumptions

The SNRA project team used the following assumptions to estimate health and safety impacts for this event:

- Historical flood events from 1993-2005 are representative of current flood risk.[13]
- Aggregations of individual reports for flood deaths/injuries represent the actual deaths/injuries from historic flood events to sufficient precision for purposes of the SNRA. These fatality and injury reports are potentially biased low compared to published reports due to underreporting in the NOAA database.

The SNRA project team used the following assumptions to estimate economic impacts for this event:

- Property and flood loss dominate the direct economic losses, such that business interruptions, medical costs, and loss of spending due to fatalities can be neglected.

[12] The 2011 SNRA referred to impacts as 'consequences' because of prior usage in quantitative risk assessment (Kaplan and Garrick [1981, March], On the quantitative definition of risk: *Risk Analysis* 1(1) 11-32). Except where it will cause confusion, 'impact' is used synonymously in this document because of pre-existing connotations of the word 'consequence' within FEMA.

[13] Flood event records for 2006 – present are also available from NOAA, but in a different format than the records used for this summary sheet. These records will be included in future analysis.

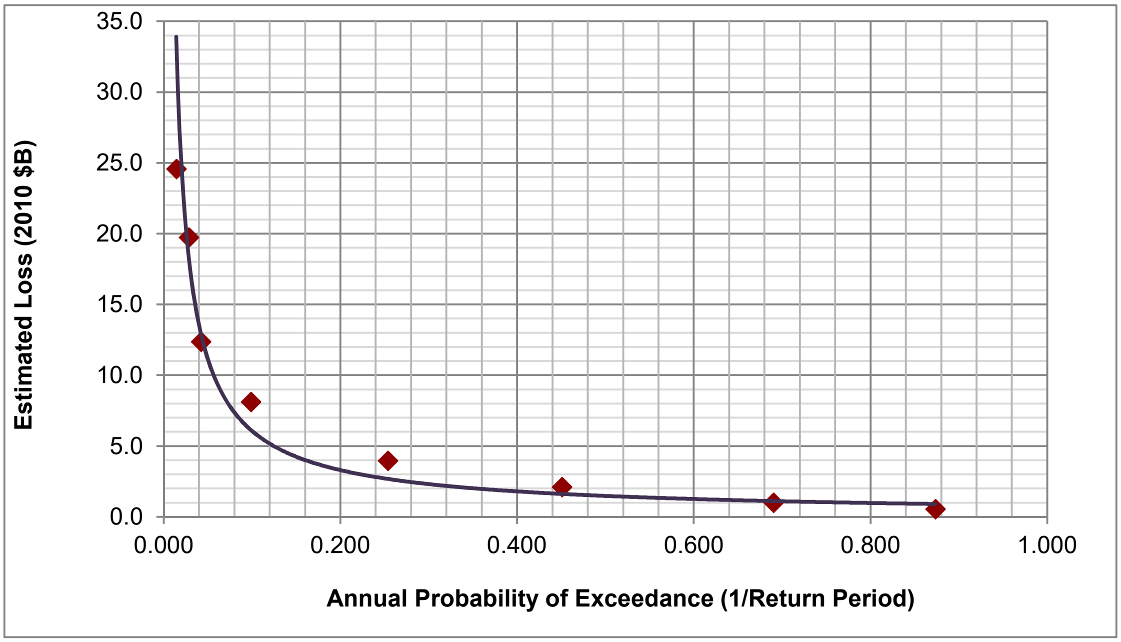
The SNRA project team used the following assumptions to estimate social displacement for this event:

- Numbers displaced by floods sufficiently dominate injuries that EM-DAT's total-affected measure may be considered an approximate measure of social displacement.

Expected Damage Versus Return Period

Results reported in Tables 1 and 2 capture actual flood events. An additional perspective into flood damage is a loss exceedance probability shown in Figure 1. The 13-year range used for impacts in Tables 1 and 2 does not provide record of all possible impacts. Low frequency events have the capacity to eclipse the greatest damage reports from historic events. Figure 1 provides a loss exceedance probability for flood damages in a given year. It is important to note that this loss is an annualized number for the entire country, not specific flood events.

Figure 1: Annual Probability of Exceeding Direct Economic Losses[14]



Additional Relevant Information

In 2010, FEMA used default analyses to estimate average annualized losses for flood for the entire nation by state. The estimated average annualized loss (AAL) addresses risk by estimating the probability of the loss occurring in the study area (largely a function of building construction type and quality). By annualizing estimated losses, the AAL factors in historic patterns of frequent, smaller events with infrequent but larger events to provide a balanced presentation of risk. The AAL analysis yielded an estimate of the national AAL of approximately $55 billion per year.

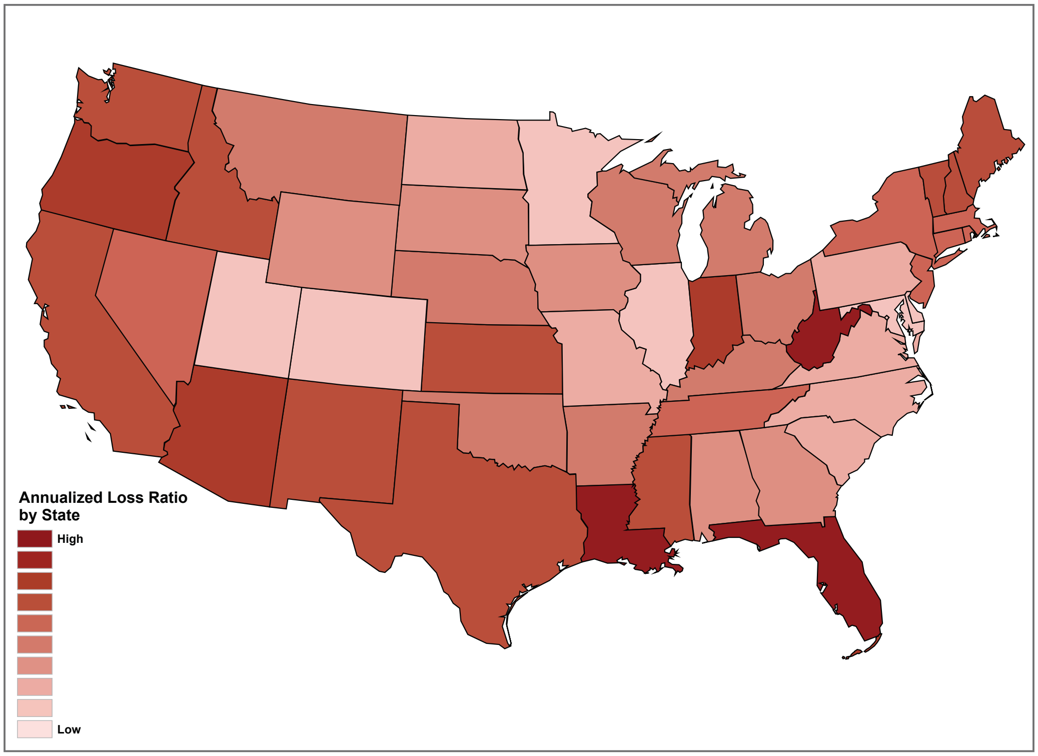
The annualized loss ratio (ALR) represents the AAL as a fraction of the replacement value of the local inventory. The ALR gauges the relationship between AAL and replacement value. This ratio can be used as a measure of vulnerability in the areas and, because it is normalized by

[14] Modeling done by FEMA HAZUS-MH contract support for the SNRA project team. Data, National Weather Service. Flood annual exceedance damage 1926-2000, 2010 dollars. Tabulated table 3-1, Pielke et al (2002), Flood damage in the United States, 1926-2000: A reanalysis of National Weather Service estimates. UCAR / University of Colorado, Boulder.

replacement value, it can be directly compared across different geographic units such as metropolitan areas or counties.

Figure 2 depicts the resulting state ALRs from this study, which helps to illustrate from a national perspective those areas that are more vulnerable to potential flood impacts. The states shown in dark red (Florida, Louisiana and West Virginia) have the highest expected ALRs among all states and therefore have a higher likelihood of experiencing flood losses in any given year.

Figure 2: Annualized Loss Ratios by State



Source: FEMA, June 2011[15]

[15] FEMA: HAZUS Average Annualized Flood Loss for the Contiguous United States, DRAFT June 2011.

Table 2: Flood Events

Description:	Date	Fatal	Injured	Econ Loss
Heavy rain in parts of OK, AR, and TX.	5/8/1993	5	0	$103,635,700
Extensive flooding due to 4 to 8 inches of rain in South Central Kansas.	5/8/1993	0	0	$157,000,000
Flooding in OK.	5/8/1993	0	0	$157,000,000
Great Flood of 93.	8/31/1993	0	0	$15,700,000,000
Steady rains in and around Springfield MO.	9/24/1993	1	0	$119,013,850
Flooding in SC and TN.	3/27/1993	3	0	$238,068,000
Heavy rains resulted in flash floods in PA and NY.	8/18/1994	3	6	$111,766,500
Texas flooding.	10/16/1994	15	0	$399,146,400
Flooding in Kern, Los Angeles and San Diego CA.	1/10/1995	0	0	$166,135,000
Flooding from Kern to Tulare CA.	3/1/1995	0	0	$168,072,000
Salinas River flooding in Monterey County CA.	3/10/1995	0	0	$447,000,000
Rain combined with snow melt caused flooding from VA to NY.	1/18/1996	22	1	$475,800,480
Melting snow and rain caused northern Oregon river flooding.	2/6/1996	7	0	$576,000,000
Record breaking rainfall fell over parts of north central and northeast Illinois.	7/17/1996	0	0	$111,888,000
Heavy thunderstorms in PA.	7/19/1996	2	1	$326,160,000
Damages in CA from rain combined with snow melt in the Sierra Nevada.	1/1/1997	3	52	$1,635,600,000
Melting snow and heavy rain in Southern Oregon.	1/1/1997	0	0	$126,900,000
Flooding from excessive rain in KY, OH, and WV.	3/1/1997	10	3	$153,368,520
Record 24 hour rainfall in Jefferson County, KY.	3/1/1997	2	0	$296,100,000
Sheyenne River flooding in ND.	4/8/1997	0	0	$5,428,500,000
Severe flash floods in MN and WI. Milwaukee Co. WI was extensively damaged.	6/20/1997	0	6	$141,751,530
Heavy rains resulting in flash floods in multiple counties of CO.	7/28/1997	5	40	$289,162,800
Large hail, strong winds and torrential rain hammered central CO.	8/11/1997	0	0	$180,480,000
A slow moving Nor'easter battered eastern VA.	2/4/1998	0	0	$104,250,000
Powerful El Nino-fed Pacific storm struck southern and central CA.	2/23/1998	5	3	$152,316,200
A slow moving weather system dumped large amounts of rain on AL.	3/8/1998	4	0	$165,389,150
An intense gulf storm dumped up to 14 inches of rain in AL and southwest GA.	3/8/1998	1	1	$543,490,000
Nearly six inches of rain in western counties of FL.	3/10/1998	0	0	$510,130,000
Agricultural damage due to a large Southern Sierra Nevada snow melt.	6/1/1998	0	0	$139,556,000
Sustained flooding through parts of East Central OH.	6/26/1998	10	0	$281,502,800
A series of slow moving thunderstorms moved through WI.	8/5/1998	2	5	$114,410,900
The Great October Flood in west Texas.	10/17/1998	25	4520	$559,266,500
Flooding from Devils Lake in ND.	8/5/1998	0	0	$136,000,000
Heavy rainfall in Jefferson and Franklin county MO.	5/7/2000	2	0	$132,660,000
Heavy thunderstorms in MN produced record rainfall amounts.	6/19/2000	0	0	$147,840,000
Thunderstorms with near torrential downpours in NJ.	8/12/2000	0	0	$237,996,000
Massive rainfall southwest FL, from low pressure system ahead of TS Leslie.	10/3/2000	0	0	$1,254,000,000
Flooding from rapid snow melt and rain.	4/1/2001	3	1	$256,000,000
Severe flash flooding in WV and VA.	7/8/2001	1	0	$280,748,800
High water in Columbia AR.	10/11/2001	0	0	$153,606,400
Flash floods in KY, VA, and WV.	5/2/2002	4	0	$141,233,400
Heavy rainfall caused the Roseau River to overflow the dikes of Roseau.	6/10/2002	0	0	$252,000,000
Heavy rains caused flooding in several counties of MS.	4/6/2003	2	0	$325,683,090
Flooding TN, GA and AL, most severe damage in Jefferson County AL.	5/5/2003	3	6	$1,474,800,000
Thunderstorm generated flash floods throughout OH.	7/21/2003	5	0	$288,261,570
A stationary front caused widespread flooding over Southeast Michigan.	5/23/2004	0	0	$120,000,000
Scattered to widespread heavy rains across south-central and southeast WI.	6/1/2004	0	0	$301,860,000
A stalled storm system dumped rain throughout many portions of UT.	1/10/2005	1	6	$348,000,000
Widespread flooding in several CA counties due to heavy rainfall.	12/30/2005	0	0	$476,298,320

Table 3: Social Displacement and Damage Estimates from EM-DAT

Start (DD/MM/YY)	End (DD/MM/YY)	Location[1]	EM-DAT Total Affected	EM-DAT Est. Damage (US$ Million)
09/06/1972	09/06/1972	Rapid City (South Dakota) ...	3,000	120
22/07/1977	22/07/1977	Johnstown (Pennsylvania)	2,700	200
19/02/1980	19/02/1980	South California	106,000	350
06/01/1993	20/01/1993	California, Arizona, Neva ...	6,000	100
28/02/1993	28/02/1993	N/A	5,200	190
24/06/1993	23/08/1993	Oklahoma, Minnesota, Wis ...	31,000	12,000
17/10/1994	23/10/1994	Houston, Galveston (Texas ...	14,070	700
07/05/1995	13/05/1995	Louisiana (New Orleans)	20,000	3,000
28/11/1995	10/12/1995	Washington, Oregon	15,000	100
15/01/1996	21/01/1996	Nevada, Arizona, New Mexi ...	200,000	700
07/02/1996	13/02/1996	Washington, Oregon, Idaho ...	24,900	500
27/12/1996	03/01/1997	Washington, Oregon, Nevad ...	18,100	1,500
01/01/1997	07/02/1997	Nevada, Idaho, California ...	125,000	1,500
17/04/1997	07/05/1997	Grand Forks, Fargo	50,400	5,000
25/07/1997	01/08/1997	Fort Collins (Northern Co ...	424	100
07/03/1998	13/03/1998	S Alabama, N and C Georgi ...	18,000	270
13/06/1998	17/06/1998	Iowa, Indiana, , Illinois ...	1,000	201
24/06/1998	01/07/1998	Kansas, IA, MO, Illinois, ...	14,000	469
23/05/2000	23/05/2000	Franklin, Jefferson, Gasc ...	300	100
12/08/2000	14/08/2000	Morris (Sussex county, Ne ...	175	166
30/06/2002	23/07/2002	New Braunfels, Bandera, U ...	144,000	1,000
05/07/2003	21/07/2003	Carroll, Adams, Cass, How ...	1,200	106
07/01/2005	11/01/2005	La Conchita, Ventura coun ...	508	200
17/02/2005	23/02/2005	Los Angeles, region (Cali ...	150	250
31/12/2005	18/01/2006	Napa, Sonoma, Mendocino, ...	3,600	245
04/04/2006	17/04/2006	Amador, Calaveras, Fresno ...	600	259
25/06/2006	01/07/2006	Maryland, Pennsylvania, N ...	65,000	1,000
16/08/2007	27/08/2007	Illinois, Colorado, Mich ...	2,840	700
24/03/2009	20/04/2009	North Dakota, Minnesota	5,060	166
20/09/2009	21/09/2009	Douglas, Floyd, Carroll, ...	3,000	500

*Note: EM-DAT data from June 2008 Midwest floods is not included because "total affected" estimate (11 million) is a large outlier which could not be independently validated against news reports.

[1] EM-DAT truncates long fields.