Flood Damage in the United States, 1926–2000

A Reanalysis of National Weather Service Estimates

by

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Cover photo credit: East Grand Forks, Minnesota, April 1997: An eerie calm settles on the water in this East Grand Forks neighborhood. Many homes floated off their foundations, all received significant damage. Photo by David Saville, Federal Emergency Management Agency.

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EXECUTIVE SUMMARY

Flood damage continues to increase in the United States, despite extensive flood management efforts. To address the problem of increasing damage, accurate data are needed on costs and vulnerability associated with flooding. Unfortunately, the available records of historical flood damage do not provide the detailed information needed for policy evaluation, scientific analysis, and disaster mitigation planning.

This study is a reanalysis of flood damage estimates collected by the National Weather Service (NWS) between 1925 and 2000. The NWS is the only organization that has maintained a long-term record of flood damage throughout the U.S. The NWS data are estimates of direct physical damage due to flooding that results from rainfall or snowmelt. They are obtained from diverse sources, compiled soon after each flood event, and not verified by comparison with actual expenditures. Therefore, a primary objective of the study was to examine the scope, accuracy, and consistency of the NWS damage estimates to improve the data sets and offer recommendations on how they can be appropriately used and interpreted.

This report presents the following three data sets, which are also available on the World Wide Web at www.flooddamagedata.org:

- Estimated flood damage in the U.S. (1926–1979 and 1983–2000, by fiscal year;
- Estimated flood damage for each state in the U.S. (1955–1979, by calendar year, and 1983–2000, by fiscal year); and
- Estimated flood damage, by river basin, for the U.S. (1933–1975, by calendar year).

We found that the NWS collection and processing of flood damage data were reasonably consistent from 1934 to the present, except during the period 1976–1982. Data from NWS files and other sources made it possible to reconstruct state and national flood damage estimates for 1976–1979. However, little data was collected during 1980–1982 and large errors were discovered in estimates developed later for that period. As a result, the years 1980–1982 are excluded from the reanalyzed data sets.

Evaluation of the accuracy of the estimates led to the following conclusions:

1. *Individual damage estimates for small floods or for local jurisdictions within a larger flood area tend to be extremely inaccurate.* When damage in a state is estimated to be less than $50 million (in 1995 dollars), estimates from NWS and other sources frequently disagree by more than a factor of two.

2. *Damage estimates become more accurate at higher levels of aggregation.* When damage in a state is estimated to be greater than $500 million, disagreement between estimates from NWS and other sources are relatively small (40% or less). The relatively close agreement between NWS and state estimates in years with major damage is reassuring, since the most costly floods are of greatest concern and make up a large proportion of total flood damage.

3. *Floods causing moderate damage are occasionally omitted, or their damage greatly underestimated, in the NWS data sets.* Missing NWS estimates were discovered for floods in which the state claimed as much as $50 million damage.

In summary, the NWS flood damage estimates do not represent an accurate accounting of actual costs, nor do they include all of the losses that might be attributable to flooding. Rather, they are rough estimates of direct physical damage to property, crops, and public infrastructure. Estimates for individual flood events are often quite inaccurate, but when estimates from many events are added together the errors become proportionately smaller.

At the national level, these findings suggest that annual damage totals are reasonably accurate because they are sums of damage estimates from many flood events. State annual damage estimates are more problematic. Both frequency and magnitude of damage must be considered, because damaging floods do not occur every year in most states. Flood frequency cannot be determined simply by the presence or absence of a damage estimate because reporting, particularly for small floods, is unreliable.

Aggregation is a key to reducing estimation errors. To compare flood damages between states, aggregate the damage estimates over many years and compare the sums. To compare damage between years, aggregate yearly state damage estimates over multi-state regions. Even when the estimates are highly aggregated, be aware that a substantial amount of variability is caused by estimation errors and interpret the results accordingly.

When properly used, the reanalyzed NWS damage estimates can be a valuable tool to aid researchers and decision makers in understanding the changing character of damaging floods in the United States. Users of the reanalyzed data are advised to take the following precautions:

- To compare flood damage over time, adjust for changes in population, wealth, or development.
- To compare damage in different geographical areas, control for differences in population and in the incidence of extreme weather events during the period of study.
- Use damage estimates for individual floods with caution, recognizing that estimation errors are large. Comparison of individual floods might be better done using nominal or ordinal damage levels. Look for qualitative descriptions to compare the nature and impacts of the damage.
- Different agencies define “flood” and “flood damage” somewhat differently. Check for incompatibilities between data from different sources before seeking to combine sources or aggregate data.

The NWS damage estimates are not reliable enough to be a basis for critical decisions, such as setting flood insurance premiums or evaluating the cost-effectiveness of specific hazard mitigation measures. Better damage data are needed to evaluate the effectiveness of specific mitigation measures designed to reduce flood losses.

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1. INTRODUCTION

A. Why We Need Historical Flood Damage Data

The National Weather Service (NWS) estimates that flooding caused approximately $50 billion damage in the U.S. in the 1990s (NWS-HIC 2001). Although flood damage fluctuates greatly from year to year, estimates indicate that there has been an increasing trend over the past century (Pielke and Downton 2000). Some have speculated that the trend is indicative of a change in climate (e.g., Hamburger 1997), some blame population growth and development (e.g, Kerwin and Verrengia 1997), others place the blame on federal policies (e.g., Coyle 1993), and still others suggest that the trend distracts from the larger success of the nation's flood policies (e.g, Labaton 1993).

To understand increasing damage and assess implications for policy, decision makers need to resolve the independent and interdependent influences of climate, population growth and development, and policy on trends in damage. Increased flood damage due to changing climate requires different policy actions than would damage increases due to implementation of flood policies.

The available records of historical flood damage are inadequate for policy evaluation, scientific analysis, and disaster mitigation planning. There are no uniform guidelines for estimating flood losses, and there is no central clearinghouse to collect, evaluate, and report flood damage. The data that exist are rough approximations, compiled by the NWS from damage estimates that are reported in many different ways. Moreover, most published summaries of the damage estimates focus primarily on aggregate national damage totals.

Scientists need historical flood damage data at a variety of spatial scales to analyze variations in flood damage and what contributes to them. For example, during El Niño years, southern California receives more precipitation than in the typical year. Conventional wisdom suggests that the increase in precipitation should result in an increase in damaging floods. If California's emergency planners knew this to be the case, they could prepare for the floods that come with El Niño, possibly reducing damage. In this case, scientists looking for a causal relationship would want to determine to what degree historical high damage years in southern California are associated with El Niño events. This requires sub-state-level data sets, rather than a national data set.

Social scientists looking at the effect of policies designed to reduce flood damage also need access to historical data at regional and local scales. Take the example of the National Flood Insurance Program, created in 1968 to "assist in reducing damage caused by floods" (42 U.S.C. § 4102 (c)(3)). Researchers evaluating the program would like to isolate the effect of the program from all other factors influencing flood damage in particular areas. At the river basin or community level, the effect of a federal policy implemented in 1968 might be isolated and measured.

In sum, historical damage data are essential for any study that seeks to understand the role that climate, population growth and development, and policy play in determining trends in flood damage. Some studies might require data at the national level, and others at the state or local level. Moreover, researchers need guidance to use the data effectively. Some data sets are not accurate enough for certain types of analysis.

B. Sources of Historical Flood Damage Data

Ideally, a national database of historical flood damage should cover the entire country over a long time period, using consistent criteria and methods in all times and places. Table 1-1 compares possible sources of damage data. The National Weather Service is the only organization that has maintained a long-term and fairly comprehensive record of flood damage throughout the U.S. Insurance company records include only insured property. Records of the Federal Emergency Management Agency (FEMA) include only property that qualifies for federal assistance in presidentially declared disasters. Few state and local governments maintain damage records beyond those required by FEMA. Only in newspaper archives from cities and towns across the nation might one find more complete reporting of historical flood damage. Indeed, a newspaper archive could be the best source of information on flood damage in a particular locale. But the parochial nature of such data makes aggregation problematic.

For long-term coverage of the entire nation, and of most states, the NWS data sets appear to be the best available source of flood damage estimates. However, the scope, accuracy and consistency of the data must be evaluated to determine how they can be appropriately used and interpreted.

C. Scope of the NWS Flood Damage Data

The NWS Hydrologic Information Center (NWS-HIC 2001) describes the data as "loss estimates for significant flooding events," providing estimates of "direct damages due to flooding that results from rainfall and/or snowmelt." However, key concepts such as "flood" and "flood loss" are defined differently by various agencies and researchers depending on their objectives. Appropriate use of NWS damage data requires understanding of what is and is not included.

Types of Flooding

Ward (1990) defines a flood broadly as "a body of water which rises to overflow land which is not normally submerged." This definition covers river and coastal flooding, rainwater flooding on level surfaces and low-gradient slopes, flooding in shallow depressions which is caused by water-table rise, and flooding caused by the backing-up or overflow of artificial drainage systems.

The NWS includes damage from most types of flooding listed above, but excludes ocean floods caused by severe wind (storm surge) or tectonic activity (tsunami). These are excluded because, although they result in water inundation, they are not hydrometeorological events. In addition, the NWS excludes damage that results from mudslides because, though they are caused by excess precipitation, they are considered primarily a geologic hazard.

Table 1-1. Sources of flood damage estimates.

Source	Timespan	Spatial Scale	Scope
National Weather Service flood damage data sets	1925–present	Nation State Basin	Estimates of direct physical damage from significant flooding events that result from rainfall or snowmelt
Insurance records (National Flood Insurance Program, private insurers)	1969–present	Nation Community	Personal property claims made by individuals holding flood insurance
Disaster assistance records (Federal Emergency Management Agency)	1992–present	Nation State	Federal and state outlays for public assistance, individual assistance, and temporary housing in presidentially declared disasters
State and local government records	Varies	State	Varies
Newspaper archives	Varies	Community	Varies

Definition of Loss, Damage, and Damage Estimates

Researchers specializing in natural hazards have expressed a need for more complete documentation of losses, including both direct and indirect costs associated with flooding (Mileti 1999; National Research Council 1999; Heinz Center 2000). Direct costs are closely connected to a flood event and the resulting physical damage. In addition to immediate losses and repair costs they include short-term costs stemming directly from the flood event, such as flood fighting, temporary housing, and administrative assistance. By contrast, indirect costs are incurred in an extended time period following a flood. They include loss of business and personal income (including permanent loss of employment), reduction in property values, increased insurance costs, loss of tax revenue, psychological trauma, and disturbance to ecosystems. They tend to be more difficult to account for than direct costs (Heinz Center 2000).

The NWS describes its flood loss data as estimates of "direct damages" including, for example, loss of property and crops and costs of repairing damaged buildings, roads, and bridges. The NWS estimates have usually been restricted to *direct physical damage*, a subset of the losses generally considered to be direct costs.

The dollar figures in the NWS damage data are estimates compiled soon after each flood event, before the actual costs of repair and replacement can be known. They are not verified by comparison with actual expenditures. The estimates are gathered from diverse sources, some who use accurate estimation methods (e.g. insurance companies) and others who do not (e.g. newspapers). Therefore, NWS damage data are best described, not as "loss data", but as "*damage estimates*."

D. Purpose and Methods

Objectives of this study are (1) to assemble a national database of historical flood damage based on NWS damage estimates, making it as complete and consistent as possible; (2) to describe what the estimates represent; (3) to evaluate the accuracy and consistency of the estimates; and (4) to develop guidelines for use of the data and make it widely available to users. Steps followed to achieve these objectives are described below.

1. Compilation of historical flood damage data sets.

The NWS Hydrologic Information Center (NWS-HIC) is responsible for compiling and archiving flood damage estimates collected from NWS field offices throughout the U.S. Its staff members provided several data sets and access to files and publications archived in their office at Silver Spring, Maryland. This report augments published NWS data with information from NWS files and reports of other federal and state agencies. The following data sets are presented:

a. Estimated flood damage in the United States (1926–1979 and 1983–2000, by fiscal year);
b. Estimated flood damage for each state in the U.S. (1955–1979, by calendar year, and 1983–2000, by fiscal year); and
c. Estimated flood damage, by river basin and drainage, for the U.S. (1933–1975, by calendar year).

2. Review of data collection and reporting methods used by the NWS.

In interviews, staff of NWS-HIC and two NWS field offices described their data and recent data collection procedures. NWS-HIC documents and several editions of the NWS Operations Manual provided additional information on past and present procedures. This report describes the nature of the damage estimates and provides a guide to their interpretation and use.

3. Evaluation of accuracy and consistency of the damage estimates.

This report critically examines criteria and methods used by the NWS in collecting past and present damage estimates to identify likely sources of inaccuracy. To understand the inaccuracy generally inherent in damage estimation, the report uses statistical comparison methods to assess a California data set containing both preliminary damage estimates and actual cost information. Then it uses similar statistical methods to compare NWS damage estimates with independent estimates from state sources to evaluate the variability in flood damage estimates. Finally, it assesses the impacts of errors and omissions on aggregated damage estimates.

4. Development of guidelines for use of the data.

Evaluation results show substantial errors in many of the damage estimates. Uncertainty about the accuracy of the estimates implies that comparisons of flood damage estimates from different flood events or different locations must be undertaken with caution. The report presents examples that illustrate appropriate and inappropriate ways of using the damage data and suggests ways of reducing the impact of errors.

The data and an associated Users Guide are available on the World Wide Web, at **www.flooddamagedata.org**.

E. Organization

This report is organized as follows. Section 2 describes NWS procedures for obtaining damage estimates and other sources used in compiling the reanalyzed data sets. Section 3 presents the reanalyzed data sets and explains how they were developed. Section 4 describes the types of inaccuracy users should expect in the damage estimates. Section 5 compares damage estimates from different sources and analyzes the accuracy of the estimates. Section 6 suggests ways of dealing with data omissions and inconsistencies. Section 7 provides guidance for use and interpretation of the reanalyzed data, with examples and warnings, and concludes with recommendations regarding future collection and dissemination of flood damage estimates.

2. SOURCES OF FLOOD DAMAGE ESTIMATES, 1926–2000

For nearly a century, the NWS and its predecessor, the U.S. Weather Bureau, have collected flood damage estimates through a nationwide system of field offices. The quality of the flood damage estimates is uneven, depending on operational constraints at particular field offices and diverse sources of damage reports. Policies and procedures for collecting and compiling the estimates have changed somewhat in the course of time.

A. Overview of Historical NWS Estimates

The NWS has published flood damage estimates almost annually since 1933. From 1933 to 1975, reporting units were defined by natural boundaries (river basins), which could be useful for local planning on issues such as water supply, agriculture, and flood control. In 1955, annual summaries of damage by state were added. Consistent administration, methodology, and format of the published reports suggest that these data form a reasonably homogeneous time series.

From 1976 through 1979, reduction of funding led to cutbacks in the compilation of flood damage data. Data collection was consistent with prior years, but there appears to have been less checking and updating of initial damage information. Publication of annual summaries ceased. In 1980, compilation of flood damage estimates was discontinued entirely.

In 1983, Congress ordered the U.S. Army Corps of Engineers (USACE) to provide annual reports of flood damage suffered in the U.S. The USACE contracted with the NWS to provide the required data. NWS estimates of flood damage in each state have been published annually since 1983 by the USACE. The NWS Hydrologic Information Center (NWS-HIC) has gradually improved its procedures for compiling and checking the damage estimates.

The long-term consistency in collection of flood damage data results from its connection to weather forecasting and storm warning operations of the NWS. Since at least 1950, reports on severe storms have been submitted regularly to NWS headquarters from field offices distributed across the U.S. The reports include descriptions of severe storms and associated deaths and damage. Since 1959, these reports have been published monthly in a NOAA periodical, *Storm Data*, and have provided the initial information used in compiling flood damage estimates. However, the field office reports are filed soon after the storm events and receive only minimal quality control before publication, thus the damage estimates provided are preliminary and incomplete. Staff at NWS headquarters perform considerable checking and follow-up to produce final flood damage estimates.

This brief overview highlights a major change in the purpose and format of the flood damage data. Before 1980, the NWS compiled damage estimates for meteorological and hydrological purposes, based on natural units such as watersheds. Annual estimates were compiled by calendar year. Since 1983, the USACE and NWS have prepared flood damage information for Congress, whose members focus on the state as a political unit. Estimates are compiled by federal fiscal year.

B. Present Methods of Compiling Flood Damage Estimates

The staff of NWS-HIC willingly answered our questions about methods used in recent years to collect and compile damage estimates. However, none had direct experience with the methods used before 1989. They provided to us copies of their flood damage data sets and made available all of the materials in their historical archives, including publications of federal agencies, files containing flood reports submitted monthly by the NWS field offices, and notes made by former staff who compiled the data into annual reports.

The NWS operates approximately 120 field offices distributed across the U.S. and its territories. Each office provides weather and hydrological forecasts for an assigned area and issues warnings during severe weather and flood events. Most offices have a Warning Coordination Meteorologist (WCM) who issues storm and flood warnings in the forecast area. The WCM is also responsible for submitting monthly reports on severe storm events to the NWS, including deaths and estimates of damage to property and crops. The descriptions, deaths, and damage estimates are published monthly in *Storm Data.*

Compiling estimates of storm damage is a minor part of the job, receiving little attention from many WCMs (Frank Richards, NWS-HIC, personal communication, 2/16/00). Field offices differ greatly in the regularity and completeness of their damage reports. Their staff obtain damage estimates from numerous local sources, and cannot always know how those estimates were made and what is included.

A meteorologist at NWS-HIC is responsible for collecting flood damage reports from all of the field offices and checking the damage estimates. NWS-HIC staff are in a good position to track damaging floods because they receive the first flood and flash flood warnings issued by all of the field offices and produce the daily National Flood Summary (NWS-HIC website under Current Flooding). They also receive monthly summaries of significant hydrological events from the field offices. Hence the meteorologist is aware of most flooding events as they occur, receives narrative descriptions monthly, and can check whether estimates are received for all severe floods.

Floods that appear to involve less than $50,000 in damage are entered into the database but generally not checked for accuracy or completeness. When it appears that damage could exceed $50,000, and estimates are missing or seem unreasonable based on descriptions of weather and flood conditions, other reports (e.g. news accounts), and prior experience in compiling damage records, the meteorologist contacts the field office and asks for more information and better estimates. In practice, it is often difficult to clearly separate the estimates of damage to property and crops. Therefore, in recent years, NWS-HIC has combined the estimates of property and crop damage into a single damage estimate.

In most cases, damage information is collected within three months after the flood event. It is most difficult to get the information for large floods because attention in the field office is focused on other more urgent tasks related to the event.

Historically, field office personnel obtained their damage estimates primarily from newspapers (Paul Polger, NWS, pers. comm., 2/16/00). Today, however, they obtain estimates through a variety of contacts in their area such as emergency managers, insurance agents, and local officials. Many offices also subscribe to a newspaper service, which allows the staff to search for any story having to do with weather.

Newspapers and emergency managers are the best sources of information, according to a WCM in Boulder, Colorado (Robert Glancy, NWS, pers. comm., 8/24/01). If a flood has received a presidential disaster declaration, information can be obtained from damage assessments by Federal Emergency Management Agency (FEMA) storm survey teams that travel to the flood scene. Estimates of damage to insured property can be obtained from local insurance agents. However, the estimation process is not performed with rigorous attention to accuracy. One WCM described using the following procedure: Since the largest insurer handles about 25% of the insured property in the local area, an estimate of insured losses is obtained by getting a cost estimate from that insurer and multiplying by four (John Ogren, NWS, pers. Comm., 8/29/01). A full survey of each damaged structure does not take place; instead, in many cases a simplifying formula is used to estimate damage (John Ogren, pers. comm., 8/29/01).

Crop damage estimates are obtained from U.S. Department of Agriculture (USDA) agents or from monthly "flash" reports that are compiled from claims that farmers make to USDA. Damage is calculated based on expected return on the crop: Average yield is multiplied by the number of acres damaged, the estimated percentage of the crop lost, and the expected sale price based on the market at the time of event (John Ogren, NWS, pers. comm., 8/29/01). Unlike property damage, the estimates of crop damage rely on self-reporting by farmers and permit reports to be submitted up to 60 days after the event. After a major flood event market prices often rise so that, by the time of filing, the market price claimed may be higher than the market price at the time of the flood event.

Storm Data's compilers vary widely in terms of training and expertise (Frank Richards, pers. comm., 6/27/01). NWS provides operations manuals to its staff, which explain how to collect and report flood damage. However, one compiler reports that he received most of his training from previous employees who had experience with *Storm Data* compilation. He was referred to NWS manuals after he had been doing the job for some time (Frank Cooper, pers. comm. 8/27/01).

Instructions for estimating damage have changed in successive versions of the NWS Operations Manual. For example, the 1985 revised manual required that damage estimates be entered by checking off damage categories (though actual dollar amounts could be entered in the narrative section of a report), and specified that damage below $5,000 could be omitted or entered as zero. Furthermore, the manual stated, "Damage resulting from flash floods and floods should be reported only if it is the result of local rainfall but not if it is the result of heavy rain upstream, i.e., that which fell more than 24 to 48 hours in advance of the flooding" (NWS 1985, chap. 42, p. 14). In other words, NWS wished to collect damage estimates only for floods that were the result of localized precipitation. It is uncertain how widely this rule was followed, but it was eliminated less than a decade later. In the 1994 revised manual, instructions simply state, "Damage resulting from flash floods and floods should be reported by each office in whose county area of forecast responsibility the damage was reported." The 1994 revision also eliminated the use of damage categories, specifying that damage estimates should be entered as actual dollar amounts, rounded to three significant digits. The manual further advised, “Focus attention on providing reasonable estimates of larger events (damages greater than $100,000)” (NWS 1994, chap. 42, p. 10).

The field office procedures for collecting flood damage data have some notable strengths and weaknesses. Damage estimators trained by their predecessors are likely to maintain continuity in the data sets, because the training ensures that collection methodology does not change from employee to employee. However, since the NWS operations manual is not always used for guidance, employees may overlook changes in official NWS data collection policies.

C. Sources of Historical NWS Estimates

The NWS and the U.S. Weather Bureau published flood reports regularly in five publications from 1918 through 2001. Table 2-1 summarizes the time periods covered and the information provided by each of these sources. In the early years, damage estimates were published only after major flood events. Annual reporting of flood damage throughout the U.S. commenced in 1933.

From 1934 to 1975, the River and Flood Service published monthly flood reports and annual summaries of flood damage by river basin, first in *The Monthly Weather Review* and later in *Climatological Data National Summary*. Two formats were consistently used for the annual summaries, one during 1934–1947, the other during 1948–1975. Annual damage estimates by state for calendar years 1955–1975, and monthly damage estimates for the nation during 1925–1975, were calculated and published in later reports (NWS 1975, 1977).

The 1978 annual summary issue of *Climatological Data National Summary* announced “Compilation of the General Summary of National Flood Events and Flood Damage Statistics has been delayed. These data will be published later.” However publication of *Climatological Data National Summary* ceased the following year.

For several years after the demise of *Climatological Data National Summary*, the only published NWS records of flood damage were those included in *Storm Data* monthly reports. As noted above, these reports often were incomplete and received little checking. Until 1995, most damage estimates were indicated by marking a damage category. (Difficulties of using estimates based on the damage categories are discussed in Section 4.) Until the mid-1970s, the cause of damage was often listed as “heavy rain”, rather than “flood”, even when flood damage was mentioned in the description. Flood descriptions gradually became more detailed in the 1980s. In general, the flood descriptions provide ample information about precipitation and river flows, but only brief mention of damage.

Table 2-1. Published sources of flood damage estimates from the NWS and U.S. Weather Bureau (WB).

Publication	Years of Flood Damage Included	Spatial Aggregation	Time Periods Summarized	Information Provided
Report of the Chief of the Weather Bureau (WB)	1918–1933	River basin	Water year (Oct – Sep)	Describes large flood events. Occasionally gives flood damage estimates for individual large events. (First national flood damage total reported in 1934.)
Monthly Weather Review (WB, 1934–1949)	1933–1947	River basin	Calendar year	Annual summaries describe damage in major floods. Tables give estimated damage for all major river drainages.
Climatological Data, National Summary (WB, NOAA, 1950–1977)	1948–1977	River basin	Calendar year	Monthly summaries describe flood damage and deaths in "notable" flood events. Annual summaries through 1975 give tables of damage in major river drainages. General summaries for 1972 and 1975 also give damage by state for each calendar year since 1955 and national flood damage and deaths by month and year since 1925.
Storm Data (WB, NOAA)	1959–present	County or multi-county area	—	Monthly reports on storm events sometimes give brief descriptions of damage. Estimated damage to property and crops checked off on logarithmic scale until 1994, reported in thousands of dollars since 1995.
Annual Flood Damage Report to Congress (USACE)	1983–present	State	Federal fiscal year (Oct – Sep)	Annual reports describe major flood events and provide table of flood damages suffered, by state. Recent reports give 10-year summary tables of flood damage and deaths, by state.

In 1983, when Congress asked the USACE for annual reports of flood damage suffered, *Storm Data* was the only available nationwide source of damage estimates. Under contract to USACE to provide estimates, NWS-HIC compiled the limited information available. In the years that followed, methods of compiling and checking the estimates were established and gradually improved. These estimates are published annually in the *U.S. Army Corps of Engineers Annual Flood Damage Report to Congress* (USACE 1983–2001).

In the USACE damage reports from 1983 to 1988, narrative descriptions of floods are quite brief (½ to ¾ page). Many states have no damage estimate but an asterisk (*) indicates that flooding occurred. The 1984 report explains that the table gives a summation of all major flood events but that damage estimates are unavailable for minor flood events. After 1988, the descriptions of flooding and flood damage are more detailed. Beginning in 1991, the asterisk is no longer used and there are few zero entries in the tables. It appears that considerably more record keeping and analysis has gone into damage reports since 1989.

Table 2-2 lists the types of flood loss reported in each of the above publications. From 1933 to 1977, estimates were divided into several categories, separated into property and agricultural damage, compiled by river basin, and presented by calendar year. In 1983, the loss categories, spatial scale, and time period changed. Estimates were summarized by state and fiscal year. In 1993, the distinction between property and agricultural damage was eliminated. Throughout the entire period, estimates focused on direct physical damage, though some data on loss of business and wages were included before 1947. Little is known about the methods used to compile and check the estimates prior to 1980. The published reports themselves show an intent to include all parts of the United States and all types of physical damage.

D. Additional Sources of Flood Damage Estimates

To compile and evaluate a continuous time series of damage estimates, we supplemented the NWS estimates with comparable data from other sources. Comparable estimates should represent direct physical damage in significant flood events. Extensive information would be required to fill the 1976–1982 gap in the state and national estimates. In addition, independent estimates or cost information were needed to assess the accuracy of the estimates. Reports from many sources were used to confirm damage estimates and to provide information about specific floods.

Reports by Federal Agencies and Task Forces

Several federal agencies prepare reports after severe flood events, in order to study the causes of particular floods and recommend improvements in systems of flood monitoring, warning, or control. Some of these reports include descriptions of earlier floods in the community, and some provide damage estimates.

Table 2-2. Types of flood loss reported during each era.

Reporting Years	Publications	Types of Flood Loss Consistently Included
1933–1946	*Monthly Weather Review*	Tangible property totally or partially destroyed Prospective crops Matured crops Livestock and other movable farm property Suspension of business, including wages of employees
1947 1948–1977	*Monthly Weather Review* *Climatological Data, National Summary*	Urban Property Residential Commercial Public Rural Property Crops Livestock Other Other Property Railroads, bridges, highways, etc. Public utilities Miscellaneous Unclassified
1959–present	*Storm Data*	Property damage Crop damage
1983–1992 --------------- 1993–present	*Annual Flood Damage Report to Congress*	Property damage Agricultural losses --------------------- Damages suffered

Post-flood reports prepared by district offices of the U.S. Army Corps of Engineers (USACE) often provide fairly detailed damage estimates that are more complete than NWS estimates because they are compiled many months after the flood event. The Tennessee Valley Authority (TVA) publishes post-flood reports, similar to USACE reports, for areas of the southeastern U.S. under its jurisdiction. Post-flood reports from USGS, NOAA, and the U.S. Weather Bureau usually focus on hydrological and meteorological conditions preceding and during the flood event, with only brief mention of damage. If damage estimates are provided, often they are obtained from the NWS or the USACE.

FEMA has appointed special task forces to study particular major floods and recommend mitigation measures (for example, Interagency Hazard Mitigation Teams for each state affected by the 1993 Midwest flood). Their reports often contain damage estimates.

National Water Summary 1988–1989: Hydrologic Events and Floods and Droughts (USGS 1991) provides historical flood information for all fifty states through 1989. In particular, floods that are considered major historical events for each state are listed, including some damage estimates for individual floods.

State Reports

State government agencies occasionally publish post-flood reports after particular flood events. To obtain additional, perhaps unpublished, information, we wrote to emergency management agencies in each state, asking them to provide information about historical flood damage. Five states were able to provide long-term historical summaries of their damaging floods, and these proved invaluable for analyzing the accuracy of the NWS estimates (see Section 5). Other states sent shorter-term information which provided useful examples.

Unpublished NWS Damage Information

The NWS-HIC staff provided copies of their state and national flood damage data sets. These data sets included unpublished estimates for 1976–1982; however, the state and national estimates were found to be incompatible, as described in Section 3. Staff members also gave us access to the historical archives at their office in Silver Spring, MD. Two sets of files proved helpful in understanding how damage estimates were compiled in the past, and were used to supplement estimates for 1976–1982.

Monthly files for 1971–1995 contain the original flood reports from field offices all over the U.S., in no particular order. (These were discontinued when electronic submission of reports began in 1996.) The reports often contain descriptions of damage, but only occasionally provide damage estimates. They do not provide a basis for computing total damage by state or river basin.

Yearly files contain notes made by the people who compiled damage estimates, as well as news clippings and agency communications during the year. These are extremely helpful in developing estimates for 1976–1979, as they contain preliminary annual damage estimates with notes on when and where major floods occurred.

Articles on flash flood damage in 1978 and 1979, published in the journal *Weatherwise* (Marrero 1979, 1980), were written by José Marrero who had been responsible for collecting the flood damage data formerly published in *Climatological Data*, *National Summary*. These articles provide many of our state damage estimates for those years.

E. Summary

The NWS effort to collect flood damage estimates has been remarkably consistent across the nation and over long time periods, resulting in the only source of long-term national flood damage information available in the United States. Similar procedures have been used to obtain estimates from field offices throughout the country, at least since 1950 and perhaps longer. Annual summaries were compiled using consistent methodologies and published in uniform formats during two extended periods, from 1933 through 1975, and from 1983 up to the present.

To create continuous time series of state and national damage estimates requires obtaining compatible estimates for the missing years, 1976–1982. It would also be desirable to base all the data on the same calendar, either fiscal years or calendar years. These tasks are addressed in Section 3.

The accuracy of the damage estimates is uncertain. Methods used to obtain the estimates suggest that they are often educated guesses. For many years they came primarily from newspaper reports. Today, short cuts are often used to extrapolate from a few good sources to make an estimate for an entire community. Evaluation of the accuracy of the estimates is undertaken in Sections 4 and 5.

3. DEVELOPMENT OF THE DATA SETS

The national data obtained from NWS consisted of annual total damage estimates for the U.S., including three territories: Puerto Rico (since 1975), the Virgin Islands (since mid-1980s), and Guam (since 1994). The state data contained annual damage estimates for each state and, in recent years, the three territories. In the national data, we subtracted estimates for the three territories from the U.S. totals to create a more uniform time series representing only the 50 states.

NWS estimates were spot-checked against those from other agencies. Estimates that appeared to be extremely large or small compared to published accounts of events were examined especially closely. In individual events that received follow-up study by the USACE, more accurate estimates were sometimes available. However, except during 1976–1982, there exists no compelling reason to change the NWS estimates or defer to another agency's estimates. Section 5 provides a quantitative assessment of uncertainty in the estimates and the implications for their effective use.

With a few important exceptions, the estimates presented as a result of this project have their origins in published NWS data. Obvious clerical errors have been corrected (see Section 4).

A. Resolving the Data Gap, 1976–1982

To compile a complete time series of annual estimates required finding additional flood damage estimates for the years 1976–1982. As explained in Section 2, NWS ceased publication of annual flood damage summaries after 1975. Publication of comparable damage estimates did not resume until 1983, when USACE reports made damage estimates available again at the state and national levels, but not at the river basin level.

To make the state and national data sets as complete as possible, we focused on obtaining and evaluating estimates for 1976 through 1982. The NWS website (NWS-HIC 2001) included previously unpublished national flood damage estimates for 1976–1982, and an NWS spreadsheet included unpublished state estimates for that period. However, the national estimates and the state total estimates differed by large margins. An old, undocumented NWS computer printout tallied individual floods, by state, in the years 1976–1988, but we found it to be filled with errors and inconsistencies.

Despite a curtailment of effort, the NWS continued to compile some damage estimates during 1976–1979, which served as a starting point for our reconstruction attempts. We were able to develop estimates for 1976–1979 based on information in the NWS files and reports from other sources, as described in Appendix A.

Although we tried to reconstruct estimates for 1980–1982, there were not enough sources of information, either from NWS or other agency publications, to provide estimates for those years comparable to the data in the overall data set. Furthermore, there were some large disparities between estimates found in the NWS-HIC archives for the period 1980–1982 and damage estimates provided by states, leading us to conclude that some of the damage estimates for this time period are highly unreliable (see Section 5). Therefore, estimates for 1980–1982 are not included in the reanalyzed data sets, and we judge that data published by NWS for this period is of consistently lower quality than in other years.

A few general comments can be made about 1980–1982. Flood damage descriptions in *Storm Data*, which were sparse in previous years, became even rarer in 1980–1981. The information that does exist for the period suggests that 1980 and 1981 were extremely dry years in most parts of the country, so flood damage was probably small compared to other years (Wagner 1982, USGS 1991, notes in NWS files). On the other hand, descriptions in *Storm Data* suggest that flood damage rose to a higher level in 1982, perhaps close to the average level of that time.

B. Annual National Flood Damage Estimates (1926–1979, 1983–2000)

Since flood damage estimates for 1983 through 2000 are available only for fiscal years (October–September), it is desirable to compile the entire national flood damage data set using fiscal years. Fortunately, in its annual flood damage summary for 1975, *Climatological Data National Summary* (NWS 1977, vol. 13, p. 117) published national flood damage estimates by month for the years 1925 to 1975. Therefore, we were able to calculate national annual damage totals based on fiscal years for 1926–1979, creating a consistent form for the full national data set.

Table 3-1 shows annual damage estimates for the United States, by fiscal year, in millions of current dollars and in millions of inflation-adjusted 1995 dollars. The implicit price deflator used to adjust for inflation is also shown in the table.

C. Annual Flood Damage Estimates for the States (1955–1979, 1983–2000)

Annual damage estimates for each of the 50 states are given in Appendix B. The estimates for 1955 through 1975 are taken from *Climatological Data National Summary* (NWS 1977, vol. 13, p. 121), and are based on calendar years. Estimates for 1976–1979 are based on our reanalysis of available data (described above), and are presented by calendar year to be consistent with the earlier data. The estimates for 1983–2000 are taken from *Army Corps of Engineers Annual Damage Report to Congress* (1993, 2001), and are based on fiscal years (October–September).

D. Annual Flood Damage Estimates in River Basins (1933–1975)

The NWS and U.S. Weather Bureau compiled annual damage estimates by river basin from 1933 through 1975, publishing them first in the *Monthly Weather Review* (1933–1947) and later in *Climatological Data National Summary* (1948–1975). To make these estimates accessible to users, we organized them by large river drainages in a uniform format for the full time period.

Table 3-1. Estimated U.S. Flood Damage, by Fiscal Year (Oct–Sep).

Fiscal Year	Damage (Millions Current Dollars)	Implicit Price Deflator*	Damage (Millions 1995 Dollars)
1926	9.243	—	—
1927	315.187	—	—
1928	88.155	—	—
1929	61.700	0.12854	480.
1930	25.832	0.12385	209.
1931	2.070	0.11091	19.
1932	10.365	0.09796	106.
1933	27.366	0.09541	287.
1934	18.903	0.10071	188.
1935	123.327	0.10265	1,201.
1936	287.137	0.10377	2,767.
1937	433.339	0.10815	4,007.
1938	108.970	0.10499	1,038.
1939	13.861	0.10387	133.
1940	40.067	0.10530	381.
1941	26.092	0.11244	232.
1942	91.548	0.12120	755.
1943	220.553	0.12773	1,727.
1944	99.789	0.13058	764.
1945	159.251	0.13425	1,186.
1946	68.930	0.15056	458.
1947	281.321	0.16667	1,688.
1948	213.716	0.17615	1,213.
1949	108.586	0.17594	617.
1950	129.903	0.17788	730.
1951	1,076.687	0.19072	5,645.
1952	254.190	0.19368	1,312.
1953	121.752	0.19623	620.
1954	74.170	0.19817	374.
1955	784.672	0.20163	3,892.
1956	305.573	0.20846	1,466.
1957	352.145	0.21539	1,635.
1958	224.939	0.22059	1,020.
1959	121.281	0.22304	544.
1960	111.168	0.22620	491.
1961	147.680	0.22875	646.
1962	86.574	0.23180	373.
1963	179.496	0.23445	766.
1964	194.512	0.23792	818.
1965	1,221.903	0.24241	5,041.
1966	116.645	0.24934	468.
1967	291.823	0.25698	1,136.
1968	443.251	0.26809	1,653.
1969	889.135	0.28124	3,161.
1970	173.803	0.29623	587.
1971	323.427	0.31111	1,040.
1972	4,442.992	0.32436	13,698.
1973	1,805.284	0.34251	5,271.
1974	692.832	0.37329	1,856.
1975	1,348.834	0.40805	3,306.

1976	1,054.790	0.43119	2,446.
1977	988.350	0.45892	2,154.
1978	1,028.970	0.49164	2,093.
1979	3,626.030	0.53262	6,808.
1980	—	0.58145	—
1981	—	0.63578	—
1982	—	0.67533	—
1983	3,693.572	0.70214	5,260.
1984	3,540.770	0.72824	4,862.
1985	379.303	0.75117	505.
1986	5,939.994	0.76769	7,737.
1987	1,442.349	0.79083	1,824.
1988	214.297	0.81764	262.
1989	1,080.814	0.84883	1,273.
1990	1,636.366	0.88186	1,856.
1991	1,698.765	0.91397	1,859.
1992	672.635	0.93619	718.
1993	16,364.710	0.95872	17,069.
1994	1,120.149	0.97870	1,145.
1995	5,110.714	1.00000	5,111.
1996	6,121.753	1.01937	6,005.
1997	8,934.923	1.03925	8,597.
1998	2,465.048	1.05199	2,343.
1999	5,450.375	1.06677	5,109.
2000	1,336.744	1.09113	1,225.

* Source: U.S. Bureau of Economic Analysis, 2001.
— Data unavailable, see text for discussion.

The basin-level damage estimates are available in spreadsheet form from our website, www.flooddamagedata.org. Estimates are presented by calendar year. The grouping of basins within drainages is somewhat different from that commonly used to define water resources regions (e.g., U.S. Dept. of Commerce, 1978 Census of Agriculture) because, over the years, the NWS sometimes changed its groupings. We developed uniform basin definitions for the full time period by using the following organizational system:

(1) Damages are grouped by drainage (e.g, St. Lawrence Drainage, Upper Mississippi, Great Basin) starting in the eastern part of the United States and moving towards the west coast, and then alphabetically by individual or grouped river basin(s).
(2) Often, the NWS grouped individual rivers together in annual summaries. For example, damage on the White and Wabash Rivers were usually included together as one estimate. If the published sources of flood data included damage for two river basins together in one year, then data for these two (or more) rivers were added together for all other years. This was the simplest way to produce a coherent data set that could be searched and produce just one row of data for one river basin.
(3) In many of the years, damage on unnamed streams was included. If the publication did not give a stream name, damage was included in a row for the drainage called "small streams."
(4) Sometimes the publications would include a river and its small tributaries together, by saying "X River and tributaries." When damage was published in this format, it was entered into the database under the river itself. So, damage listed for some rivers in some years may include not just the river, but its small tributaries (such as creeks).
(5) Creeks that were included separately in NWS publications from the rivers to which they are tributaries were entered into the database separately. Creeks can be differentiated from rivers in the database because they are labeled "Cr.," whereas rivers are entered with the river name only. An exception to this rule is for rivers with Spanish names, such as the Rio Hondo and Rio Grande. Since users may want to search for "Rio Hondo" rather than "Hondo," "Rio" is included in the database.
(6) Users looking for damage information on rivers with branches (such as North Platte, South Platte, and Platte) should look for each of these branches. In some cases, all of the branches of one stream are included together, and in some cases they are not.
(7) Several of the streams in the data set cross drainage boundaries. If there is a question about which drainage a stream is in, a user should look in both drainages.

E. Use of the Damage Estimates

Users of these data sets should be aware that there is uncertainty in the damage estimates, with a likelihood of large errors in some estimates. Types of inaccuracy are described in Section 4, and the magnitude of errors is analyzed in Section 5. In consideration of uncertainty, recommendations regarding appropriate uses of the data are offered in Sections 6 and 7.

4. SOURCES OF INACCURACY IN THE DAMAGE DATA

Sections 4 and 5 analyze the accuracy of flood damage data received from the NWS Hydrologic Information Center. The goals are to (1) identify errors, inconsistencies, and uncertainties in the estimates, and (2) assess the accuracy of the estimates. The analyses focus on national and state annual damage estimates for the period 1955–1998.

Discussions with staff and comparison of the available materials revealed several sources of inaccuracy and inconsistency in the time series of historical damage estimates:

1. Clerical errors
2. Inconsistency in reporting over time
3. Low precision of reported estimates
4. Inadequate estimation methods

Each source of inaccuracy is described briefly below. Many of the clerical errors were correctable. Inconsistencies are inevitable in data collected over a long time period; their existence should be noted, but the effects are not measurable. Assessment of the inaccuracy introduced by poor estimation methods is undertaken in Section 5.

A. Clerical Errors

These include mistakes in data entry, transcription, and labeling. Clerical errors were found and corrected, if possible, by comparing the data sets with published sources and material in the archive files. Mistaken labeling included, for example, the statement that all damages were summed by fiscal year (Oct. – Sep.) when, in fact, the national data had been summed by calendar year (Jan. – Dec.) through 1982.

B. Inconsistency in Reporting over Time

Published NWS reports of flood damage are uniform in format and content for extended periods, leading us to assume that fairly consistent methods were used within the periods 1934–1979 and 1983–present (see Section 2). However, collection of flood damage data was greatly curtailed in 1980, then restarted in 1983 with a new purpose and less detailed reporting. Before 1980, the data were aggregated by river basin and calendar year with several types of flood loss itemized separately. After 1982, data were aggregated by state and fiscal year (Oct.–Sep.), at first with distinction between damage to property and crops, later with only the total of the two. The difference in data collection between the two periods introduces errors when one attempts to develop a uniform data series for the full timespan.

Inconsistency in spatial units

Flooding naturally occurs in river basins, not necessarily bounded by individual states. When rivers form the state lines or floods cross state lines, assigning historical losses to the proper state is problematic. Our efforts to assemble estimates for 1976–1979 shed some light on the uncertainties involved. For example, the Wabash River rises in Indiana, but it forms a part of the border between Indiana and Illinois. NWS records on floods in 1976 and 1977 did not indicate how Wabash River flood damage should be divided between Indiana and Illinois; therefore, we had to decide the allocation arbitrarily. Another example is the Pearl River, which rises in Mississippi and flows through Louisiana. The NWS reported high flood losses in 1979 in the Pearl River and adjoining basins, including parts of Alabama, but we could not accurately assign the damage among the three states. It is likely that similar uncertainties existed when the NWS converted 1955–1975 river basin damage estimates into state estimates. Thus, occasional mistakes in assigning damage to particular states should be expected.

Inconsistency in time periods

NWS flood reports have usually been filed monthly, but aggregation periods have changed. Fiscal or calendar years are useful for accounting purposes; water years (which differ by geographic location) are more meaningful for scientific purposes. For example, NWS use of calendar years (through 1979) was problematic in aggregating data for locations along the Pacific coast. There, December – January is the peak flood season, leading to uncertainty in assigning damage to the correct year. (It appears that the NWS resolved this by assigning all the damage from a particular flood season to the year in which the hydrologic flooding peaked.) The present use of October – September fiscal years corresponds well to water years across the U.S, since fewer floods occur in the autumn dry season.

Inconsistency in losses included

NWS policies on what kinds of losses to include have changed somewhat over the years. Damage estimates published through 1975 focused primarily on damage to property and crops, but included some indirect losses (loss of business and wages, 1934–1947; a "miscellaneous" loss category, 1948–1975). Since 1975, estimates routinely collected for *Storm Data* have been labelled only as property damage and crop damage. Present policy is to focus exclusively on physical damage to property and crops (John Ogren, NWS, personal communication, 8/29/01). However, the estimates come from diverse independent sources, so other types of damage could be included occasionally.

The NWS process of collecting damage data has always focused more attention on larger floods. Possible inconsistencies related to the exclusion of floods involving low damage are examined in Section 6.

It is sometimes impossible to separate damage by flood and other storm-related causes (e.g. wind, hail, snow, or ice). Typically, the full amount has been labeled as flood damage if heavy rain or river flows are considered to be the primary cause. Thus, NWS flood damage estimates are sometimes inflated by including other causes. Conversely, flood damage may be omitted when the major cause of damage is wind (hurricanes, tornadoes), snow, or ice. These uncertainties have existed throughout the entire data series and sometimes lead to incompatibilities with data from other agencies.

C. Low Precision of Reported Estimates

The estimates have always been collected from myriad sources, differing greatly in precision and accuracy. Field office estimates sometimes include very precise figures; more often they give only one or two significant digits. Aggregated sums give a misleading impression of greater precision. For example, separate estimates of $7 million, $400,000, and $17,000 add to a more precise-looking annual estimate of $7,417,000 but the accuracy is limited by that of the largest estimate ($7 million, in this case).

Even one-digit accuracy is not assured. Published reports sometimes disagree greatly on the amount of damage in a particular flood event. For example, shortly after the failure of the Teton Dam in Idaho in 1976, damage estimates ranged from $400 million to $1 billion (Chadwick et al. 1976). In subsequent reports from several agencies, the $1 billion estimate was used repeatedly with no further refinement (for example, USACE Walla Walla District 1977). A final report on the Teton Dam failure (Eikenberry et al. 1980) gave the only specific figures: loss of a $102.4 million project investment and over $315 million paid to more than 7,500 claimants. This establishes a minimum loss of about $417 million, but only covers a portion of the total damage. In creating the reanalyzed data set, we chose to use the geometric mean of the minimum and maximum estimates, producing a damage estimate of $650 million.

After NWS reports on flood damage were discontinued in 1980, *Storm Data* became the primary source of flood damage estimates (see Section 2). From 1980 until about 1984, the accuracy of available estimates is limited by *Storm Data* reporting procedures. At that time, NWS field offices reported damage estimates by checking categories on the following logarithmic scale:

1	Less than $50
2	$50 to $500
3	$500 to $5,000
4	$5,000 to $50,000
5	$50,000 to $500,000
6	$500,000 to $5 million
7	$5 million to $50 million
8	$50 million to $500 million
9	$500 million to $5 billion

Such estimates indicated only the order of magnitude of the damage (e.g. roughly a $100,000 flood, a $1 million flood, a $10 million flood). Occasionally, more specific damage estimates were included in narrative descriptions of a flood event.

To add a set of these categorical estimates, each category must be assigned a point value. Proportional errors are minimized by using the geometric mean of a category's end points. That is, category k is from $\$0.5 \times 10^k$ to $\$5 \times 10^k$ (when $k > 1$), so the best estimate is

$$(2.5)^{0.5} \times 10^k = 1.58 \times 10^k.$$

However, *the individual estimates could be in error by more than a factor of 3*. For example, an event with damage originally estimated anywhere between $500,000 and $5 million would be entered into the data set as damage of $1.58 million. This is about 3 times higher than an estimate at the low end of the range, and about 1/3 of an estimate at the high end of the range.

Errors associated with these logarithmic categories are of concern primarily in the 1980–1984 flood damage estimates. By 1985, it appears that NWS-HIC had instituted some follow-up checking and refinement of the estimates, at least for major floods. Use of logarithmic categories in *Storm Data* was discontinued in 1995. Since then, one- or two-digit estimates have been given in thousands or millions of dollars (e.g. $60K or $3.2M).

D. Inadequate Estimation Methods

Potentially the most serious source of inaccuracy is the ad hoc approach to obtaining damage estimates from each NWS field office (described in Section 2). The estimates are collected by staff members who have little or no training in damage estimation and who rely on diverse sources. Estimation methods used by their sources are unknown, and completeness of coverage varies. Estimates are usually obtained within 2 months after a flood event and are not compared by the NWS with records of actual damage.

Incomplete reports and omissions

A state emergency management official (Kay Phillips, Ohio Emergency Management Agency, personal communication, 7/25/00) complains that the NWS calls her asking for a damage estimate within a few weeks after a disaster. At that time, the extent of damage is unknown and emergency managers are scurrying to respond to immediate needs. They have some knowledge of losses to individuals, but little knowledge of damage to infrastructure, which makes up a large part of total losses. Thus, in her opinion, early loss estimates tend to be much too low in relation to final tabulations.

An example of underestimation is the NWS damage estimate for California flooding associated with Hurricane Kathleen in 1976. The NWS dataset (which had not been fully updated because annual summaries were discontinued that year) gave a damage estimate of $42 million, whereas estimates in subsequent published reports (e.g., Montane 1999) are 3 to 4 times higher.

Errors of omission occur when a significant flood event is overlooked entirely. For example, flash floods in California in July 1979 caused damage estimated at $26–50 million (Montane 1999), but the NWS dataset reported no damage.

Potential biases

A substantial bias toward underestimation is expected due to incomplete reporting and omission of some floods. However, we hypothesize that some damage estimates provided to the NWS field offices might be biased upward if, for example, losses were exaggerated to improve chances of getting state or federal assistance. Accuracy and bias in early damage estimates are examined in Section 5.

5. ACCURACY OF DAMAGE ESTIMATES

In general, estimates of damage contain a high degree of uncertainty. Ideally, estimation errors would be measured by systematically comparing estimates with actual costs, which often are not known until long after a flood event. Unfortunately, actual cost data are seldom collected in a form that can be compared with estimates made at the time of the flood. This section examines the accuracy of flood damage estimates in two ways: (1) by comparing estimates with actual costs in one large flood disaster, and (2) by comparing pairs of estimates from different sources for many flood events.

A. Errors in Early Damage Estimates

NWS flood damage estimates are usually compiled within three months after a flood event, long before the actual costs can be known. Until recently, even in serious disasters, actual total damage costs were not systematically compiled by any agency. There was no way of checking the accuracy, or even the reasonableness, of most damage estimates.

In recent years, however, FEMA has systematically collected cost data for the programs it administers – admittedly only a fraction of total disaster costs. Beginning in 1992, FEMA instituted a computerized system for recording and tracking applications for federal assistance in presidentially declared disasters. State and county governments have gradually developed the capabilities to link to this system. The damage estimates submitted by local officials to FEMA probably represent the best available early estimates under disaster conditions. A team visits each damage site to view the extent of losses and make preliminary estimates. Thus, in some disasters and some jurisdictions, it is now possible to systematically compare early damage estimates with actual costs. Data from FEMA's Public Assistance Program are particularly appropriate for our purposes because a large portion of the losses involve physical damage to property. Public assistance covers damage to public facilities such as roads and bridges, schools, government buildings, and nonprofit agencies.

In the aftermath of a natural disaster, damage information is assembled according to guidelines established by FEMA. The following stages are described by FEMA (1998) and Michael Sabbaghian[1] of the California Office of Emergency Services (OES) (personal communication 8/30/00).

(1) Initial Damage Estimate (IDE): Local officials provide estimates of physical damage based on early reports and descriptions, without necessarily visiting the damage sites.
(2) Preliminary Damage Assessment (PDA): A team including local, state, and FEMA officials visits the damage sites to do a "windshield estimate," perhaps viewing the sites from a car window or walking around. The PDA estimates are used to decide whether federal assistance is needed. If so, they are submitted to FEMA as part of the governor's request for a presidential disaster declaration.

[1]Michael Sabbaghian, Deputy Public Assistance Officer for the California OES, manages disaster recovery activities for infrastructure and is responsible for grant management. He explained the process for estimating and recording losses in presidentially declared disasters. He also provided the damage estimates and cost data for the 1998 California El Niño disaster, which is used in this section.

(3) Damage Survey Report (DSR): Applicants submit requests for public assistance with detailed worksheets estimating the cost of repairs. FEMA or the state perform inspections (physical surveys) for each large project and "verify documentation on a portion of the small projects" (FEMA 1998). The DSR is used to obligate federal and state disaster assistance funds. The DSR obligations change as bids are received to accomplish the repair work, and computer records are updated accordingly.

(4) Actual Cost: Final total costs when all projects are completed and the DSR is closed. For large disasters, closure might not occur until 4 to 5 years after the disaster event.

Descriptions of the NWS procedures for obtaining flood damage estimates suggest that, in most cases, the estimates have been qualitatively similar to the IDE and certainly no better than the PDA. Indeed, NWS field offices obtain some of their estimates from FEMA's survey teams (Section 2). Only in the largest floods (notably, the widespread flooding of the upper Mississippi basin in 1993) have extensive efforts been made to update the damage estimates over an extended period.

Therefore, to estimate the errors in early damage estimates that can be expected under good conditions (that is, from officials who have systematically viewed the damage), we use FEMA records from a recent flood disaster as a case study. In February 1998, winter storms with heavy rains led to widespread flooding in California. The president declared a major disaster in 41 counties, designated the "1998 California El Niño" disaster (FEMA-1203-DR). Table 5-1 shows the IDE and PDA estimates for each county under the public assistance program. It also shows the funds that had been obligated in the FEMA database as of June 1, 2001. Although the DSR has not been closed at the time of this writing, it is expected that nearly all costs have been obligated; therefore we will treat these figures as the "actual costs."

The bottom line of Table 5-1 shows that total public assistance costs in the state were approximately $316 million. The PDA underestimated the total costs by only 6% ($19 million). Because no IDE was provided for several counties, the total IDE of $240 million should be compared with the total actual cost of $279 million from the matching 33 table entries. On that basis, the IDE underestimated total costs by about 14% ($39 million).

Estimates for smaller units (individual counties and the "state agencies" category) are much less accurate, however. Errors in the IDE are particularly large, ranging from underestimation by $26 million (82%) in Los Angeles County to overestimation by $20 million (316%) in San Benito County. In the PDA, errors range from underestimation by $16 million (52%) in the state agencies category to overestimation by $23 million (304%) in San Bernardino County.

Table 5-1. California 1998 El Niño Disaster: Estimated and actual public assistance costs, in thousands of current dollars.

County	Actual Cost (By 6/1/01)	IDE Estimate	IDE Prop.of Actual	PDA Estimate	PDA Prop.of Actual
State Agencies	30091	7129	0.24	14497	0.48
Alameda	18471	12971	0.70	8176	0.44
Amador	258	235	0.91	176	0.68
Butte	1726	665	0.39	706	0.41
Calaveras	131	--	--	162	1.24
Colusa	4652	25000	5.37	1829	0.39
Contra Costa	5631	3885	0.69	4760	0.85
Del Norte	271	--	--	461	1.70
Fresno	1701	820	0.48	1052	0.62
Glenn	3802	21250	5.59	9884	2.60
Humboldt	7748	1049	0.14	1753	0.23
Kern	12312	--	--	10306	0.84
Lake	1889	1395	0.74	3044	1.61
Los Angeles	31229	5660	0.18	35516	1.14
Marin	6449	3319	0.51	5447	0.84
Mendocino	2836	4259	1.50	3846	1.36
Merced	2327	490	0.21	734	0.32
Monterey	26182	20181	0.77	11822	0.45
Napa	468	720	1.54	448	0.96
Orange	12617	3992	0.32	16720	1.33
Riverside	3130	--	--	5964	1.91
Sacramento	2366	--	--	3066	1.30
San Benito	6455	26870	4.16	10595	1.64
San Bernardino	7525	--	--	30429	4.04
San Diego	6977	--	--	9180	1.32
San Francisco	3859	12300	3.19	3703	0.96
San Joaquin	2657	655	0.25	3155	1.19
San Luis Obispo	4006	772	0.19	4915	1.23
San Mateo	21951	16110	0.73	26328	1.20
Santa Barbara	15816	75	0.00	12954	0.82
Santa Clara	13638	9846	0.72	13310	0.98
Santa Cruz	12459	13673	1.10	6320	0.51
Solano	3346	3628	1.08	8564	2.56
Sonoma	11779	11180	0.95	4127	0.35
Stanislaus	2122	--	--	909	0.43
Sutter	1039	1582	1.52	758	0.73
Tehama	881	20000	22.70	616	0.70
Trinity	1091	1970	1.81	975	0.89
Tulare	2149	--	--	919	0.43
Ventura	20391	3302	0.16	14350	0.70
Yolo	909	4321	4.75	4484	4.93
Yuba	592	196	0.33	249	0.42
Total	315929	239500	0.86*	297204	0.94

* Proportion of actual cost ($279 million) of cases with an IDE.

Figures 5-1(a,b) show scatterplots of (a) the IDE vs. actual costs and (b) the PDA vs. actual costs. Logarithmic scales are used on the axes to highlight proportional differences between estimates and actual costs. The solid diagonal line represents perfect agreement. Data points outside of the two dashed lines are cases in which the estimate differs from the actual costs by more than a factor of two. Clearly the IDE is less accurate than the PDA: the points are much more scattered. (Correlations between the logs of estimates and actual costs are $r = 0.46$ for the IDE and 0.88 for the PDA.)

Since the Initial Damage Estimates are based on rather superficial damage descriptions, it is not surprising that large errors are the norm: Over half of the IDEs (18 out of 33) are off by at least a factor of two, and 13 of them are off by more than a factor of four. As a percentage of the actual costs, the IDE errors can be enormous, ranging from a 99.5% underestimate in Santa Barbara County to a 2170% overestimate in Tehama County. The Preliminary Damage Assessments are somewhat better, yet over one-third (15 out of 42) are off by at least a factor of two and 3 of them are off by more than a factor of four. The PDA errors range from a 77% underestimate in Humboldt County to a 393% overestimate in Yolo County.

The population of some California counties exceeds that of many small states. So estimation errors in the larger counties are indicative of the error levels to be expected in many states. For example, Los Angeles County, with a 1990 population of 8.9 million, is larger than 42 of the states. Table 5-1 shows that, in this disaster, the IDE underestimated actual costs by 82%.

To check for systematic bias in these early damage estimates, we used a statistical paired-comparison test. A systematic tendency to *underestimate* might be expected if some types of damage cannot be observed without careful inspection. On the other hand, we wondered if there might be a tendency for local officials to *overestimate* damage in order to increase the chance of being considered for federal aid. The IDE and PDA estimates were compared with actual costs, as follows:

Let e_i = estimated damage, a_i = actual cost. We wish to test the null hypothesis that the geometric mean of $e_i/a_i = 1$. This is equivalent to the hypothesis that $\text{mean}[\log(e_i) - \log(a_i)] = 0$. We tested the hypothesis twice, first letting e_i represent the IDE values in Table 5-1 (N = 33), then letting e_i represent the PDA values (N = 42). A *t*-test is appropriate, even in these small samples, because the sample values $\log(e_i) – \log(a_i)$ are approximately normally distributed. For the IDE, $t = –1.27$, and for the PDA, $t = –1.10$, neither of which is statistically significant at a 95% confidence level. Though there may be a tendency to underestimate the amount of damage, the bias is not statistically significant.

In summary, this example indicates that positive and negative estimation errors tend to average out when estimates are highly aggregated in a large flood event (over $300 million damage in 1998 dollars, in this case). The initial rough estimates (IDE) tended to underestimate actual damage and the more careful PDA estimates were reasonably accurate. It shows, however, that in smaller flood events ($30 million damage or less in 1998 dollars), which involve substantially less aggregation, the errors can be extremely large. Half of the PDA estimates

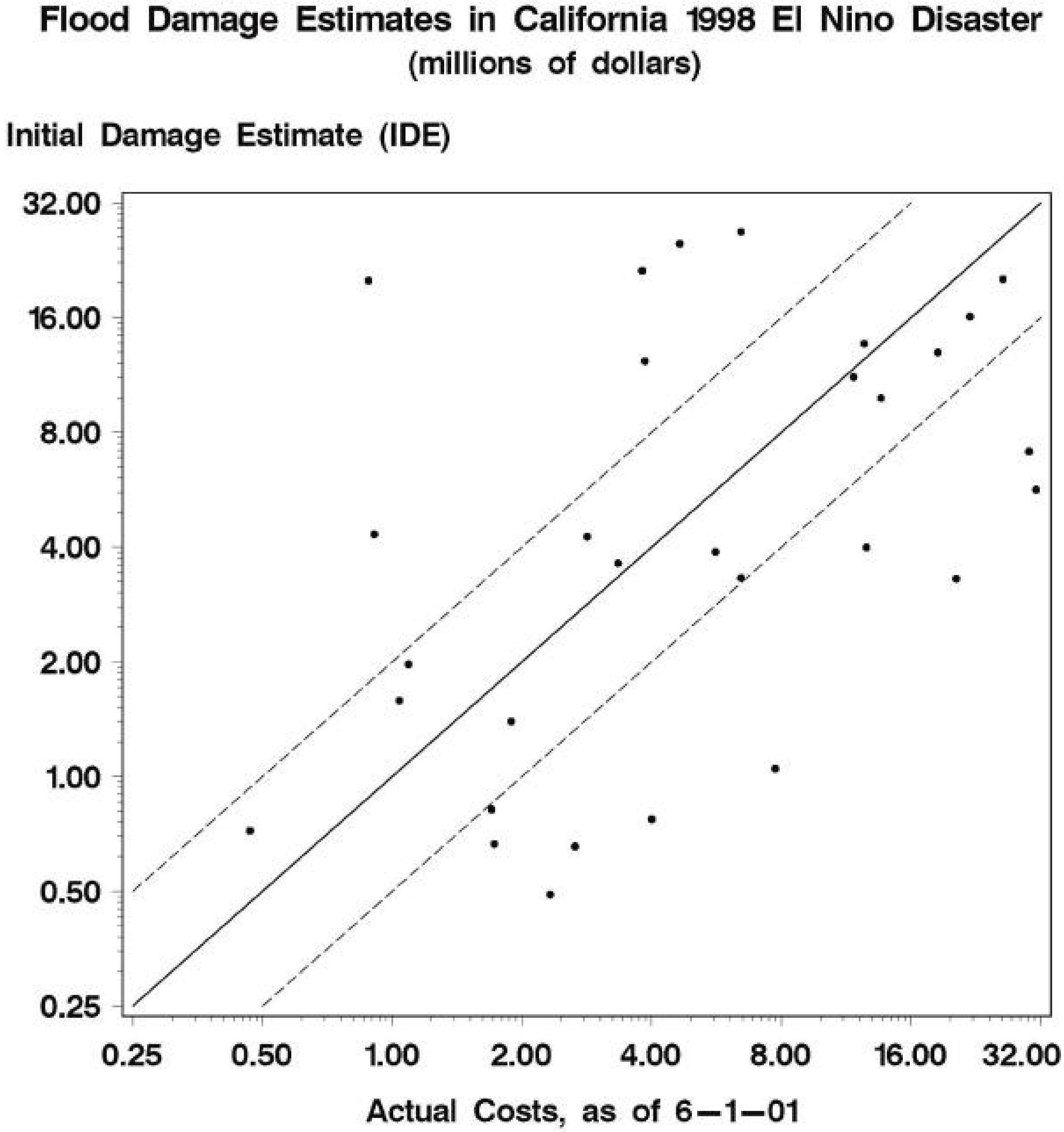

Figure 5-1. Estimated flood damage in California counties in the 1998 El Niño disaster, compared with actual costs as of June 1, 2001: (a) Initial Damage Estimate.

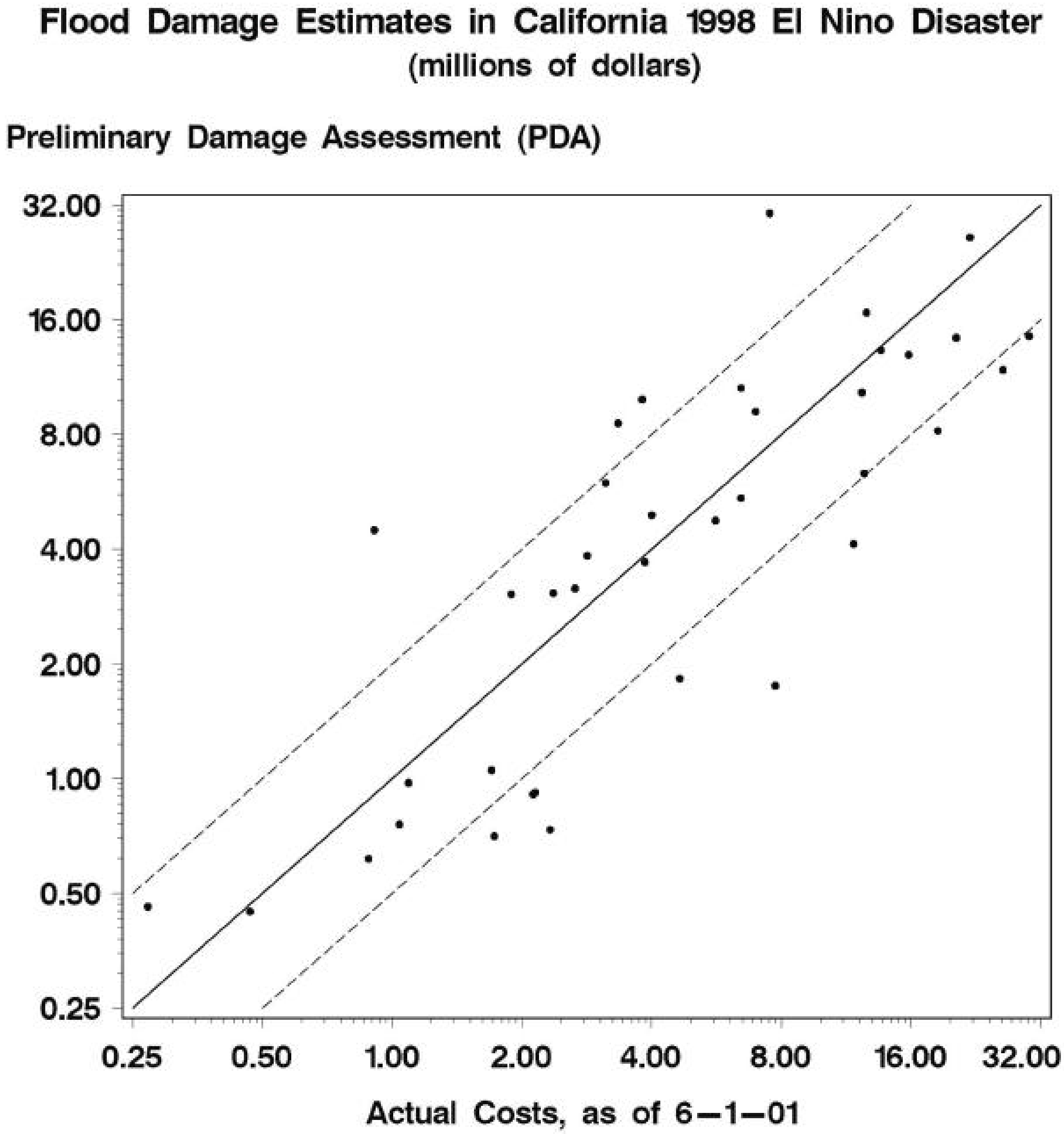

Figure 5-1, continued. (b) Preliminary Damage Assessment.

were in error by more than a factor of 1.5; and half of the IDEs were in error by more than a factor of 2 (with many off by more than a factor of 4).

Given the methods used by NWS field offices to obtain flood damage estimates (described in Section 2), it is unlikely that the NWS estimates are much better than the IDEs examined here. Thus, when an annual flood damage estimate for a state is less than about $30 million, one should not expect the NWS estimate to depict actual losses accurately. However, the above analysis does not indicate systematic bias in the individual estimates, and errors tend to average out when the estimates are summed.

From the above results, we conclude that aggregation of many damage estimates in floods that have caused high levels of damage ($300 million or more in 1998 dollars) provides reasonably good estimates of total damage. However, estimates at a low level of aggregation ($30 million or less) often are in error by factors of 2 or more. Such small estimates should be used with great caution: Direct comparisons of individual estimates are likely to be misleading.

B. Comparison of Damage Estimates from NWS and States

Appropriate data are not available for comparing NWS estimates with actual flood damage costs. However, comparable *estimates* are available from independent state sources to do an assessment of typical estimation variability.

Every state in the U.S. has an emergency management agency. In July 2000, we wrote to the head of the emergency management agency in each state asking for historical data on flood damage in their state. The letter was followed by a phone call to the appropriate administrator if a response was not received within three weeks. Twenty-one states responded[2], but many of them could provide damage information only after 1990 and only related to losses covered by FEMA. Five states either had published historical summaries of flood damage or were able to compile flood damage estimates from their files covering at least 20 years which were based on criteria similar to those used by the NWS.

(1) California: A report (Montane 1999) describes disasters from 1950 through 1998 including for each disaster a brief description, general location, estimated damage, number of deaths, and whether a presidential disaster declaration was issued. We selected the disasters that involved flood, heavy rainfall, or severe storms for this comparison.

(2) Colorado: The state has formally collected flood data since 1937. A report (McLaughlin Water Engineers, Ltd. 1998) summarizes flood history and provides damage estimates for major floods since 1864.

(3) Michigan: A report (Michigan Dept. of State Police 1999) summarizes the 14 floods during 1975–1998 that resulted in a disaster declaration by either the governor or the president. Damage estimates are given for all of the floods that received a presidential declaration and four that received only a gubernatorial declaration.

(4) Virginia: Damage estimates in presidentially-declared flood disasters during 1977–1999 were provided by Michael Cline, State Coordinator of the Virginia Dept. of Emergency

[2]States that responded were AL, CA, CO, FL, GA, HI, IL, IN, LA, MA, MI, MN, MO, OH, OR, SC, TX, VA, WA, WV, WY.

Services (personal communication 2000).

(5) Wisconsin: One report on the 1993 Midwest flood summarizes flood losses in Wisconsin from 1973 through 1992 (FEMA 1993), and another report provides loss estimates for the 1993 flood (Wisconsin Dept. of Natural Resources 1993).

In the state reports, the loss estimates are provided for each major flood event, sometimes with two or more events occurring in a given year. To match the annual loss estimates provided by NWS-HIC, we added up the flood losses in each state for each year, using calendar years during 1955–1982 and fiscal years (Oct–Sep) during 1983–1998 to match the time periods used in the NWS estimates.[3] Our comparison covers a total of 155 years in the 5 states: 44 years each in California and Colorado (1955–1998), 24 years in Michigan (1975–1998), 22 years in Virginia (1977–1998), and 21 years in Wisconsin (1973–1993).

Of course, the state estimates are subject to the same types of error as the NWS estimates – neither is assumed *a priori* to be more accurate. The intent of this section is to investigate large discrepancies between estimates from different sources in order to understand how estimates of the same event vary and to determine whether some floods are overlooked. In the following analysis, all loss estimates are reported in inflation-adjusted 1995 dollars.

When estimates are very low or missing

Table 5-2 provides a comparison of the estimates in all 155 years, with cases along the diagonal (from upper-left to lower-right) showing the closest agreement. An obvious difference between the NWS and state estimates is in the amount of missing data – a result of different purposes of the data. NWS flood loss estimates are collected every year, with relatively small losses included; hence, estimates are missing or zero in only 28 years and are below $5 million in 56 years. In contrast, the state reports focus on more serious floods, so years of relatively low flood loss are not included. The states did not report losses in 91 cases, and included losses below $5 million in only 6 cases.[4] The threshold for reporting appears to be somewhat higher in California, where the lowest reported loss was $15 million.

We conclude that these five states do not attach great importance to floods that cause less than $5 million in damage; therefore, annual losses below that threshold will be described as "low" flood losses. Lumping the low and missing categories together, the NWS and states agree that 78 (50%) of the 155 cases involved little or no flood damage. Disagreements arise, however, when at least one estimate is above $5 million.

[3] Estimates for 1980-82 were included at this stage of the analysis. California flood damage in Dec 1982 could be attributed differently by the two sources because of the overlap in definition of calendar year 1982 and fiscal year 1983. The other four states did not report losses in Oct-Dec 1982.

[4] During 1955-98, California reported losses in 26 years (59%), while Colorado reported losses in only 13 years (30%). The other three states reported losses in 33-41% of the years covered by their reports (8 years in Michigan, 9 years in Virginia, and 8 years in Wisconsin).

Table 5-2. Crosstabulation of flood damage estimates from the NWS and five states. Estimates are in millions of 1995 dollars.

	NWS Estimate					
State Estimate	Missing	Est < 5 (Low)	5 < Est < 50 (Moderate)	50 < Est < 500 (High)	500 < Est (Major)	Total
Missing	26	48	14	2	1	91 (59%)
Est < 5 (Low)	0	4	2	0	0	6 (4%)
5 < Est < 50 (Moderate)	2	4	13	3	0	22 (14%)
50 < Est < 500 (High)	0	0	5	16	1	22 (14%)
500 < Est (Major)	0	0	0	1	13	14 (9%)
Total	28 (18%)	56 (36%)	34 (22%)	22 (14%)	15 (10%)	155

Disagreement #1: State estimate above $5 million, NWS estimate missing or low. California describes flood losses of $50 million in 1979 and $15 million in 1984, both years in which the NWS provides no loss estimate. In addition, states claim moderate losses in four years when the NWS estimate is low (< $5 million): Colorado 1969 and 1983 ($20 and $24 million, respectively), California 1972 ($29 million), and Virginia 1998 ($13 million). Because these floods were cited as significant in the state reports, it seems likely that the damage was considerably greater than the NWS estimates would indicate. The differences between estimates range from a factor of 6 in the 1998 Virginia case to a factor of 169 in the 1983 Colorado case.

Out of 84 cases in which the NWS indicated flood losses were low or missing, 78 (93%) were in reasonable agreement with the state reports; but 6 cases in which over $5 million damage was claimed by a state were either overlooked entirely by the NWS or underestimated by a large factor.

Disagreement #2: NWS estimate above $5 million, state estimate missing or low. The top row of Table 5-2 shows 17 cases, not mentioned in the state reports, in which the NWS indicates flood losses over $5 million. In all but one case, the NWS estimate is below $51 million. We assume that some flood damage probably occurred, but the state did not include it in their report. Four of these cases are in Virginia and would have been omitted because they did not receive a Presidential disaster declaration. Excluding Virginia, the three largest NWS estimates are for California, where flood losses are generally high and a $50 million loss might be considered relatively unremarkable.

In one case, however, the NWS estimate is very high: $806 million in Michigan in 1981. This is contradicted by Michigan's report (Michigan Dept. of State Police 1999), which lists eight floods since 1975 and describes the 1986 flood (with losses of about $400 million) as the most damaging, but makes no mention of a flood in 1981. This blatant error casts doubt on the NWS estimates for 1980–1982, which were derived from broad damage categories in *Storm Data*, apparently with little or no verification. (See also Section 3 on 1980–1982 damage estimates.)

Comparisons of estimates

For California, Figures 5-2(a,b) show cases in which at least one estimate is greater than $50 million. For the other states, Figures 5-2(c–f) show cases in which at least one estimate is greater than $5 million. Visually, the graphs are dominated by the major floods (over $500 million), where most of the disagreements appear to be relatively small (except for the erroneous estimate we have already noted for Michigan in 1981). At the moderate-to-high damage levels ($5–500 million), however, some differences are proportionately large. For example, estimates differ by more than a factor of two in California in 1965, 1973, 1976 and 1993, Colorado in 1984 and 1995, Michigan in 1982 and 1998, Virginia in 1979, 1984, 1992 and 1996, and Wisconsin in 1973, 1978, 1980 and 1986.

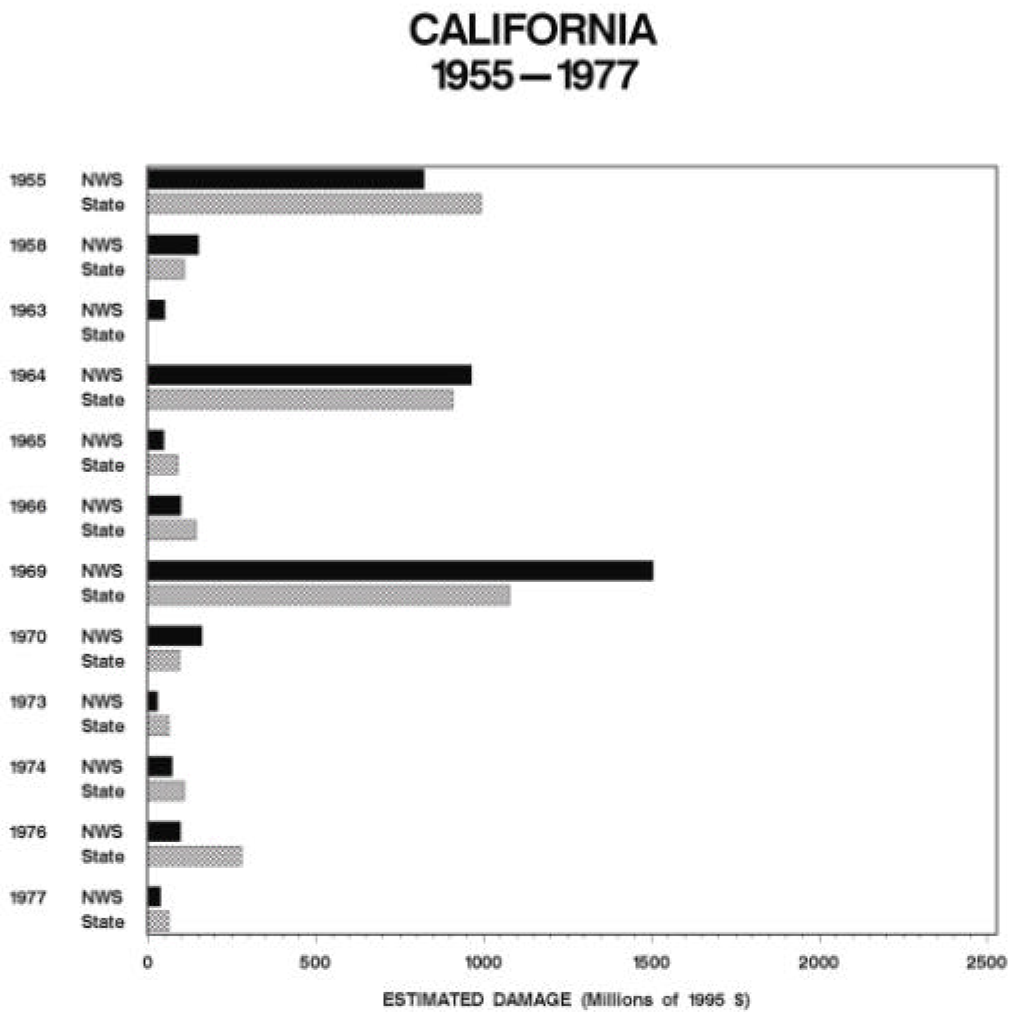

Figure 5-2. Comparison of National Weather Service flood damage estimates with estimates obtained from five states: (a) California, 1955–1977.

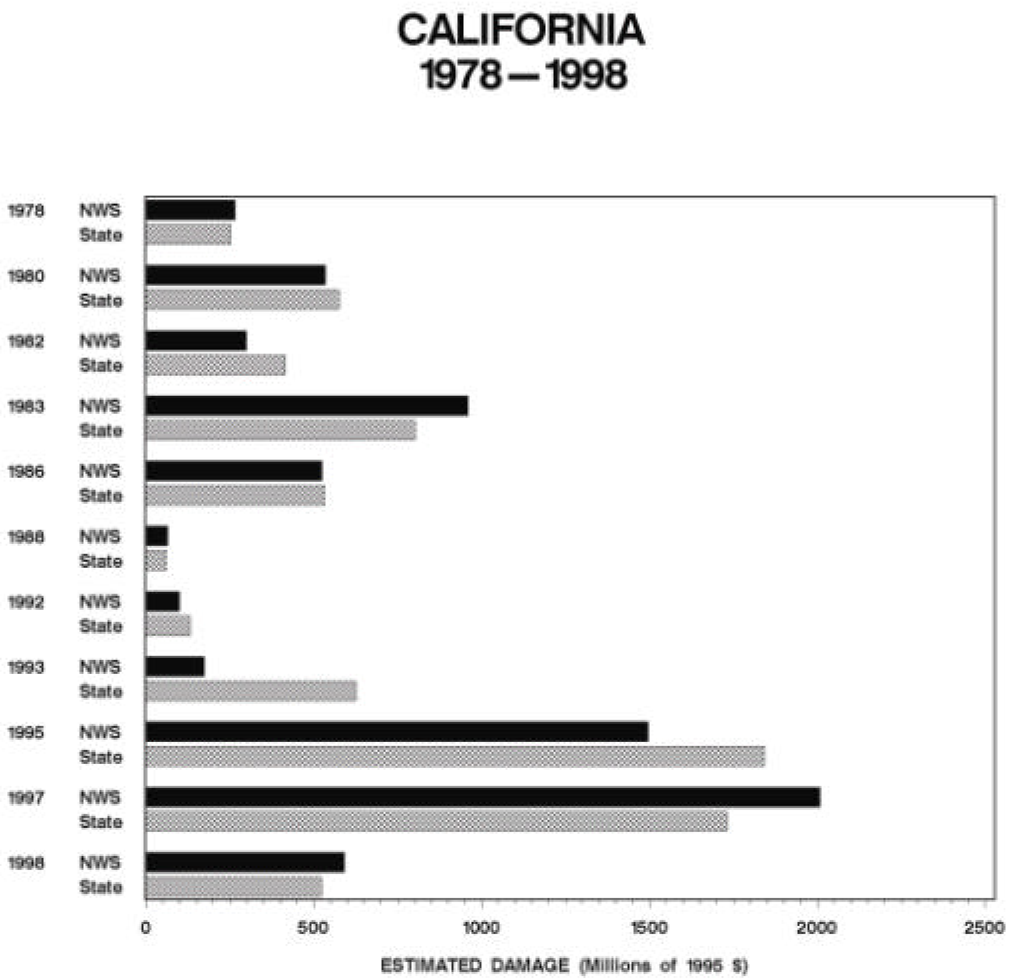

Figure 5-2, continued. (b) California, 1978–1998.

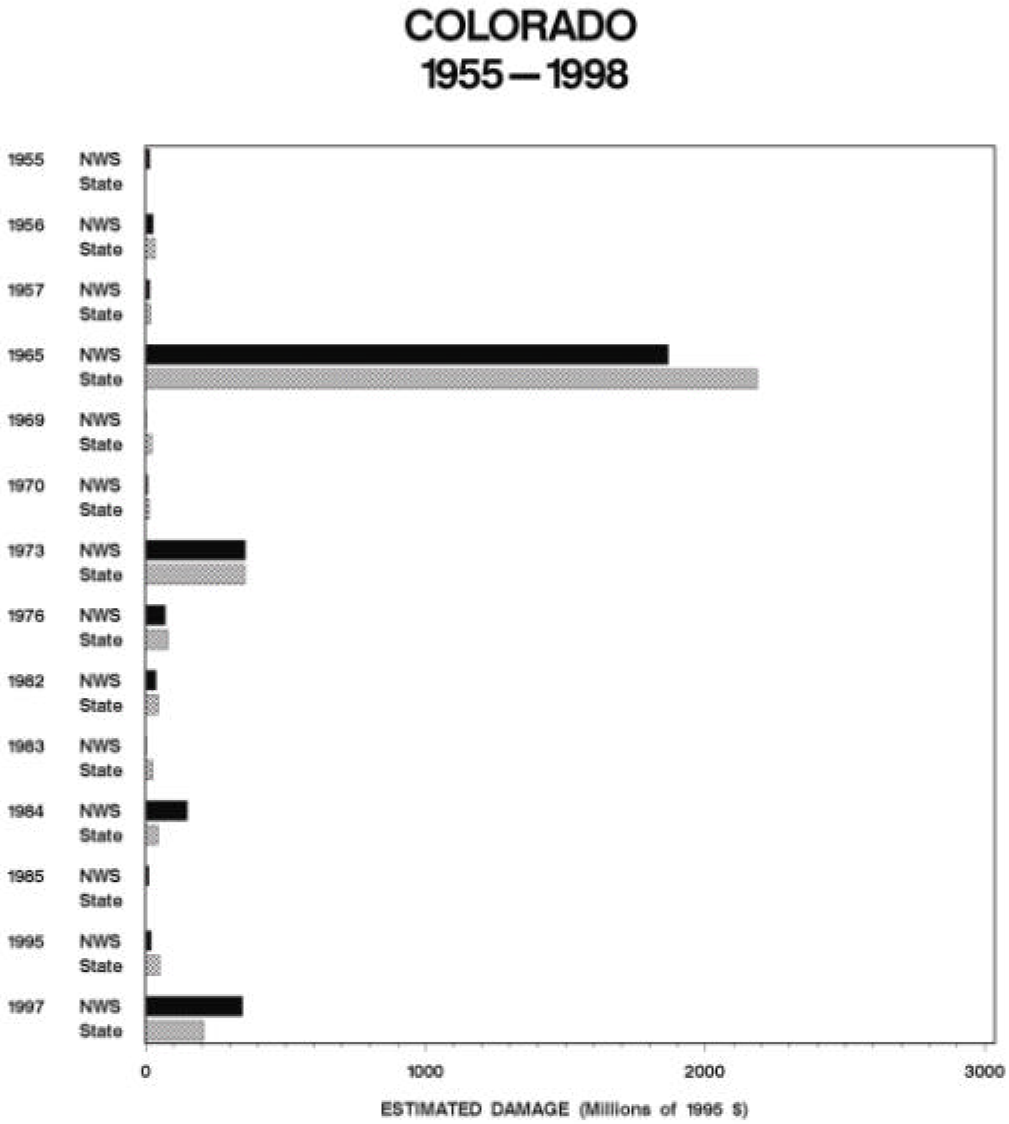

Figure 5-2, continued. (c) Colorado, 1955–1998.

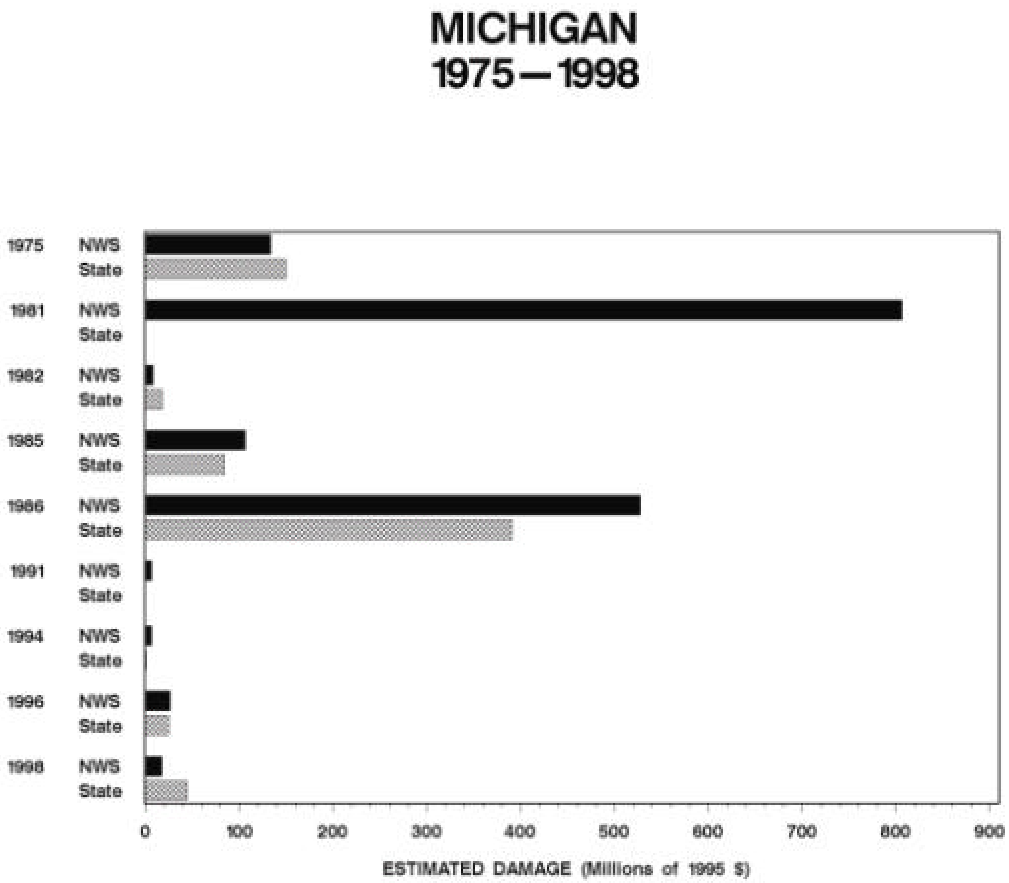

Figure 5-2, continued. (d) Michigan, 1975–1998.

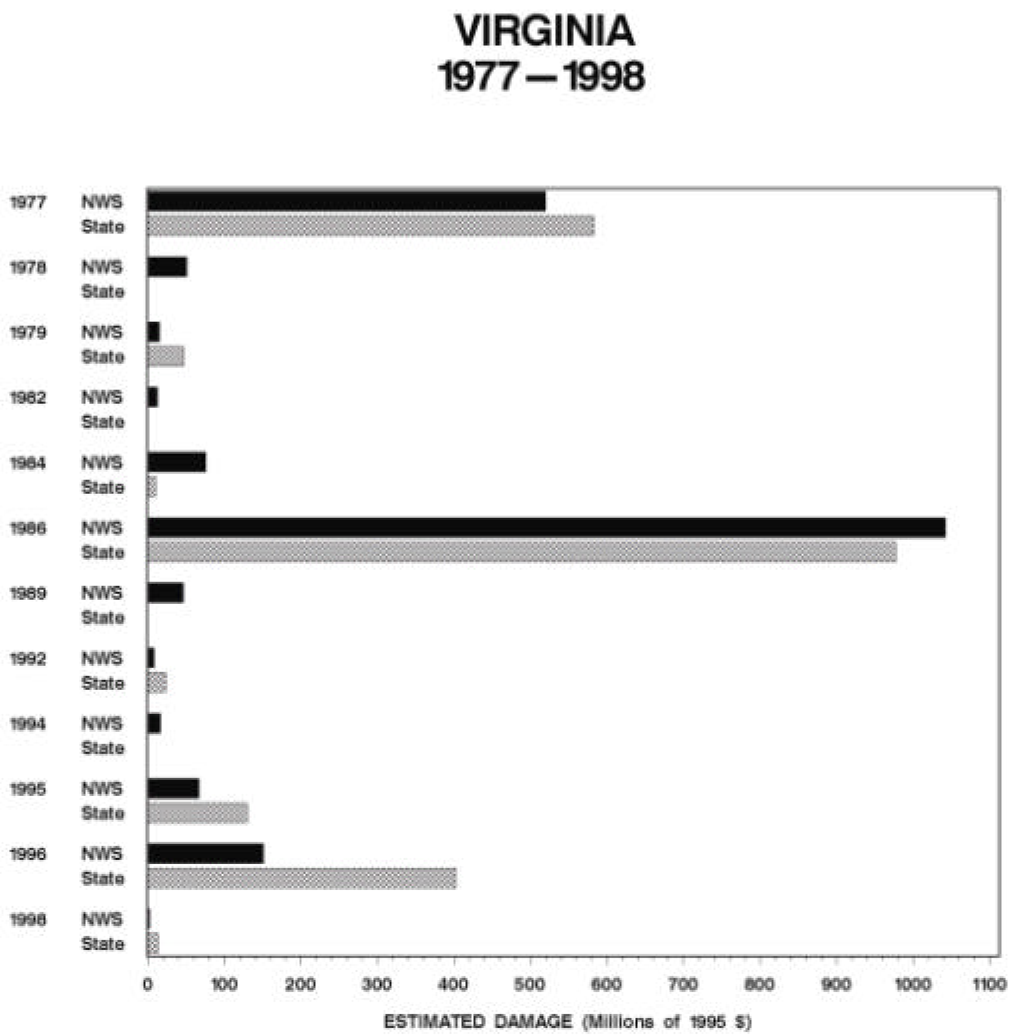

Figure 5-2, continued. (e) Virginia, 1977–1998.

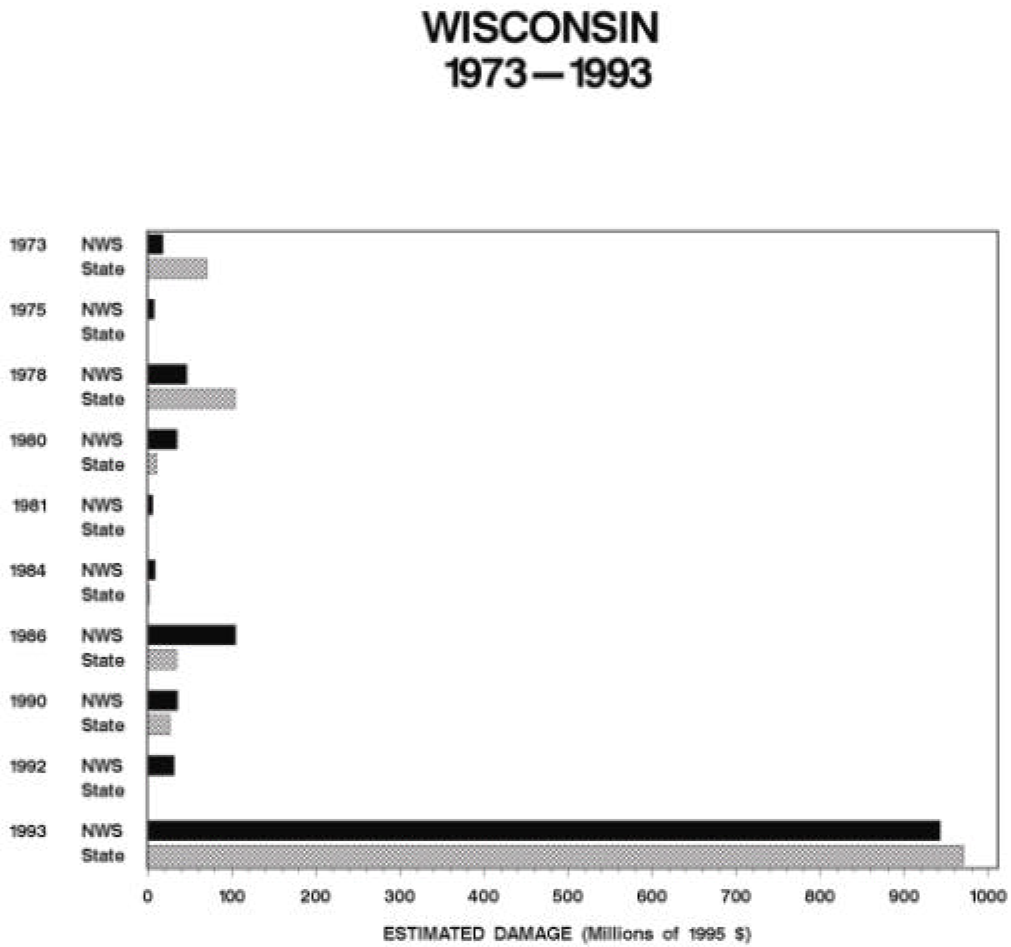

Figure 5-2, continued. (f) Wisconsin, 1973–1993.

Figure 5-3 is a scatterplot of all cases that have estimates from both NWS and the state. Logarithmic scales are used on the axes to highlight proportional differences in the estimates. The solid diagonal line represents perfect agreement between the estimates. Data points outside of the two dashed lines are cases in which the estimates differ by more than a factor of two. Seventeen cases are above the upper dashed line, representing state estimates more than twice as large as the NWS estimate. Six cases are below the lower dashed line, with NWS estimates more than twice as large as the state estimate.

The closest agreement between state and NWS estimates occurred in floods involving major damage (over $500 million). At the other extreme, the largest proportional disagreements (cases farthest outside the dashed lines) occurred when both sources indicated that flood damage was low or moderate (under $50 million).

From the standpoint of the NWS estimates, when the NWS damage estimate was:
(1) moderate ($5–50 million), then 55% of state estimates differed by a factor of 2 or more;
(2) high ($50–500 million), then 30% of state estimates differed by a factor of 2 or more;
(3) major (over $500 million), then none of the differences exceeded a factor of 1.4.

There are many plausible explanations why agreement might improve as total damage increases. First, the crisis of a major flood spurs studies by numerous agencies. Collection of damage information is more likely to be systematic and complete in a major flood than in a smaller one. Second, agencies are more likely to share information about major floods (which would lead to increased agreement, but does not guarantee greater accuracy). In smaller floods, on the other hand, collection of damage information is likely to be haphazard and there is less interest in checking and correcting early damage estimates. Third, the damage in large floods is aggregated from many individual damage estimates so that random errors tend to cancel out. Small floods involve less aggregation and, hence, relatively larger errors.

C. Accuracy: Summary and Conclusions

The following conclusions are drawn from the analysis of accuracy and consistency presented in Sections 4 and 5.

1. The collection and processing of flood damage data by the NWS has been reasonably consistent from 1934 to the present, except during the period 1976–1982. Errors are probably somewhat larger in the first few years after data collection resumed in 1983.

Data from NWS files and other sources made it possible to reconstruct state and national flood damage estimates for 1976–1979. However, little data was collected during 1980–1982 and large errors were discovered in estimates developed later for that period. As a result, the years 1980–1982 have been excluded from the reanalyzed data sets. Annual compilation of damage estimates resumed in 1983, but depended mainly on information from *Storm Data* in the first few years. Particularly in 1983–1984, omissions are more likely and estimates probably contain somewhat larger errors because of the use of damage categories.

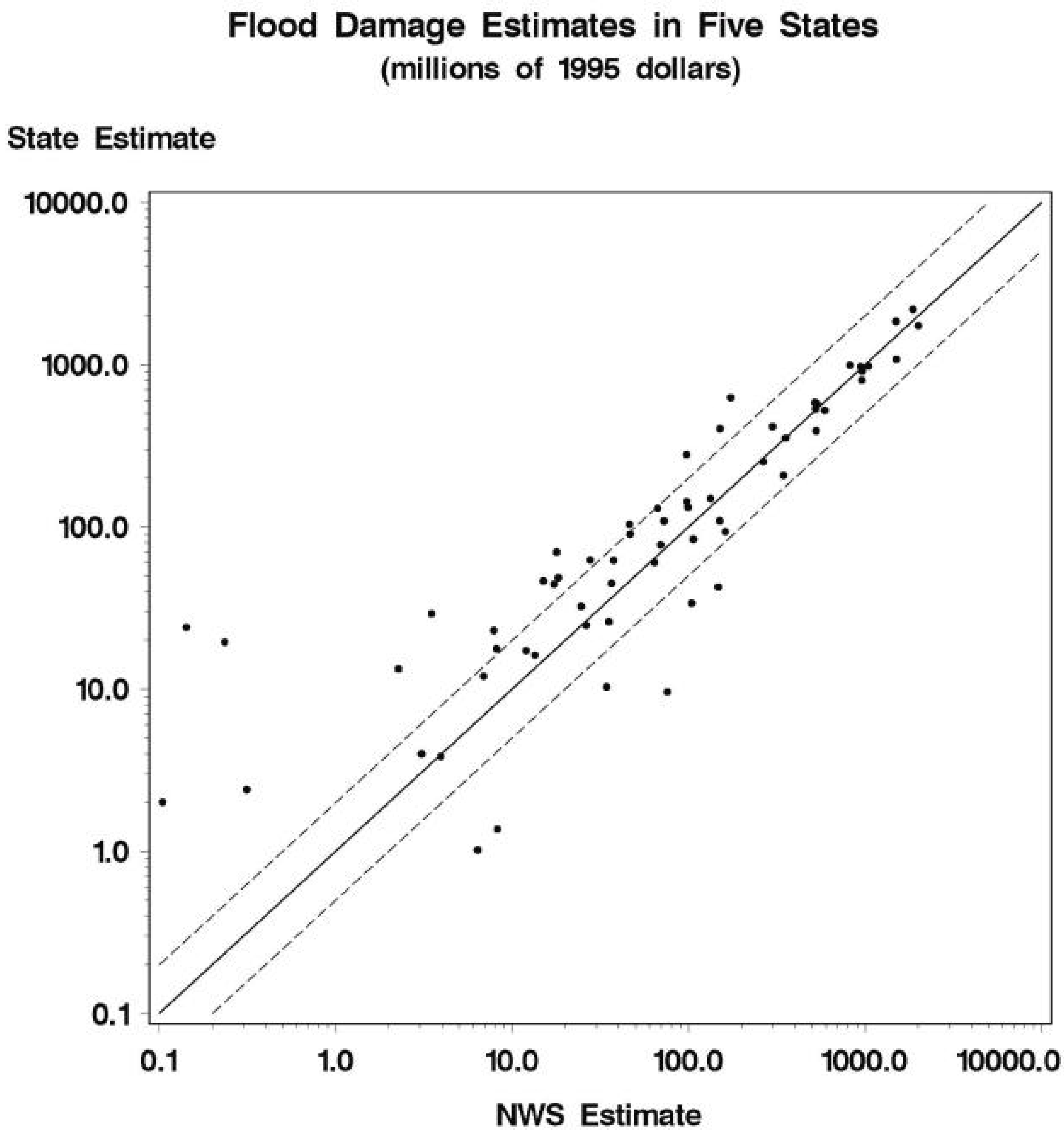

Figure 5-3. Scatterplot of National Weather Service flood damage estimates versus estimates obtained from five states, in millions of 1995 dollars.

2. *Individual damage estimates for small floods or for local jurisdictions within a larger flood area tend to be extremely inaccurate.*

It is rare to have actual cost data to compare with damage estimates. The above analysis of one large flood disaster indicates that, in cases where actual costs are less than $30 million, a large proportion of estimates are off by at least a factor of two and sometimes much more. When damage in a state is estimated to be less than $50 million, estimates from NWS and other sources frequently disagree by more than a factor of two.

3. Damage estimates become more accurate at higher levels of aggregation. Thus NWS estimates totaled over large geographic areas or many years are likely to be fairly reliable (within about a 50% margin of error).

Errors tend to average out, as long as the local estimates are not systematically biased. For example, the sum of estimates from many counties in a large flood area are found to be quite close to the actual total costs for the area as a whole. When damage in a state is estimated to be greater than $500 million, disagreement between estimates from NWS and other sources are relatively small (40% or less). The relatively close agreement between NWS and state estimates in years with major damage is reassuring, since the most costly floods are of greatest concern and make up a large proportion of total flood damage.

4. Floods causing moderate damage are occasionally omitted, or their damage greatly underestimated, in the NWS data sets.

When discrepancies between NWS and state estimates are large, most often the state estimate is the higher one. Occasionally, NWS estimates are missing for floods in which the state claims as much as $50 million damage. Such omissions would have little effect on national total damage estimates. However, they might be important in analyses of damaging floods at the state or river basin level. Researchers studying flood damage in states or river basins should be aware that the NWS estimates occasionally overlook some locally significant damage.

6. DEALING WITH DATA OMISSIONS AND INCONSISTENCIES

Used appropriately, reanalyzed NWS damage estimates can provide valuable information about historical flood damage in the U.S. But users should be aware of the deficiencies in the damage data sets and choose methods of analysis that guard against misleading results. Omissions and inconsistencies are of particular concern if they introduce systematic biases in the damage estimates that might distort comparisons of flood damage between different time periods or locations. This chapter examines frequency distributions of state damage estimates to evaluate the impact of omissions and inconsistencies and to suggest appropriate methods of analysis.

A. Frequency of Damaging Floods at the State Level

Few states report flood damage every year; indeed, many states experience damaging floods rather infrequently. In studying the flood damage history of a state or region, it is of interest to know how often damaging floods occur. However, the lack of a damage estimate does not necessarily imply zero flood damage because reporting of dollar damages, particularly in small flood events, is somewhat unreliable. To assure consistent comparisons across different times and locations, it would be helpful to know what levels of damage have been reported fairly consistently.

The NWS defines its flood damage data as “loss estimates for significant flooding events” (NWS-HIC 2001). Floods that cause deaths or extensive damage have always received the most attention, but the records do not indicate any formal criteria on which floods to include. When small estimates are submitted, NWS-HIC has usually included them in the damage totals. (An exception occurred during 1993–1998, when local damage estimates below $50,000 were not entered in the flood damage database.) However, field office reports often mention damage without providing dollar estimates. When pressed for a definition of which floods are “significant” enough that intensive efforts are made to obtain complete estimates, NWS-HIC Director Frank Richards offered a rough guideline of at least $1 million in losses (personal communication, 6/27/01). This applies to NWS practice since 1990, but earlier guidelines, if used, are unknown.

Frequency distributions of state flood damage estimates suggest that floods with total state damage less than $100,000 (in 1995 dollars) have often gone unreported, and those under $1 million also have sometimes been omitted. Figure 6-1 shows the distribution of all state flood damage estimates in recent years (1983–1999) and in an earlier period (1955–1978). Estimates were missing nearly 30% of the time in the earlier period, and only 16% of the time in recent years. This could imply either fewer damaging floods or different reporting standards in the earlier period — perhaps both. Because the early period had a high frequency of flood damage *over* $1 million, it is unlikely that the incidence of damage less than $1 million was as small as the distribution suggests. It is likely that lower level damages were not consistently reported before 1980.

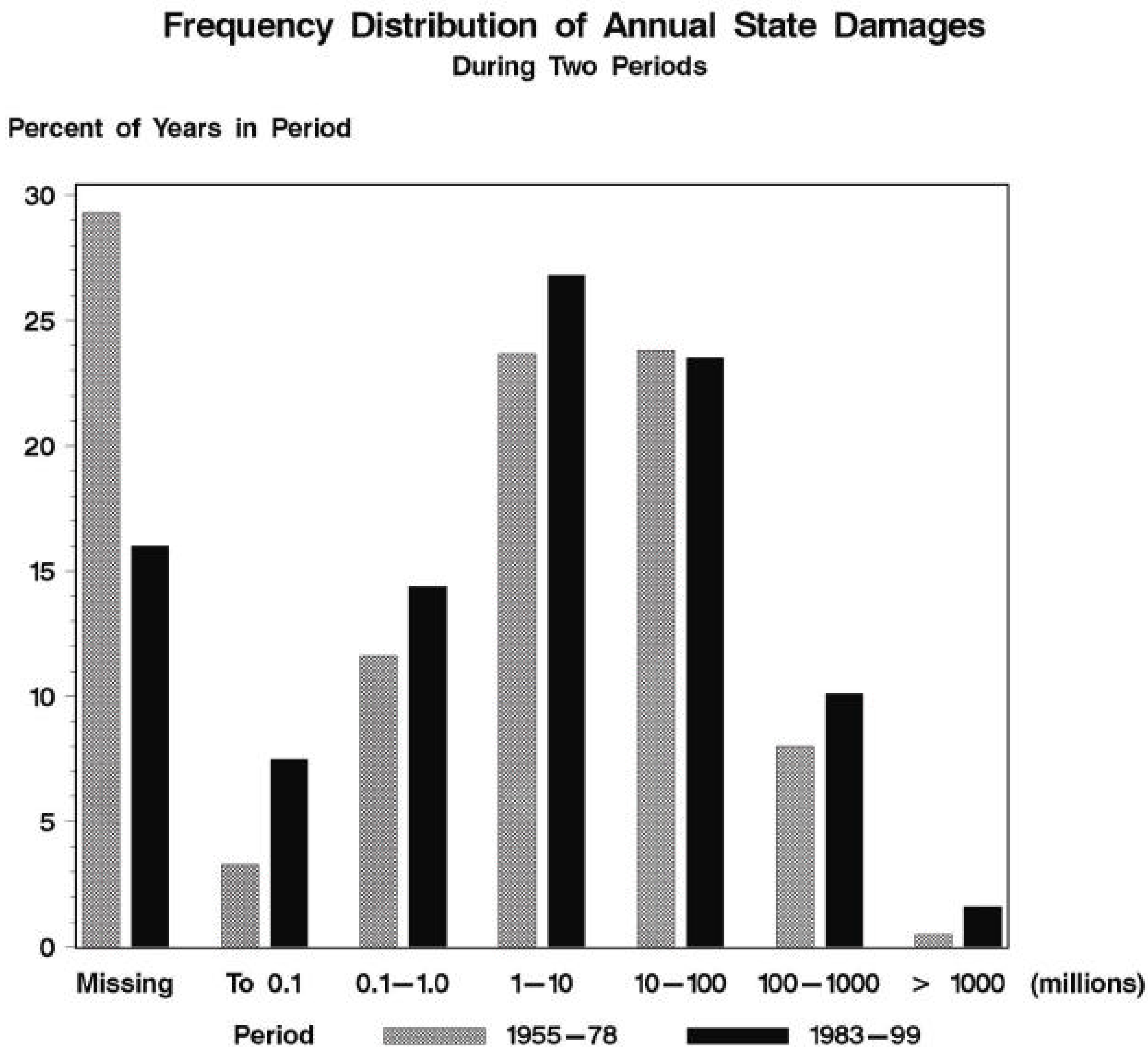

Figure 6-1. Frequency distributions of annual state flood damages (1995 dollars), 1955–1978 and 1983–1999.

For determining the frequency of damaging floods, we recommend establishing a threshold above which damage estimates are expected to be provided consistently. In our analysis we have chosen to use the frequency of inflation-adjusted state flood damage estimates above $1 million.

B. Magnitude of Damages

Individual states differ greatly, both in flood frequency and in the magnitude of damage in a "typical" flood event. Figure 6-2 shows, for each state, the estimated total damage during the years 1955–1978 and 1983–1999, as well as the damage in the worst flood year. A few states have had many major floods (e.g. California, Texas). Many others have suffered most of their total damage in just one or two major flood events (including Pennsylvania and Iowa, among the worst in total damage). Many states had no yearly damage greater than $500 million in this period, and there are 10 states whose total damage for the entire 41-year period is less than $500 million.

These state comparisons do not include 1979 damage estimates because some estimates for that year are available only for large regions, not for individual states (see Section 3). Estimates of 1979 damage are available for many states, however, and are useful to illustrate how rankings of states by total damage can differ depending on the time period covered. For example, 1979 flood damage in Texas was $3.76 billion — substantially greater than in any of the years included in Figure 6-2. Texas would move from 6th to 3rd place in the rankings if 1979 were included.

The frequency distributions of flood damage in each state give another perspective on past flood vulnerability. Table 6-1 shows how states differ in both frequency and severity of damaging floods during 1955–1978 and 1983–1999. The states are ordered by their median annual flood damage based on all 41 years, including years with no reported damage. The number of missing, very low (< $1 million) and relatively high (> $100 million) damage estimates are shown to indicate both frequency and relative magnitudes of flood damage. Three "historical vulnerability categories" can be loosely defined to illustrate the differences between states. (Although the worst flood, indicated by maximum damage, is shown for each state, it is *not* considered in defining historical categories.)

(1) *Low vulnerability: Floods are relatively infrequent, and damage is less than about $2 million in the majority of years (1995$).* Includes New England states, some mid-Atlantic coastal states, low-population states in the arid west, plus Hawaii and Alaska. Damage rarely exceeds $100 million. (Frequency distributions of flood damage in Maine and New Mexico are surprisingly similar, despite their geographic differences.)

(2) *Medium vulnerability: Damaging floods occur in most years, and median damage is in approximately the $2 – 8 million range (1995$).* Includes most states in the southeast, the lower Mississippi basin, and the Pacific northwest. Most of these states have few instances of flood damage over $100 million. (Louisiana is a notable exception.)

(3) *High vulnerability: Damaging floods occur in most years, and damage exceeds about $8 million in the majority of years (1995$).* Includes states in the upper Mississippi, Missouri,

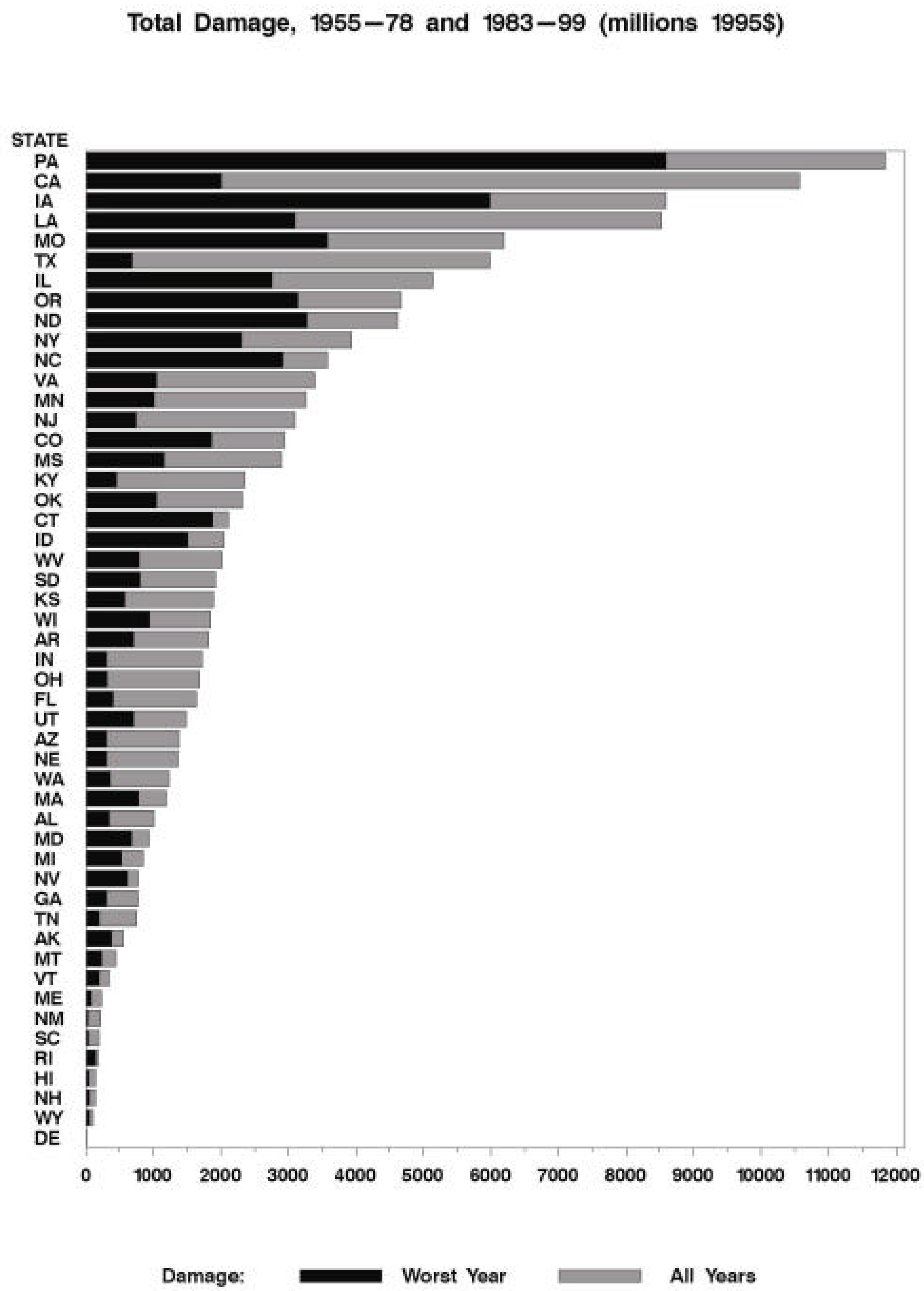

Figure 6-2. States ranked by estimated total damage during 1955–1978 and 1983–1999.

Table 6-1. Comparison of Damage Estimates by State, 1955–1978 and 1983–1999. States are ordered by increasing median damage. Missing estimates are treated as zero; all estimates are in millions of 1995 dollars.

State	Region	Median Damage (all years)	Maximum Damage*	Years with no estimate	Years with 0<est#1.0	Years with est > 100.
Rhode Island	New England	0.00	143.	33	5	1
Delaware		0.00	7.	32	7	0
Massachusetts	New England	0.00	774.	25	5	2
New Hampshire	New England	0.00	56.	23	6	0
Hawaii		0.00	44.	23	2	0
Connecticut	New England	0.00	1881.	21	6	2
Vermont	New England	0.00	194	20	9	1
Wyoming	Arid West	0.05	53.	17	14	0
Maine	New England	0.06	77.	20	3	0
New Jersey		0.06	749.	18	5	8
Alaska (29 yr)		0.07	383.	14	4	1
Maryland &DC		0.14	681.	15	14	1
Nevada	Arid West	0.16	616.	13	12	1
Michigan		0.21	528.	17	11	3
N. Dakota	N. Central	0.41	3280.	14	9	4
S. Dakota	N. Central	0.51	796.	10	13	4
Colorado	Arid West	0.57	1866.	11	10	4
S. Carolina		0.66	40.	5	18	0
New Mexico	Arid West	0.73	34.	16	6	0
Utah	Arid West	0.84	712.	7	14	2
Montana	Arid West	1.04	229.	10	10	1
Idaho		1.21	1507.	9	10	2
Wisconsin		1.61	943.	11	8	4
Georgia	Southeast	1.86	307.	5	7	3
Virginia		1.91	1042.	9	9	6
Arizona	Arid West	2.27	306.	7	9	4
Minnesota		2.40	1006.	4	12	7

Florida	Southeast	2.48	410.	6	9	5
N. Carolina		3.99	2919.	5	5	3
Oregon	Pacific NW	4.06	3143.	2	6	4
Washington	Pacific NW	4.32	363.	5	7	3
Louisiana	Lower Miss.	5.60	3097.	7	7	10
Tennessee	Southeast	6.01	193.	2	8	1
Alabama	Southeast	6.10	351.	4	4	3
Arkansas	Lower Miss.	6.87	712.	2	6	4
Mississippi	Lower Miss.	8.07	1157.	1	3	4
W. Virginia	Ohio R.	8.60	782.	1	7	5
Kansas	Central	8.61	575.	3	4	6
Oklahoma	Central	8.97	1045.	4	8	5
Pennsylvania		10.39	8590.	3	7	6
Nebraska	Upper Miss.	13.89	307.	4	4	4
New York		14.60	2305.	7	3	6
Illinois	Upper Miss.	15.31	2754.	1	3	8
Iowa	Upper Miss.	17.18	5987.	4	6	9
Kentucky	Ohio R.	17.67	453.	1	7	7
Indiana	Ohio R.	19.29	310.	0	3	3
Ohio	Ohio R.	22.06	313.	3	5	4
Missouri	Upper Miss.	25.42	3577.	0	7	12
California		45.64	2007.	3	4	13
Texas		77.44	691.	1	1	16

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* Estimates of maximum damage can be misleading. For example, in Idaho the maximum was caused by failure of the Teton Dam in 1976; the worst damage directly from precipitation and streamflow is estimated at $120 million. In Texas, the maximum appears small but much greater damage occurred in a year not covered by this table ($3.76 billion in 1979).

and Ohio basins, parts of the mid-Atlantic region, California and Texas. Flood damage over $100 million occurs relatively frequently, especially in Missouri, California, and Texas.

Perception of flood damage in a state is influenced by historical experience. A state's median damage can be taken as the expectation of the flood damage threat in a "typical" year, its maximum damage as the public view of a "major flood". These categories are useful in describing how state perspectives on flood damage might differ. Although some states in each category have experienced massive flood damage (over, say, $1 billion), such damage occurs most frequently in the high vulnerability category.

One might expect that reporting of flood damage by NWS field offices would be influenced by the flood history of an area. In low vulnerability states, floods causing over $1 million damage are notable events and seem unlikely to go unreported. Conversely, in high vulnerability states, damage of $5 million or more occurs frequently so smaller damages might seem unremarkable and be easily ignored.

However, the analysis in Section 5 indicates that these expectations are false. In California, a high vulnerability state, the NWS often reports damage under $5 million, but no NWS estimates were provided in two years when the state claimed substantial damage (1979 and 1984).[5] Likewise in Colorado, a low vulnerability state, damage of $24 million went virtually unreported in 1983 (the NWS estimate is $140,000). From these examples and others in Section 5, we conclude that omissions of estimates in the $5 – 25 million range in the NWS data sets are not systematically related to the size of a state or its typical damage level; rather, the omissions can be considered random inconsistencies in data collection operations.

C. Implications for Analysis of State Damages

States typical of the three vulnerability categories are shown in Figures 6-3(a–c) and Table 6-2. California represents the high vulnerability states, Alabama the medium vulnerability states, and Maine the low vulnerability states. In all three states, damage *totals* for the full 41 year period (Table 6-2) would be affected little by occasional omission of damage under $1 million. Indeed, California and Alabama totals would be affected little by a few $25 million omissions. But in Maine, a $25 million flood is relatively large, representing over 10% of total damage. Its omission could greatly influence the result of, say, a comparison of damages during two time periods. Furthermore, since floods in Maine involve relatively low damage there is less aggregation of damage estimates, therefore less tendency for errors to average out.

For low vulnerability regions, we recommend spatial aggregation to reduce the impact of errors and omissions. Several contiguous regional groupings of states with similar frequency distributions are suggested in the second column of Table 6-1. For example, estimates of damage in New England are expected to be more reliable than estimates of damage in Maine. Other groupings might be appropriate depending on the purpose of a particular analysis.

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[5] The largest known omission — of $50 million damage in California in 1979 — occurred when NWS data collection had been seriously curtailed. It has been corrected in the revised data sets that we provide.

Table 6-2. Levels of annual state flood damage in three states, during all years, 1955–1978 and 1983–1999.

Annual State Flood Damage Level	Flood Damage Estimates (Millions of 1995 dollars)					
	California (High Vulnerability)		Alabama (Medium Vulnerability)		Maine (Low Vulnerability)	
	N	Sum of Damages	N	Sum of Damages	N	Sum of Damages
Over $1 billion	3	5,008.4 (47.4%)	0	—	0	—
$100 – 1,000 million	10	4,873.8 (46.1%)	3	601.86 (59.6%)	0	—
$10 – 100 million	14	657.9 (6.2%)	13	332.89 (33.0%)	5	167.66 (72.3%)
$1 – 10 million	7	22.4 (0.2%)	17	72.81 (7.2%)	13	63.25 (27.3%)
$0.1 – 1 million	2	1.1 (0.0%)	4	1.82 (0.2%)	2	0.81 (0.3%)
$0.1 million or less	2	0.1 (0.0%)	0	—	1	0.06 (0.0%)
Missing	3	—	4	—	20	—
Totals	41	10,563.7 (100.0%)	41	1,009.38 (100.0%)	41	231.78 (100.0%)

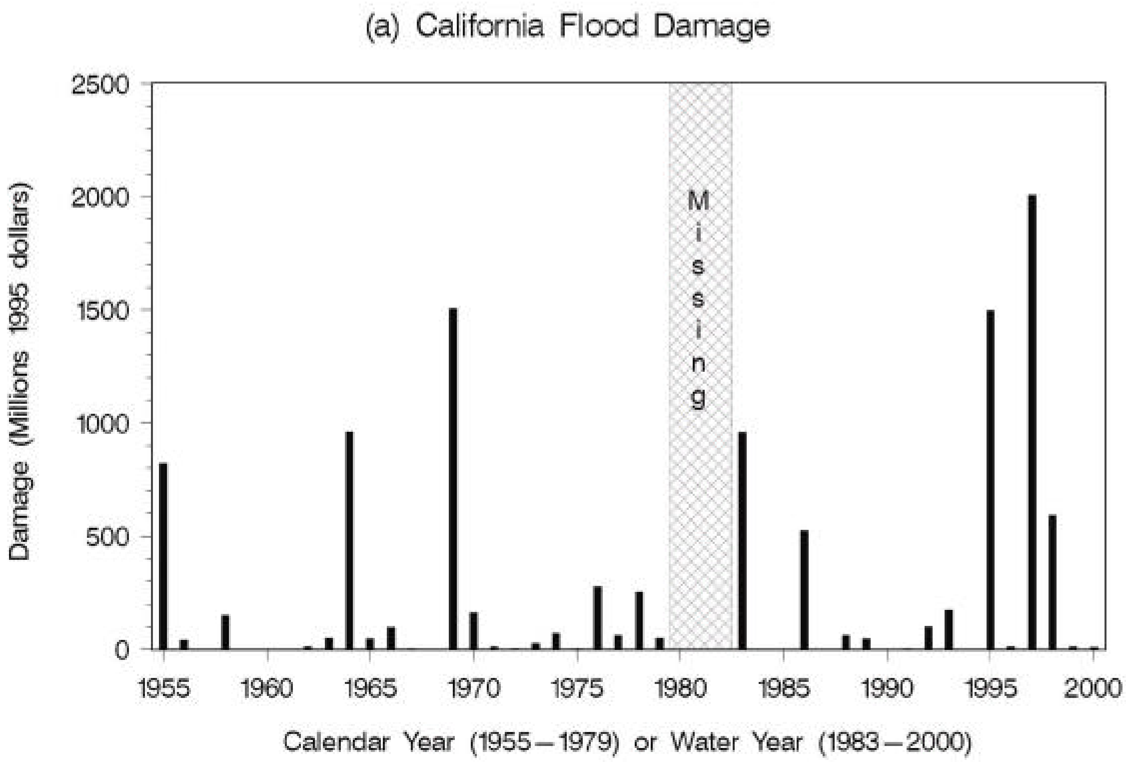

Figure 6-3. Historical flood damage in states representing different levels of vulnerability: (a) High vulnerability, California.

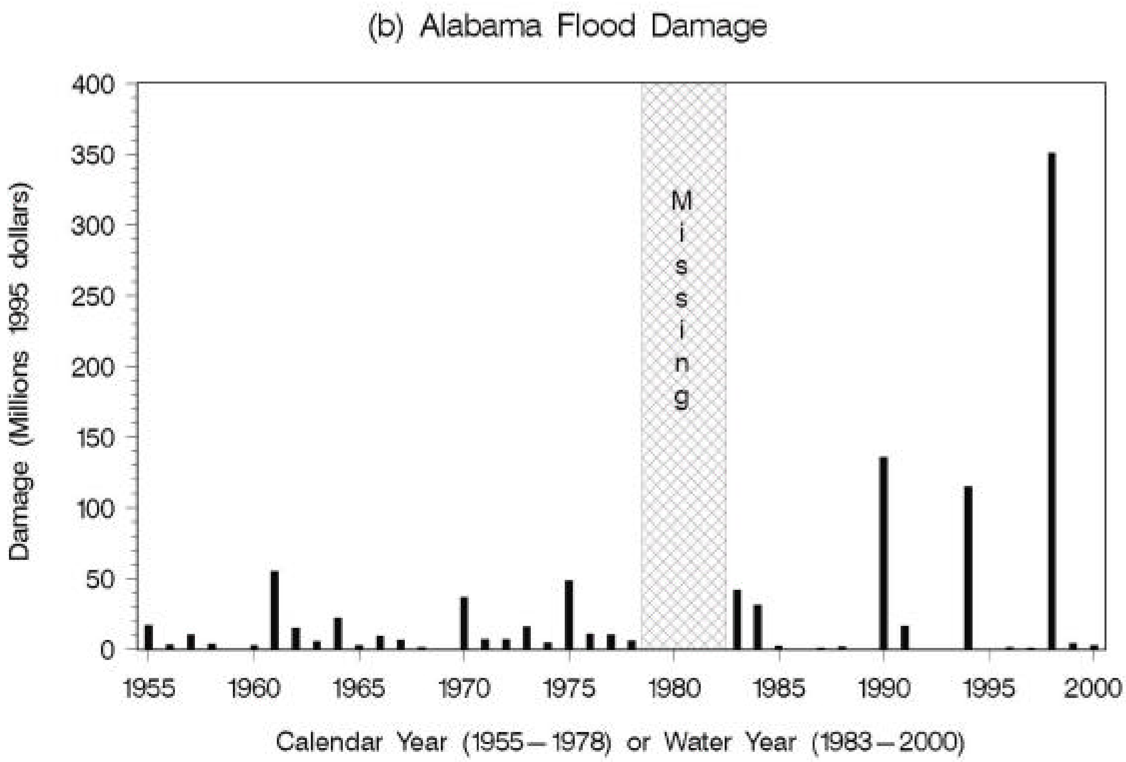

Figure 6-3, continued. (b) Medium vulnerability, Alabama.

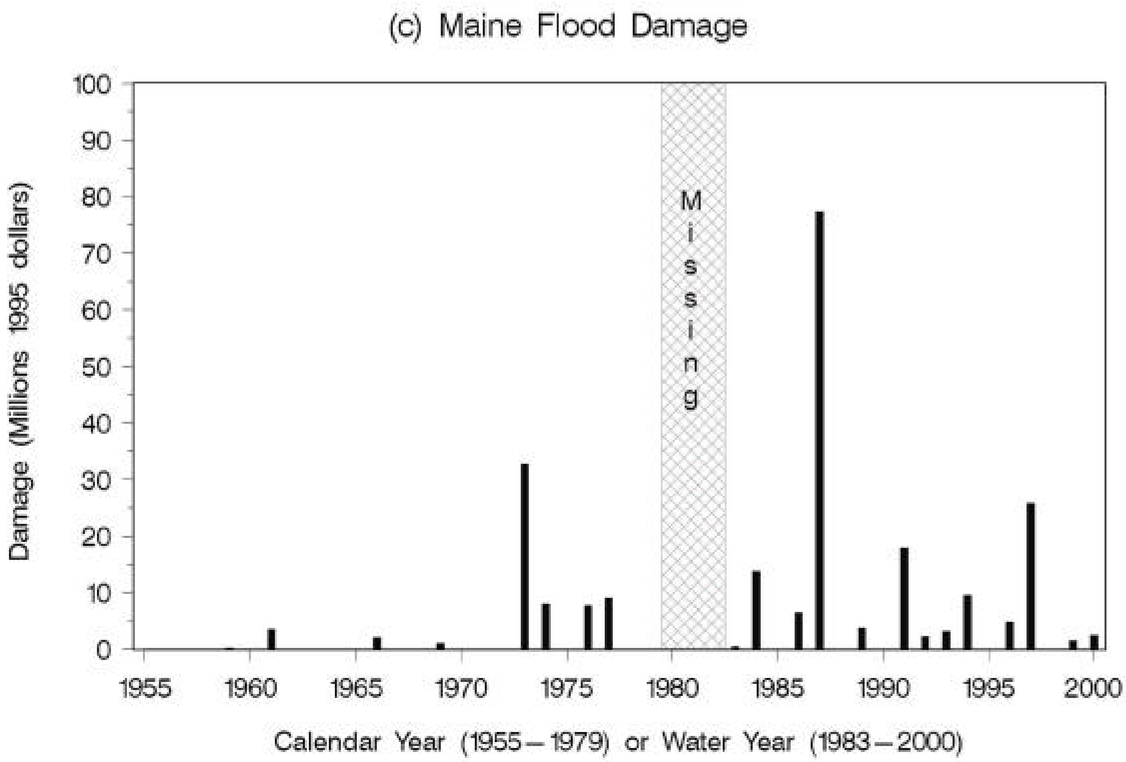

Figure 6-3, continued. (c) Low vulnerability, Maine.

D. Recommendations

In summary, the following two procedures are recommended to reduce the impact of errors and omissions in the NWS state damage estimates:

1. To determine the frequency of damaging floods in a state, establish a threshold above which damage estimates are consistently provided and report the number of floods that have exceeded the threshold. Our analysis indicates that reporting of state flood damages greater than $1 million (in 1995 dollars) has been reasonably consistent since 1955, although state damages in the $1 – 50 million range prior to 1990 occasionally went unreported.

2. To reduce the impact of errors and omissions in the estimates, increase the level of aggregation; this can be done either by (a) using total damages in a state or states over an extended period of years, or (b) computing damages for multi-state regions rather than using individual states. This is especially important for statistical analysis of low vulnerability states.

7. USE AND INTERPRETATION OF NWS FLOOD DAMAGE DATA

"Estimate" is the key word for describing the NWS flood damage data. They do not represent an accurate accounting of actual costs, nor do they include all of the losses that might be attributable to flooding. Rather, they are rough estimates of direct physical damage to property, crops, and public infrastructure. Damage estimates for individual flood events are often quite inaccurate, but as estimates from many events are added together the errors become proportionately smaller.

These findings suggest that, at the national level, annual damage totals are reasonably accurate because they are sums of damage estimates from many flood events. Flood damage occurs every year, and the frequency distribution of national damages during 1934–1999 approximates a log normal distribution. Therefore, the national data can be analyzed using conventional parametric statistics.

State annual damage estimates are more problematic. Both frequency and magnitude of damage must be considered, because damaging floods do not occur every year in most states. Flood frequency cannot be determined simply by the presence or absence of a damage estimate because reporting, particularly for small floods, is unreliable. (To estimate flood frequency, we recommend establishing a threshold below which estimates are simply classified as "low" or "minimal", as in Section 6.) Estimates of the magnitude of annual damage are often highly unreliable. In many states, most of the annual damage estimates are below $500 million (in inflation-adjusted 1995 dollars), therefore likely to contain proportionately large errors, as shown in Section 5. Even when damage is greater than $500 million, estimates from different sources have been found to disagree by as much as 40%.

Aggregation is one key to reducing estimation errors. To compare flood damages between states or river basins, it is advisable to aggregate the damage estimates over many years and compare the sums. To compare damage between years, it is advisable to aggregate yearly state damage estimates over multi-state regions, or river basin damages over large river drainage systems. Even when the estimates are highly aggregated, the user still needs to be aware that some of the variability is caused by error, and interpret the results accordingly.

A. Analyzing Trends Over Time

There are several ways of looking at trends in flood damage. Economic damage results from an interaction between flood waters and human activities in the flooded area, so one must consider changes in population and development. Figure 7-1 shows (a) U.S. total flood damage, (b) flood damage per capita, and (c) flood damage per million dollars of tangible wealth.[6] (All

[6]Flood damage per capita is computed by dividing the inflation-adjusted losses for each year by the estimated population on July 1 of that year (www.census.gov). Flood damage per million dollars of tangible wealth uses the net stock of fixed reproducible tangible wealth as estimated by the U.S. Dept. Of Commerce, Bureau of Economic Analysis (www.bea.doc.gov) for December 31 of each year (depreciating stock carried over from prior years). Thus, the flood damage per million dollars of tangible wealth reflects the proportion of the nation's wealth in that year lost due to floods. All three damage time series have log normal frequency distributions, therefore the displayed trends are transformations of linear trends computed on the logarithm of the damage values.

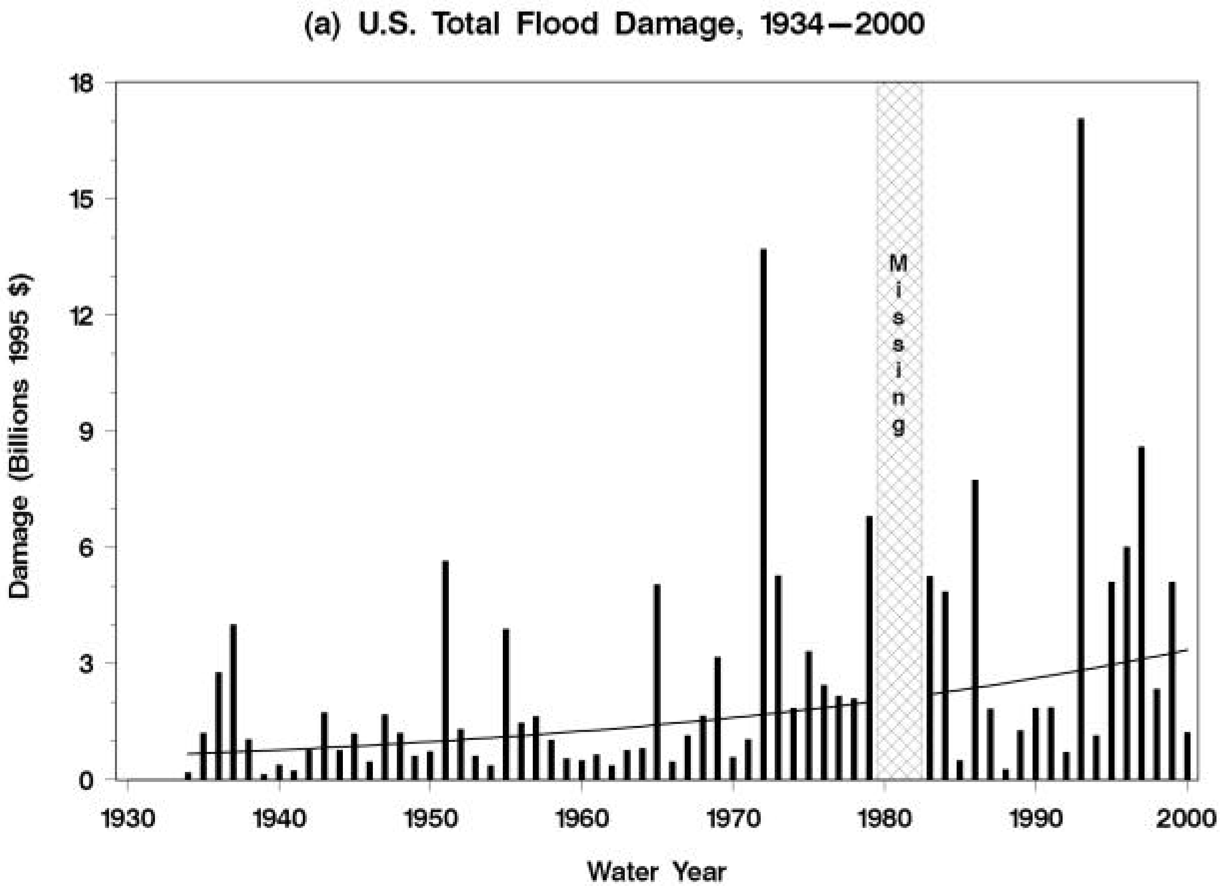

Figure 7-1. Estimated annual flood damage in the United States, 1934–1999: (a) Total flood damage.

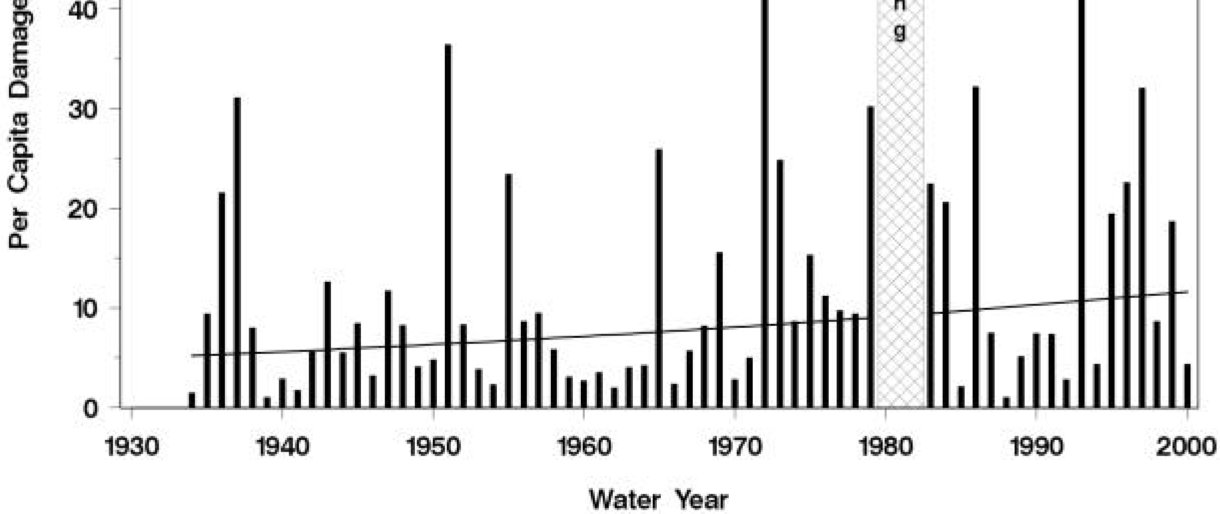

Figure 7-1, continued. (b) Flood damage per capita.

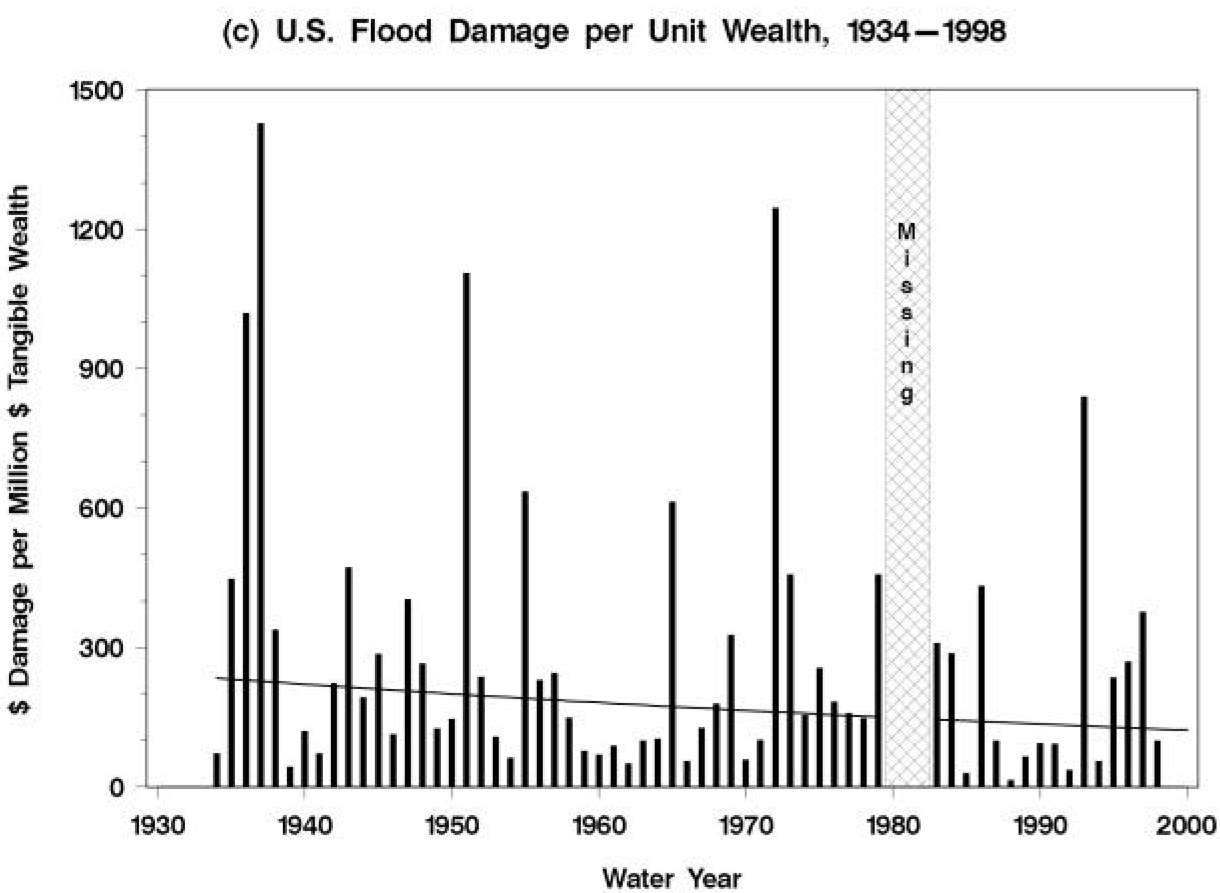

Figure 7-1, continued. (c) Flood damage per million dollars of tangible wealth.

estimates are adjusted for inflation.) The three graphs give quite different pictures of how U.S. flood damage has changed over time. Total damage and per capita damage show statistically significant increasing trends since 1934. On the other hand, damage per unit wealth has declined slightly, although the trend is not statistically significant (a = 0.05).

Caution #1: *In analyzing flood damage over time, it is important to control for changes in population, wealth, or development.*

B. Comparing States

Comparing states on the basis of their historical flood damage is complicated by the rarity of extreme damage. In a limited time period of study, some states will have experienced a low-probability flood event and others will not. Damage totals for the period depend greatly on a few extreme events. Although aggregating state damage estimates over many years helps reduce estimation errors, it does not account for differences in the timing of severe damage. For example, the inclusion of data for just one more year, 1979, would change the position of Texas in the ranking of total damages in Figure 6-2, moving it from 6th to 3rd place (Section 6).

Figures 7-2(a, b) compare rankings of the states based on their total flood damage in two periods, 1955–1978 and 1983–1999. Pennsylvania suffered the greatest damage in the earlier period, but its rank slips to 26th in the later period. Iowa moves in the opposite direction, from 28th in the earlier period to first in the later period. In both states, a single flood event determines the first-ranked status. A single year constitutes the majority of damage in many other states, as well. Differences in the timing and location of extreme weather events contribute to quite different rankings during the two periods.

Population differences are also an important factor when comparing states. In Figure 7-3, states are ranked according to their annual average damage per capita during 1983–1999, giving a quite different picture than the ranking by total damage in Figure 7-2(b). North Dakota moves to the top, with a whopping $363 damage per person per year (mostly attributable to flooding in 1997), while California slips to 25th place.

Caution #2: *When comparing damage in different geographical areas, it is important to control for differences in population and in the incidence of extreme weather events during the period of study.*

C. Comparing Individual Flood Events

In comparing annual state estimates, we recommend coarse comparisons using broad damage categories, perhaps similar to those used in Section 5 (low, medium, high, major).[7] Uncertainty in the dollar estimates can make comparisons difficult, even in major floods where estimates are highly aggregated. Some of the difficulties are illustrated by the following comparison of two years of major flood damage (over $500 million) in Minnesota in the 1990s.

[7] For comparing floods at the county level, where damage estimates are extremely unreliable, damage categories can be based on descriptive information instead of dollar estimates. This approach was used in a study of flooding in two Iowa counties (Pielke et al. 2000).

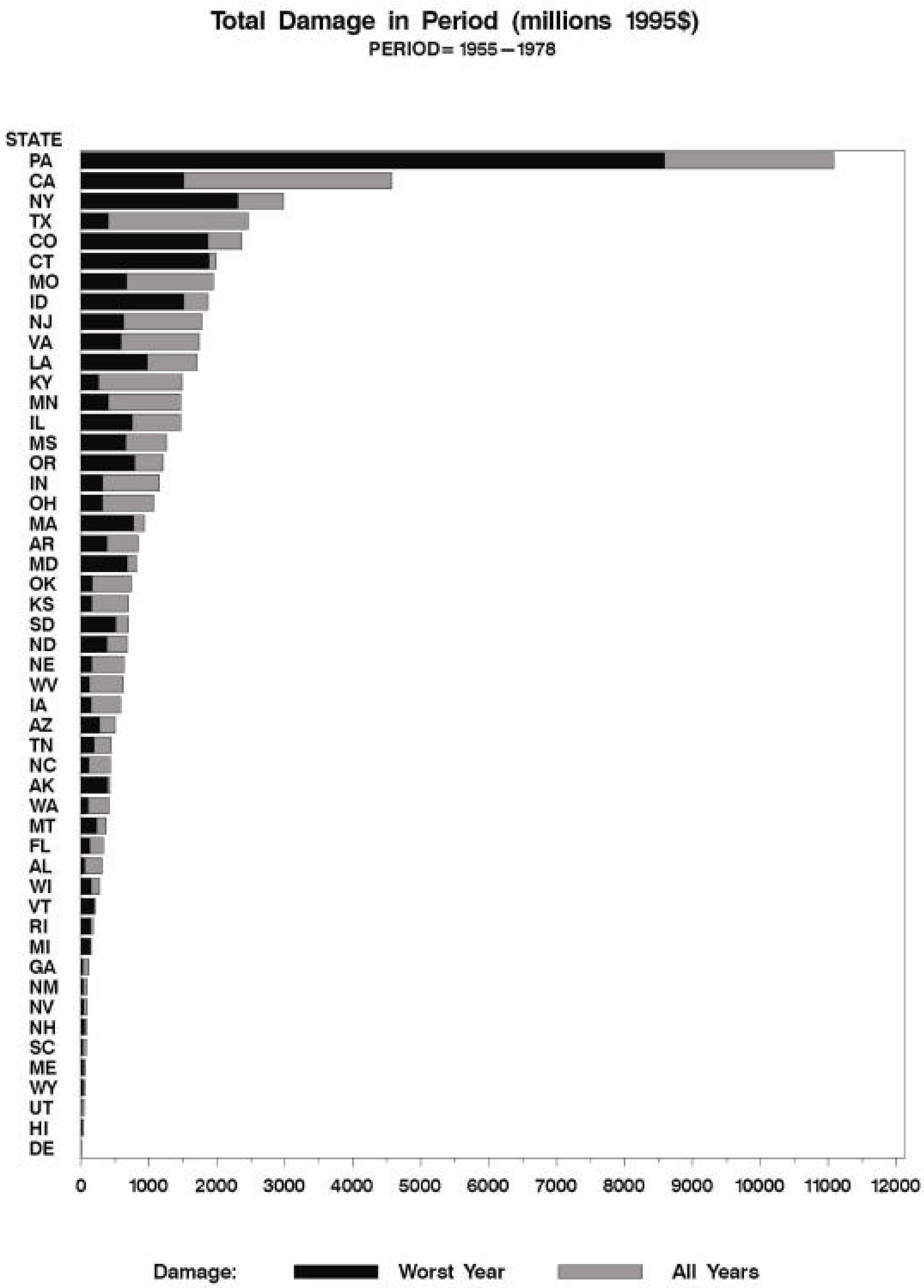

Figure 7-2. States ranked based on total flood damage (a) during 1955–1978.

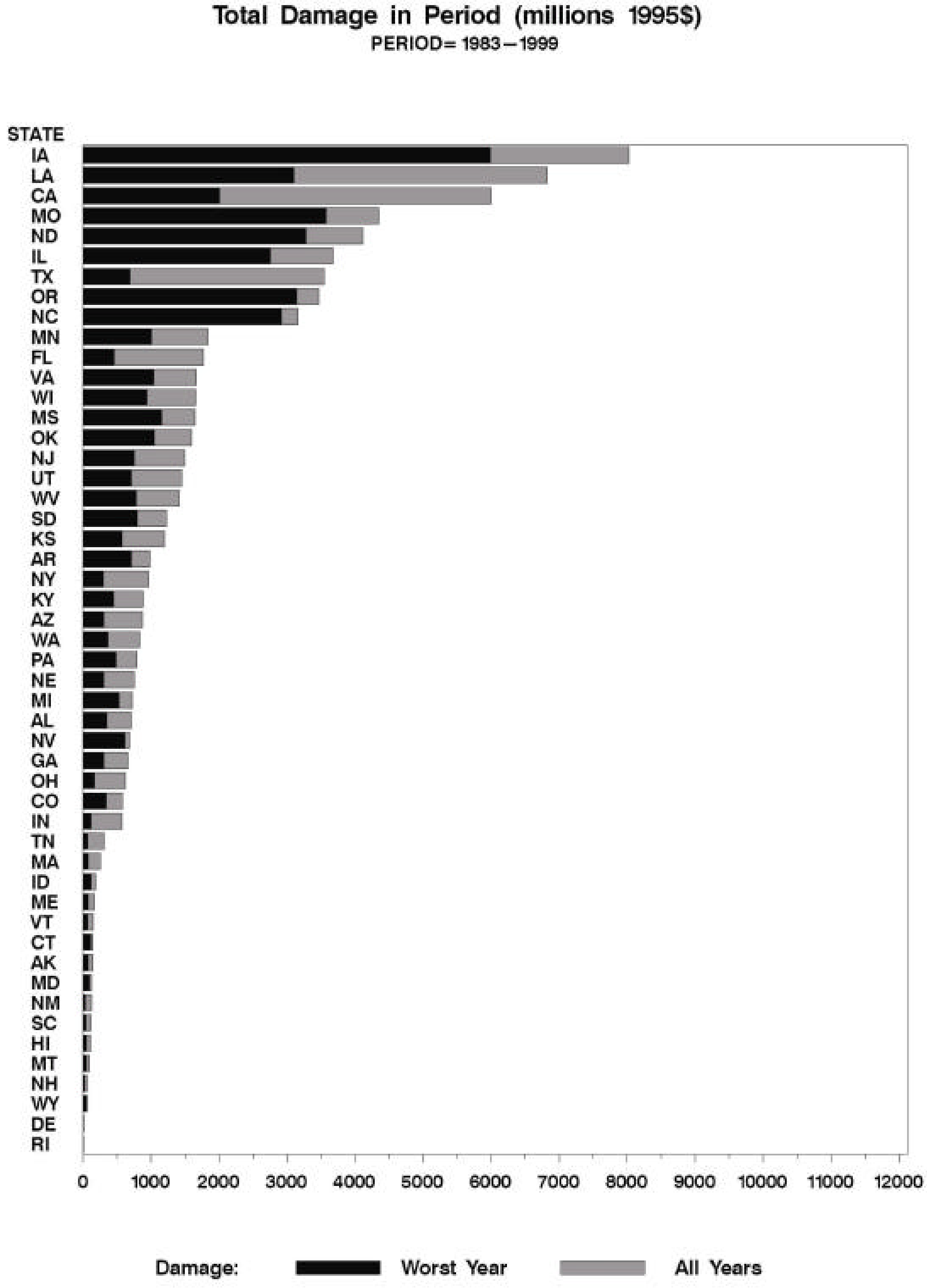

Figure 7-2, continued. (b) during 1983–1999.

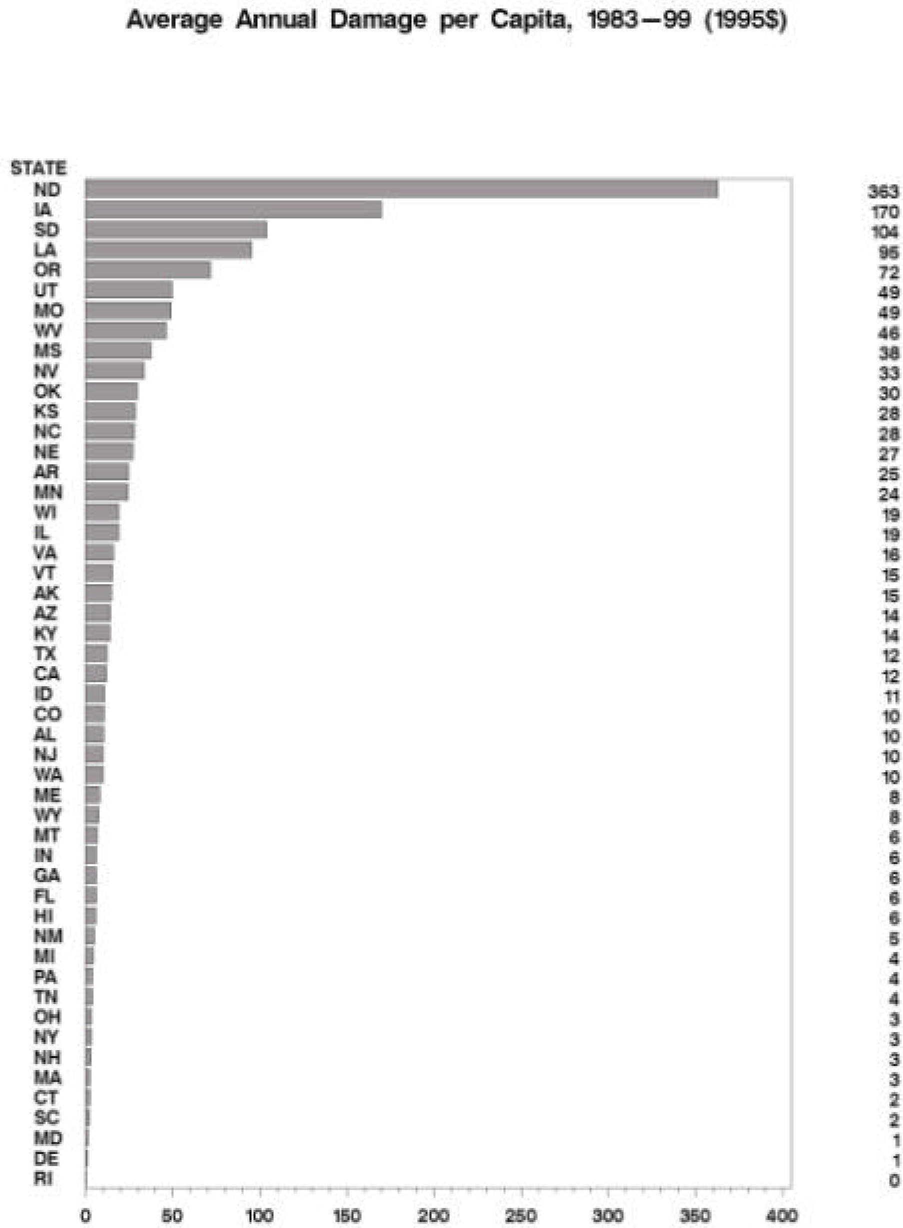

Figure 7-3. States ranked based on average annual flood damage per capita, 1983–1999.

1993: Unusually heavy rainfall from May through August over most of the state produced widespread flooding that resulted in a presidential disaster declaration for 57 of Minnesota's 87 counties, and an agricultural disaster declaration for an additional eight counties. The NWS estimated damage of $1.0 billion (in 1995 dollars).

1997: Heavy snow and ice followed by spring rains and rapid snowmelt led to severe flooding in April and May. Damage was extensive in East Grand Forks and many smaller communities. A presidential disaster declaration was issued covering 58 Minnesota counties. Additional storms and flooding in June and July led to another disaster declaration for 7 metropolitan area counties. The NWS estimated damage of $715 million (in 1995 dollars).

In which year was the damage more severe? The answer to this question depends upon how "severe" is defined. The NWS estimates suggest that damage was substantially greater in 1993. However, a report issued by the Minnesota Department of Public Safety leads to the opposite conclusion. Table 7-1 shows actual costs reported in *A Decade of Minnesota Disasters* (MDPS 2000). (We have excluded costs that are not associated with direct damage, such as temporary housing, hazard mitigation, and economic injury due to loss of business.) FEMA assistance programs, insurance, and SBA loans all indicate that non-agricultural losses were much higher in 1997 than in 1993. A representative of Minnesota's Division of Emergency Management reinforced this conclusion, telling us that in 1997 entire Minnesota towns were flooded, while in 1993 the main effects of the great Midwest flood occurred in states farther south (Sherrill Neudahl, personal communication, 10/5/00).

Agricultural damage was greater in 1993 than in 1997, however. The value of Minnesota's final crop output in 1993 was 44% less than the average of the previous three years (USDA 2000). In contrast, final crop output in 1997 was equal to the average for the previous three years, suggesting that the floods did little to diminish agricultural productivity that year. Twice as much money was awarded in FSA loans to Minnesota farmers in 1993 as in 1997 (Table 7-1).

Lumping agricultural and non-agricultural losses into a single damage estimate is problematic. Enormous discrepancies are found in historical estimates of agricultural damage because of different perspectives on and methodologies for the measurement of losses. For example, one official publication estimated that Minnesota's total damage in the 1993 flood exceeded $1.7 billion (MDPS 1994) — substantially more than the NWS estimate. Of that, $1.5 billion was attributed to crop "losses" based on the amount that crop production fell short of the previous 4-year average. This is a loss in expectation, perhaps, but not a loss of actual investment.

This comparison does not lead us to challenge the NWS estimates for these two flood years. Rather, it provides another reason for caution in interpreting and comparing damage estimates. Given the error magnitudes found in Section 5, the difference of 40% in estimates for the two years is not large enough to say with confidence that one year's economic damage was worse than the other's, only that there was major damage in both years. Most Minnesotans would

Table 7-1. Minnesota flood damage expenditures in major flood years 1993 and 1997 (in millions of 1995 dollars). Source: MDPS 2000.

	1993	1997
Disaster costs itemized by Minnesota Dept. of Public Safety		
Federal, state, and local government direct costs associated with FEMA assistance programs* (excluding temporary housing and hazard mitigation)	129.7	404.3
Insured losses (estimate)	73.0	154.0
Total direct damage costs (non-agricultural)	202.7	558.3
Small Business Administration loans to cover physical damage		
SBA physical damage loans for homes and businesses	16.0	74.6
U.S. Dept. of Agriculture loans to farmers, year following disaster		
Emergency loans through the Farm Service Agency	21.2	10.3

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* FEMA-993-DR-MN in 1993; FEMA-1175-DR-MN and FEMA-1158-DR-MN in 1997.

probably consider the floods of 1997 to be much more severe than those of 1993, while farmers might hold the opposite view.

Caution #3: *Because of the large estimation errors found in the NWS data, estimates for individual floods should be used with caution. For some purposes the comparison of individual floods may be better done using nominal or ordinal data categorizations. For specific events, detailed descriptions should be sought to compare the nature and impacts of the damage.*

D. Possible Inconsistencies With Other Sources

The NWS defines flood damage more narrowly than many other agencies. Emergency management agencies generally include both river and coastal flooding whenever water rises to overflow land that is not normally submerged. In contrast, the NWS estimates include only flooding whose primary cause is rainfall, snowmelt, or river flows, excluding flooding caused by wind-driven waves associated with coastal storms or hurricanes. For example, FEMA records show a Presidential disaster declaration of type "flood" for Massachusetts in February 1978, and the USACE reports $520 million flood damage due to storm surge and huge waves (USACE New England Division 1979; converted to 1995 dollars), but that damage is not included in NWS flood damage estimates.

The NWS estimates do include floods caused by dam failure, however. In the NWS record, Idaho's worst flood resulted from the failure in 1976 of the newly-constructed Teton Dam, with damage estimates in the $1 – 2.3 billion range (in 1995 dollars). Idaho's largest estimated flood damage due to natural causes was much smaller: $120 million in 1997.

Caution #4: *Different agencies define "flood" and "flood damage" somewhat differently. Check for incompatibilities between data from different sources before seeking to combine sources or aggregate data.*

E. Uses of the Reanalyzed NWS Damage Estimates

With the precautions noted above, we conclude that the reanalyzed NWS flood damage estimates can be a valuable tool to aid researchers and decision makers in understanding the changing character of damaging floods in the United States. Data sets of annual damage at national, state, and river basin levels are available at www.flooddamagedata.org.

In climate research, these data can contribute to understanding the relationship between climatic influences and damaging floods. For example, they have been used to examine the relationship of national and regional flood damage with several measures of precipitation, in a study that controlled for changes in population and wealth (Pielke and Downton 2000). For policy makers and emergency managers, the data provide a nationwide overview of flood vulnerability and can be useful in evaluating policies related to management of flood hazards. For example, we have investigated the role of politics in presidential disaster declaration decisions by comparing disaster declarations involving floods with estimated flood damage (Downton and Pielke 2001).

F. Recommendations for Future Collection of Flood Damage Estimates

A series of natural disasters in the 1990s, accompanied by skyrocketing costs of federal disaster assistance, has prompted calls for development of national databases to record losses from past and current disasters (Mileti 1999, NRC 1999, Heinz Center 2000). The NWS damage estimates are not reliable enough to be a basis for certain decisions regarding flood policy, such as setting specific flood insurance premiums or evaluating the cost-effectiveness of particular hazard mitigation measures. Better damage data are needed to evaluate the effectiveness of mitigation measures designed to reduce flood losses.

Substantial improvement of flood damage records in the U.S. would require additional funding and should have a clear purpose based on intended uses of the data. A committee of the National Research Council (NRC) points out that reliable loss data are critical for cost-effective hazard mitigation and planning for future disaster response. The NRC (1999) report recommends measures for developing a comprehensive and consistent database of losses resulting from natural disasters. Recommendations include:

(1) One agency of the federal government should be responsible for compiling the loss data, working with states and localities to collect the data. The Bureau of Economic Analysis (BEA) within the Department of Commerce is suggested as the agency best-suited to the task.

(2) The data should focus on *direct* losses (loss in asset value), including losses that are not reimbursed by insurance or disaster aid.

(3) A uniform framework should be used in reporting and compiling loss estimates, classified according to who initially bears the loss (government, businesses, individuals, etc.) and the type of loss (property, agricultural products, deaths and injuries, cleanup and response costs, temporary housing, etc.). These loss estimates should be more complete and accurate than the initial estimates made at the time of a disaster and should include events that may not qualify for a presidential disaster declaration.

(4) The database need not contain loss information for every event; rather, the objective should be to compile data on disasters that cross some threshold. The definition of a "major" natural disaster for which loss data are to be compiled should be consistent with expectations for how the data will be used.

Clearly, the NWS flood damage database does not provide the level of accuracy and detail envisioned in the NRC recommendations, nor is it intended to do so. Nevertheless, the collection of damage information in severe weather events by NWS field offices provides a model, of sorts, for nationwide collection of damage data. It is administered fairly uniformly throughout the nation, collects information on multiple natural hazards, focuses on direct losses including some unreimbursed losses, and is not limited to declared disasters. As the NWS field offices collect storm damage information, they are in a good position to identify weather events that appear to meet whatever minimum criteria might be established for loss data to be compiled.

In the absence of additional funding, only minor improvements can be expected in the NWS collection of flood damage estimates. The following modest changes are suggested to improve accuracy, consistency, and usefulness.

(1) Clearly define the purposes of the damage estimates and what types of loss are to be included.

(2) Provide uniform instructions to staff members responsible for compiling damage estimates at all NWS field offices. Instructions should include how to obtain damage estimates and some training in damage estimation.

(3) It would be valuable to provide separate estimates of different types of loss, as was done in *Climatic Data National Summary* through 1975. At a minimum, distinguish on-farm losses of agricultural products from other property losses.

(4) It is reasonable to set a lower limit below which loss estimates need not be reported, such as $50,000 for a single flood at the county level. The NWS-HIC practice of focusing greatest attention on floods with damage greater than $1 million at the state level is also reasonable. These practices would save staff time and have little impact on total damage estimates.

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ABBREVIATIONS

DSR – Damage Survey Report

FEMA – Federal Emergency Management Agency

IDE – Initial Damage Estimate

NOAA – National Oceanic and Atmospheric Administration

NWS – National Weather Service

NWS-HIC – National Weather Service, Hydrologic Information Center

OES – California Governor's Office of Emergency Services

PDA – Preliminary Damage Assessment

TVA – Tennessee Valley Authority

USACE – U.S. Army Corps of Engineers

USDA — U.S. Department of Agriculture

USGS – U.S. Geological Survey

WCM – Warning Coordination Meteorologist

Appendix A

COMPILATION OF DAMAGE ESTIMATES FOR 1976–1979

Monthly damage estimates by river basin in 1976 and 1977 were published in *Climatological Data National Summary*. NWS staff prepared some 1978 and 1979 estimates which were summarized in *Weatherwise* (Marrero 1979, 1980). We augmented these estimates with unpublished information housed at NWS-HIC, including reports from regional NWS offices, preliminary tabulation sheets, and notes made by NWS employees. Wherever possible, we also compared damage estimates from NWS-HIC files with reports on specific floods by other agencies, including USACE, USGS, and NOAA. Final estimates were chosen using the following rules:

- In order to change any estimates in the NWS tabulated data set, a published source had to provide good reason to doubt the NWS estimates and the published source had to provide more reliable estimates.
- There were instances when we had to choose between two or more estimates. In general, we chose published source estimates over NWS "grey" sources.
- Asterisks were added to the estimates wherever published sources indicated that a damaging flood occurred but provided no estimates.

1976 Flood Damage Estimates

Reconstructed 1976 damage estimates by state and month are shown in Table A-1. Data sources are as follows:

- September in California is from the NOAA Cooperative Observer (NOAA 1976).
- July in Colorado is from a USGS/NOAA report (1979).
- May in Oklahoma is from a report concerning flood hazard mitigation in Oklahoma (Patton 1993).
- All other damage estimates are from NWS notes and summaries archived at NWS-HIC, which had been compiled for publication in *Climatological Data National Summary*, but had not been published.

1977 Flood Damage Estimates

Reconstructed 1977 damage estimates by state and month are shown in Table A-2. Data sources are as follows:

- The following totals are from USACE reports: October in Arizona (USACE, Los Angeles District 1978) and December in Oregon and Washington (USACE, Portland District 1978).
- The estimate for a flood in Kansas City, Kansas and Kansas City, Missouri in September of 1977 is from NOAA (1977) and USGS (1991) reports.
- 1977 damage totals for Tennessee, Virginia, and West Virginia have been changed based on information on April flooding in Appalachia from a TVA flood report (TVA 1978).
- All other damage estimates are from NWS notes and summaries archived at NWS-HIC.

1978 Flood Damage Estimates

Reconstructed 1978 damage estimates by state and month are shown in Table A-3. It was more difficult to piece together the flood estimates for 1978 and 1979 than for 1976 and 1977.

Several different sets of state-level estimates exist in the NWS files for 1978, and in many cases the estimates do not agree. Data sources are as follows:

- All estimates for California are from the California Office of Emergency Services (Montane 1999).
- Most of the entries represented by asterisks rather than damage figures are based on information in *Storm Data*. In these cases it was apparent that flooding had occurred, but damage figures were not available.
- The following numbers are from USACE reports: March in Arizona (USACE, Los Angeles District 1979a); March in Ohio (USACE, Buffalo District 1978); August in New Mexico (USACE, Albuquerque District 1978); September in Arkansas (USACE, Little Rock District 1978); September in Texas (USACE, Albuquerque District 1979a); December in Arizona (USACE, Los Angeles District 1979b and USACE, Los Angeles District 1980); and December in New Mexico (USACE, Los Angeles District 1980).
- Montana and Wyoming in May are from a jointly authored USGS/NOAA paper (USGS 1984).
- The following estimates are from Marrero (1979): March in Nebraska and Indiana; April in North Dakota and Virginia; May in Louisiana and Texas; July in Alabama, Minnesota, and Wisconsin; August in Texas; and September in Louisiana.
- The following estimates are from *Storm Data*: May in Arkansas; July in Colorado; August in Illinois, Indiana, and Maryland; and December in Idaho.
- All other estimates are from NWS files.

1979 Flood Damage Estimates

Reconstructed 1979 damage estimates by state and month are shown in Table A-4. Data sources are listed below. Users of 1979 estimates should note that a flood in "New Jersey, New York, and southern New England" in January caused $62 million in damage (Marrero 1980). This estimate could not be assigned to individual states. Similarly, a flood in April in Louisiana, Mississippi, and Alabama caused $1 billion in damage that could not be assigned to individual states (Marrero 1980). These floods are included in the national total for 1979, but not in the state estimates.

- All estimates for Virginia are from the state emergency management office (Michael Cline, personal communication 2000).
- The following estimates are from Marrero (1980): March in Indiana and Iowa; April in Texas; July in Texas; September in Maryland, Louisiana, and Texas; October in Kansas and Florida; and November in Hawaii.
- The following are from USACE reports: March in Minnesota and North Dakota (USACE, St. Paul District 1979) and June in New Mexico (USACE, Albuquerque District 1979b).
- Estimates from *Storm Data* include: February in Arkansas; April in Arkansas, Florida, Illinois; March in Florida and New York; May in South Dakota; June in Colorado; July in Alabama, Illinois, New York, and West Virginia; August in Minnesota, Utah, and West Virginia; and September in Florida.
- February in Hawaii is from USGS (1991).
- April in Ohio is from NWS notes.
- All other estimates are from NWS files.

Table A-1. 1976 damage estimates (thousands of current dollars)

State	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Alabama				4,610		100	*						4,710
Alaska									*				0
Arizona		*					*		6,000				6,000
Arkansas					*								0
California		*							120,100	*			120,100
Colorado							35,540	*					35,540
Connecticut								7,100					7,100
Delaware													0
Florida					*	*						*	0
Georgia			*	1,450	6,650							30	8,130
Hawaii		270											270
Idaho						650,000		*					650,000
Illinois		1,570	*			1,800							3,370
Indiana		3,130	550										3,680
Iowa				160									160
Kansas				110			1,220						1,330
Kentucky		*											0
Louisiana			*										0
Maine				860		*		2,500					3,360
Maryland										4,900			4,900
Massachusetts		1,000				*							1,000
Michigan		*	*	790			*						790
Minnesota													0
Mississippi				2,840									2,840
Missouri				810			*	*					810
Montana					50								50
Nebraska													0
Nevada							200						200
New Hampshire													0
New Jersey								*					0
New Mexico							*	500	*				500
New York	*	1,100	2,120			11,000	14,000	9,000	700	100			38,020
North Carolina		200			8,920				*				9,120
North Dakota				2,420									2,420
Ohio		40											40
Oklahoma					34,250		18,390						52,640
Oregon	1,040	130						*					1,170
Pennsylvania	*	410				30			*				440
Rhode Island													0
South Carolina		*	*		840	7,000				3,330		40	11,210
South Dakota					*	5,500							5,500
Tennessee		200											200
Texas				2,940	200	30,000			250				33,390
Utah													0
Vermont	*			*			*	*				*	0
Virginia									*				0
Washington								2,500					2,500
West Virginia							*			3,260			3,260
Wisconsin			*										0
Wyoming						100	*						100
	1,040	8,050	2,670	16,990	50,910	705,530	69,350	21,600	127,050	11,590	0	70	1,014,850

* indicates that a flood occurred, but damage figures are unavailable or under $30,000.

Table A-2. 1977 damage estimates (thousands of dollars)

State	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
Alabama			610	3,490					660				4,760
Alaska					200	*			*				200
Arizona								340	*	15,250			15,590
Arkansas			130						*				130
California								28,500					28,500
Colorado					750	*	*	500					1,250
Connecticut		*	1,520						50			*	1,570
Delaware													0
Florida	140												140
Georgia			240	1,350							2,570		4,160
Hawaii													0
Idaho						*							0
Illinois			*	830	2,880					1,840		1,640	7,190
Indiana				450				750		3,690		3,270	8,160
Iowa		*			*	*		*					0
Kansas					*	6,350			40,000				46,350
Kentucky				100,000			*	*		*	1,000		101,000
Louisiana				48,040						*		*	48,040
Maine			4,190										4,190
Maryland													0
Massachusetts		*											0
Michigan				*			*						0
Minnesota			*					6,000	1,870				7,870
Mississippi			*	2,780									2,780
Missouri			2,500			*			50,000				52,500
Montana													0
Nebraska		*			*	*	870		720				1,590
Nevada													0
New Hampshire			610										610
New Jersey											95,880		95,880
New Mexico							*	*					0
New York			4,540				460		1,840	3,760		*	10,600
North Carolina			*							500	52,000		52,500
North Dakota							80						80
Ohio		*		370									370
Oklahoma			*		12,000			720					12,720
Oregon												10,690	10,690
Pennsylvania		*					330,020	*	*				330,020
Rhode Island													0
South Carolina			*	80					160		20		260
South Dakota								*					0
Tennessee				21,000									21,000
Texas		50	2,000	250	*	*	*		50	100			2,450
Utah					*		260	40					300
Vermont			2,710										2,710
Virginia				242,500						1,400	24,800		268,700
Washington						140	*					5,490	5,630
West Virginia		*		50,000				*			500		50,500
Wisconsin													0
Wyoming					100	*	*						100
Total U.S.	140	50	19,050	471,140	15,930	6,490	331,690	36,850	95,350	26,540	176,770	21,090	1,201,090

* indicates that a flood occurred, but damage figures are unavailable or under $30,000.

Table A-3. 1978 damage estimates (thousands of dollars)

State	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	**Total**
Alabama	1,000		*		*	*	2,000						3,000
Alaska	*				*								0
Arizona	7,100		33,100					*			8,000	83,160	131,360
Arkansas					200				23,700				23,900
California	6,130	*	117,800						300				124,230
Colorado	*					*	70	*					70
Connecticut		*											0
Delaware													0
Florida	3,300	420			*								3,720
Georgia	*												0
Hawaii													0
Idaho				*	*							60	60
Illinois					*		*	50					50
Indiana			35,000			3,000	*	960					38,960
Iowa						*							0
Kansas													0
Kentucky												100,000	100,000
Louisiana					100,000	*			45,000				145,000
Maine													0
Maryland	*		*					150					150
Massachusetts													0
Michigan					*	*		*	*				0
Minnesota						5,000	60,000						65,000
Mississippi			*	*	*								0
Missouri							2,000	*	*	*			2,000
Montana				1,500	17,560								19,060
Nebraska			67,000										67,000
Nevada			*										0
New Hampshire						900							900
New Jersey		12,220				*		2,500		*			14,720
New Mexico			*			*	*	6,000			*	8,450	14,450
New York	*	*											0
North Carolina													0
North Dakota				13,000		*	*						13,000
Ohio			1,520			*							1,520
Oklahoma					*								0
Oregon								*					0
Pennsylvania	6,630		*		*	*							6,630
Rhode Island													0
South Carolina	60					*		*					60
South Dakota								250					250
Tennessee							*						0
Texas				10	30,000	*		100,000	1,120		1,600		132,730
Utah													0
Vermont													0
Virginia	*			10,000									10,000
Washington							*						0
West Virginia	700					*		*				2,200	2,900
Wisconsin						18,000	53,000	*					71,000
Wyoming					16,320								16,320
Total U.S.	24,920	12,640	254,420	24,510	164,080	26,900	117,070	109,910	70,120	0	9,600	193,870	1,008,040

* indicates that a flood occurred, but damage figures are unavailable or under $30,000.

Table A-4. 1979 damage estimates (thousands of dollars)

State	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	**Total**
Alabama		*		#			500						500
Alaska					*		*					*	0
Arizona	*												0
Arkansas		620		2,000	*	*	*						2,620
California						25,900							25,900
Colorado					*	50							50
Connecticut	#												0
Delaware		*											0
Florida			4,990	15,000					1,000	1,000			21,990
Georgia		*	*	*									0
Hawaii		6,000									5,000		11,000
Idaho	*	*											0
Illinois			*	32,000			250	*					32,250
Indiana			15,000				1,000	*					16,000
Iowa			2,000		*			*					2,000
Kansas						*				7,000			7,000
Kentucky							*		*				0
Louisiana		*		#	*				8,000				8,000
Maine													0
Maryland	*								69,000				69,000
Massachusetts	#												0
Michigan							*						0
Minnesota			10,140		*	*	*	3,000					13,140
Mississippi	*			#		*							0
Missouri				*	*		*						0
Montana					*								0
Nebraska					*	*	*	*					0
Nevada			*					*					0
New Hampshire			*										0
New Jersey	#	*			*								0
New Mexico					*	3,210							3,210
New York	#	*	3,920	*	*		14,850		*				18,770
North Carolina									*				0
North Dakota			20,100	*									20,100
Ohio				60,000		*							60,000
Oklahoma							*	*			*		0
Oregon		*											0
Pennsylvania	*	*	*			*	*	*					0
Rhode Island	#												0
South Carolina			*										0
South Dakota					49,000								49,000
Tennessee			*	*			*	*	*				0
Texas	*		*	500,000	*	*	750,000	*	750,000			*	2,000,000
Utah								130					130
Vermont													0
Virginia		*		*			7,800		*	17,000			24,800
Washington								3,100				*	3,100
West Virginia					*		2,000						2,000
Wisconsin			*	*			*						0
Wyoming								*					0
LA, MS, AL				1,000,000									1,000,000
NY,NJ,CT,MA,RI	62,000												62,000
Total U.S.	62,000	6,620	56,150	1,609,000	49,000	29,160	776,400	6,230	828,000	25,000	5,000	0	3,452,560

* indicates that a flood occurred, but damage figures are unavailable or under $30,000.

Damage estimate is included in an estimated total for several states.

Appendix B

ESTIMATED FLOOD DAMAGE, BY STATE

Damage estimates are given in current dollars for the year in which the damage occurred. To adjust for inflation, the estimates can be converted to 1995 dollars by dividing by the implicit price deflator in Column 2 (U.S. Bureau of Economic Analysis 2001). Estimates are for calendar years during 1955–1979, and for fiscal (or water) years during 1983–2000. For example, fiscal/water year 1990 covers from October 1, 1989, through September 30, 1990.

An entry of zero indicates that no damage estimate was reported. It can be assumed that actual flood damage was small, but it is quite possible that some damage occurred.

Data are unavailable for 1980–1982 and for Alaska before 1967.

Damage in Thousands of Current Dollars

	Deflator	AL	AK	AZ	AR	CA	CO	CT	DE
1955	0.20163	3,379		226	61	165,767	2,567	379,360	117
1956	0.20846	720		0	255	8,745	5,135	0	0
1957	0.21539	2,324		0	27,938	13	2,901	0	0
1958	0.22059	872		0	6,202	33,063	240	0	0
1959	0.22304	0		100	3,090	4	0	0	0
1960	0.22620	670		0	580	516	0	750	0
1961	0.22875	12,625		325	3,503	95	0	0	0
1962	0.23180	3,529		1,000	91	2,780	80	0	0
1963	0.23445	1,280		0	2,500	11,834	50	0	0
1964	0.23792	5,343		55	598	229,168	0	0	0
1965	0.24241	723		11,330	143	11,321	452,293	0	0
1966	0.24934	2,366		3,050	5,055	24,347	707	0	0
1967	0.25698	1,695	98,550	3,576	1,497	1,370	0	0	0
1968	0.26809	408	0	188	21,099	0	0	100	0
1969	0.28124	88	0	0	3,411	423,296	66	528	0
1970	0.29623	10,891	0	5,000	639	47,798	2,040	0	0
1971	0.31111	2,170	8,631	3,476	2,549	3,522	0	0	50
1972	0.32436	2,278	1,090	20,868	1,780	1,132	15	15,414	0
1973	0.34251	5,439	1,500	0	129,579	9,480	121,383	1,950	0
1974	0.37329	1,731	0	2,605	8,746	27,124	0	0	5
1975	0.40805	19,815	0	927	21,387	1,845	0	9,360	0
1976	0.43119	4,710	0	6,000	0	120,100	35,540	7,100	0
1977	0.45892	4,760	200	15,590	130	28,500	1,250	1,570	0
1978	0.49164	3,000	0	131,360	23,900	124,230	70	0	0
1979	0.53262	#	0	0	2,620	25,900	50	#	0
1980	0.58145								
1981	0.63578								
1982	0.67533								
1983	0.70214	29,431	0	179,938	500,000	673,000	100	0	0
1984	0.72824	23,000	7,150	223,000	5,000	0	107,050	81,700	5,000
1985	0.75117	1,700	50	1,350	19,823	0	7,000	0	50
1986	0.76769	0	0	3,000	2,240	402,000	166	0	0
1987	0.79083	755	20,000	7	15,045	1,015	0	5,000	0
1988	0.81764	1,721	500	71	12,612	52,353	0	0	0
1989	0.84883	178	6,000	33,636	2,320	38,738	481	800	1,600
1990	0.88186	120,000	0	3,220	143,056	570	130	10	0
1991	0.91397	15,055	0	258	12,006	3,376	2,820	16	0
1992	0.93619	320	7,302	5,189	909	93,152	1,602	10,366	2
1993	0.95872	0	0	228,900	2,680	165,920	100	0	0
1994	0.97870	112,696	74,000	1,616	2,024	1,792	1,242	1,316	741
1995	1.00000	0	10,025	6,618	0	1,495,960	18,240	0	0
1996	1.01937	1,649	0	701	205	13,205	4,058	2,092	300
1997	1.03925	1,354	1,271	85	12,874	2,086,125	358,890	52	0
1998	1.05199	368,938	314	66	2,045	621,588	2,550	40	0
1999	1.06677	4,663	0	12,796	1,777	14,176	50,675	1,112	0
2000	1.09113	3,087	110	90	2,773	9,238	297	6,010	0

Damage estimate available for large region, but not for individual state.

Damage in Thousands of Current Dollars

	Deflator	FL	GA	HI	ID	IL	IN	IA	KS
1955	0.20163	105	1	0	1,371	102	1,003	35	474
1956	0.20846	1,891	212	0	6,222	1,026	4,021	51	33
1957	0.21539	0	1,068	0	20,896	1,206	66,748	1,543	9,164
1958	0.22059	0	323	400	3	17,970	52,302	7,508	4,606
1959	0.22304	150	0	0	500	1,506	12,958	128	4,061
1960	0.22620	12,047	392	0	0	7,503	2,649	7,612	1,947
1961	0.22875	317	5,236	0	939	11,553	13,306	9,389	13,397
1962	0.23180	1,481	0	0	8,112	891	670	6,778	1,826
1963	0.23445	0	445	2,300	2,766	513	8,266	70	168
1964	0.23792	426	3,641	0	11,704	3,044	12,327	240	370
1965	0.24241	144	397	0	4,184	30,564	20	32,462	29,792
1966	0.24934	548	1,628	0	0	577	3,098	904	97
1967	0.25698	95	23	1,029	792	2,629	4,618	4,416	15,093
1968	0.26809	46	133	2,500	0	2,576	22,463	1,650	2,304
1969	0.28124	2,858	79	0	111	9,095	6,672	6,233	10,991
1970	0.29623	145	348	0	38	9,124	2,300	977	4,138
1971	0.31111	476	243	500	1,187	462	1,690	684	1,644
1972	0.32436	41,206	328	0	355	5,927	4,700	13,262	1,646
1973	0.34251	2,282	5,143	0	0	258,704	6,326	12,724	53,772
1974	0.37329	23,050	405	3,869	36,118	75,068	15,805	56,367	3,700
1975	0.40805	15,839	3,002	0	378	20,598	12,317	7,300	3,255
1976	0.43119	0	8,130	270	650,000	3,370	3,680	160	1,330
1977	0.45892	140	4,160	0	0	7,190	8,160	0	46,350
1978	0.49164	3,720	0	0	60	50	38,960	0	0
1979	0.53262	21,990	0	11,000	0	32,250	16,000	2,000	7,000
1980	0.58145								
1981	0.63578								
1982	0.67533								
1983	0.70214	0	0	0	2,200	202,500	20,000	0	0
1984	0.72824	200,000	5,050	6,055	1,000	7,992	22,194	600,550	50,050
1985	0.75117	30,000	0	3,100	0	11,500	50,000	50	5,000
1986	0.76769	7,275	2,000	0	2,005	104,705	2,500	45,307	181,700
1987	0.79083	645	1,470	2,050	17	150,000	1,906	16,755	152,000
1988	0.81764	50,350	230	35,647	0	102	89	0	0
1989	0.84883	2,109	1,792	3,392	178	1,600	716	7,286	3,394
1990	0.88186	500	30,658	665	113	71,045	105,550	351,401	2,048
1991	0.91397	0	106,158	23,715	2,574	19,834	89,504	195,703	16,551
1992	0.93619	41,938	1,156	9,260	224	189	45,424	50,800	10,127
1993	0.95872	2,080	7,340	2,910	0	2,640,140	9,550	5,740,000	551,070
1994	0.97870	182,605	300,000	3,700	0	32,606	2,852	9,124	10,437
1995	1.00000	18,536	8,845	0	2,096	27,240	6,789	3,498	8,874
1996	1.01937	158,001	2,581	1,935	49,400	107,585	21,575	165,265	3,969
1997	1.03925	49,707	464	0	125,060	4,295	68,598	3,680	102
1998	1.05199	431,311	166,291	0	1,005	2,380	19,611	168,101	4,888
1999	1.06677	60,080	8,520	0	1,297	3,666	50,124	111,221	60,030
2000	1.09113	499,080	2,101	400	85	3,113	819	14,877	250

Damage estimate available for large region, but not for individual state.

Damage in Thousands of Current Dollars

	Deflator	KY	LA	ME	MD	MA	MI	MN	MS
1955	0.20163	6,629	30	0	5,450	155,982	0	0	3,132
1956	0.20846	568	0	0	888	0	1,278	11	1,270
1957	0.21539	55,233	4,147	0	0	0	0	9,128	2,693
1958	0.22059	3,817	2,842	0	100	0	0	17	13,826
1959	0.22304	2,480	0	61	0	0	0	50	280
1960	0.22620	3	112	0	0	6,400	1,181	212	744
1961	0.22875	12,969	6,074	800	0	0	0	552	15,918
1962	0.23180	16,885	1,908	0	0	0	0	1,290	1,982
1963	0.23445	36,917	0	0	0	0	0	26	19
1964	0.23792	35,476	30	0	0	0	0	0	3,152
1965	0.24241	1,044	0	0	53	0	0	97,603	1,931
1966	0.24934	1,671	250	528	0	0	0	4,300	2,706
1967	0.25698	17,583	0	0	125	0	0	0	1,192
1968	0.26809	6,036	2,810	0	0	35,000	100	1,197	6,269
1969	0.28124	8,075	251	300	200	0	13	67,168	1,900
1970	0.29623	707	1,000	0	15	0	0	4,350	3,586
1971	0.31111	6,099	0	0	8,600	0	0	15	12,431
1972	0.32436	15,841	100	0	220,739	10	10	64,318	10,248
1973	0.34251	10,491	334,904	11,200	0	0	530	242	226,885
1974	0.37329	5,218	10,343	3,000	0	0	240	16,939	27,827
1975	0.40805	26,302	90,204	0	27,200	0	54,358	139,726	70,990
1976	0.43119	0	0	3,360	4,900	1,000	790	0	2,840
1977	0.45892	101,000	48,040	4,190	0	0	0	7,870	2,780
1978	0.49164	100,000	145,000	0	150	0	0	65,000	0
1979	0.53262	0	#	0	69,000	#	0	13,140	#
1980	0.58145								
1981	0.63578								
1982	0.67533								
1983	0.70214	100	651,000	375	100	0	0	310	812,600
1984	0.72824	180,236	6,550	10,050	10,015	50,560	0	5,000	6,050
1985	0.75117	460	8,050	45	50	0	80,000	500	2,000
1986	0.76769	25	1,515,250	5,000	0	21,500	405,000	1,501	651
1987	0.79083	68	1,175	61,250	51	47,480	15	27,800	6,380
1988	0.81764	250	8,708	0	0	0	206	555	39,420
1989	0.84883	27,445	322,118	3,200	1,600	0	180	17,600	3,635
1990	0.88186	5,664	115,901	0	23	50	627	3,032	21,805
1991	0.91397	9,034	221,720	16,336	48	9,716	6,133	1,280	313,359
1992	0.93619	46,870	4,191	2,179	339	176	355	1,760	1,010
1993	0.95872	4,980	4,020	3,040	0	160	1,600	964,050	4,480
1994	0.97870	2,544	675	9,323	4,524	0	6,236	1,867	1,352
1995	1.00000	17,673	3,097,250	0	1,620	0	2,900	3,750	1,092
1996	1.01937	21,323	121	4,916	90,481	2,663	26,690	460	200
1997	1.03925	470,915	4,359	26,845	198	75,024	325	743,218	32,774
1998	1.05199	16,639	17,845	0	334	13,510	18,190	2,529	3,498
1999	1.06677	506	5,979	1,580	9,715	250	325	466	1,769
2000	1.09113	17,631	153	2,814	2,452	206	25,430	43,112	408

Damage estimate available for large region, but not for individual state.

Damage in Thousands of Current Dollars

	Deflator	MO	MT	NE	NV	NH	NJ	NM	NY
1955	0.20163	666	63	1,500	7,398	0	23,102	1,066	30,072
1956	0.20846	167	317	865	237	0	0	0	1,089
1957	0.21539	9,618	33	5,983	0	0	0	0	166
1958	0.22059	38,718	1	3,064	0	0	3	0	42
1959	0.22304	6,018	82	3,753	0	4,500	0	0	5,667
1960	0.22620	13,506	57	8,884	0	100	0	0	7,229
1961	0.22875	27,375	0	674	891	0	0	0	608
1962	0.23180	557	147	2,630	762	0	0	0	0
1963	0.23445	152	148	13,394	2,858	0	0	620	33,102
1964	0.23792	6,591	54,389	5,146	2,454	0	0	1,235	3,275
1965	0.24241	33,976	253	1,368	4	0	0	4,833	0
1966	0.24934	2,781	0	11,628	307	0	0	1,048	0
1967	0.25698	39,080	2,947	40,644	45	0	1,438	0	777
1968	0.26809	890	0	6,029	1	800	166,690	0	0
1969	0.28124	36,601	388	1,826	0	400	580	0	3,383
1970	0.29623	14,926	581	0	138	0	0	0	3,953
1971	0.31111	191	412	5,941	0	0	138,700	0	1,000
1972	0.32436	5,783	595	73	0	0	15,050	6,613	747,674
1973	0.34251	231,438	0	10,388	0	19,100	50,868	251	5,000
1974	0.37329	62,594	4,217	126	1,000	0	0	0	0
1975	0.40805	7,611	24,123	0	6,200	0	60,687	577	60,064
1976	0.43119	810	50	0	200	0	0	500	38,020
1977	0.45892	52,500	0	1,590	0	610	95,880	0	10,600
1978	0.49164	2,000	19,060	67,000	0	900	14,720	14,450	0
1979	0.53262	0	0	0	0	0	#	3,210	#
1980	0.58145								
1981	0.63578								
1982	0.67533								
1983	0.70214	50,000	0	0	1,000	75	0	6,000	0
1984	0.72824	96,293	663	100,550	0	6,000	334,200	23,000	217,500
1985	0.75117	100	0	500	0	50	0	24,000	24,700
1986	0.76769	155,000	38,674	28,482	20,650	5,962	0	0	30,820
1987	0.79083	100,550	0	25,890	13	19,100	17,050	10	75,275
1988	0.81764	69	0	61	12	0	50	0	230
1989	0.84883	16,067	2,194	29,772	23	0	1,600	3,378	38,271
1990	0.88186	1,842	1,758	36,536	51	1,200	1	1,187	6,530
1991	0.91397	1,960	10,743	53,615	2	0	16,002	1,567	19,603
1992	0.93619	2,044	1,403	6,683	1,621	0	500	32,264	1,862
1993	0.95872	3,429,630	6,720	294,500	0	0	0	210	55,480
1994	0.97870	37,864	3,392	2,710	160	0	3,520	2,000	25,707
1995	1.00000	25,415	510	5,129	11,970	110	0	954	1,485
1996	1.01937	871	2,243	31,233	370	4,000	36,720	1,285	220,011
1997	1.03925	692	2,874	10,273	640,110	10,952	38,700	380	55,909
1998	1.05199	10,227	3,001	1,483	1,300	700	750	713	38,627
1999	1.06677	36,862	184	22,765	25,009	1,002	800,000	3,980	18,715
2000	1.09113	109,760	30	23,456	221	515	179,100	160	18,498

Damage estimate available for large region, but not for individual state.

Damage in Thousands of Current Dollars

	Deflator	NC	ND	OH	OK	OR	PA	RI	SC
1955	0.20163	625	2	753	977	9,515	141,381	28,830	74
1956	0.20846	831	0	1,056	0	6,376	7,199	0	0
1957	0.21539	788	100	7	35,665	310	1,048	0	60
1958	0.22059	3,201	0	4,867	169	363	3,582	0	680
1959	0.22304	506	28	54,840	8,907	20	21,109	0	122
1960	0.22620	100	136	191	2,638	360	3,072	0	72
1961	0.22875	1,400	0	1,217	2,483	757	612	0	369
1962	0.23180	0	0	6,512	792	1,550	15	0	97
1963	0.23445	0	0	22,359	413	299	5,397	0	89
1964	0.23792	15,816	0	28,039	798	187,101	16,938	0	1,809
1965	0.24241	88	5,192	0	2,508	5,679	0	0	268
1966	0.24934	198	9,700	1,893	12	2,283	705	0	140
1967	0.25698	1,168	0	6,622	3	1,044	7,251	588	579
1968	0.26809	0	0	20,074	3,021	538	421	9,000	0
1969	0.28124	1,338	37,436	87,916	762	938	3,310	0	625
1970	0.29623	2,326	13,832	2,478	5,212	2,518	365	0	52
1971	0.31111	965	1,266	782	23,166	4,350	20,899	0	295
1972	0.32436	10,772	537	12,929	12,006	12,977	2,786,294	0	69
1973	0.34251	39,004	0	8,317	38,119	2,699	5,935	0	7,674
1974	0.37329	1,028	8,291	1,500	29,083	64,017	0	0	78
1975	0.40805	7,932	154,715	15,513	300	7,898	270,600	0	1,477
1976	0.43119	9,120	2,420	40	52,640	1,170	440	0	11,210
1977	0.45892	52,500	80	370	12,720	10,690	330,020	0	260
1978	0.49164	0	13,000	1,520	0	0	6,630	0	60
1979	0.53262	0	20,100	60,000	0	0	0	#	0
1980	0.58145								
1981	0.63578								
1982	0.67533								
1983	0.70214	470	0	0	0	7,300	0	0	0
1984	0.72824	40,000	5	10,122	268,000	52,900	75,500	5	1,110
1985	0.75117	50	0	10,000	15,030	50	100	0	100
1986	0.76769	1,990	315	10,000	802,250	33,900	71,540	0	3,070
1987	0.79083	20,461	4,943	20,518	22,250	900	28	550	31,771
1988	0.81764	0	0	2	3,437	125	62	0	0
1989	0.84883	21,072	16,000	52,240	2,121	98	7,106	0	370
1990	0.88186	1,075	0	40,846	40,650	1,070	792	50	677
1991	0.91397	2,694	32	55,165	90	9,010	8,342	174	11,871
1992	0.93619	12,927	0	20,078	10,871	32	1,805	16	0
1993	0.95872	1,400	413,600	25,800	44,720	1,760	440	0	17,920
1994	0.97870	2,032	58,552	39,913	166	0	16,194	0	6,228
1995	1.00000	26,596	44,366	28,511	3,275	11,320	10,385	0	28,169
1996	1.01937	42,119	220	22,721	0	3,203,500	494,862	0	668
1997	1.03925	17,994	3,408,298	66,666	155	173,200	3,136	0	1,105
1998	1.05199	16,135	2,583	181,409	262	10	1,103	0	4,044
1999	1.06677	3,117,160	100,355	963	9,578	2,100	27,642	0	75
2000	1.09113	7,605	191,177	8,839	11,691	5,734	27,476	0	2,885

Damage estimate available for large region, but not for individual state.

Damage in Thousands of Current Dollars

	Deflator	SD	TN	TX	UT	VT	VA	WA	WV
1955	0.20163	11	977	5,165	226	0	10,695	1,165	5,187
1956	0.20846	10	279	3,715	210	0	0	6,472	3,185
1957	0.21539	3,969	5,118	78,881	169	3	139	1,664	11,052
1958	0.22059	0	128	18,101	10	0	0	50	1,170
1959	0.22304	0	0	2,886	4	0	28	4,914	709
1960	0.22620	3,417	226	8,093	0	0	211	0	370
1961	0.22875	1	2,263	2,846	281	0	231	130	3,455
1962	0.23180	3,030	651	1,948	1,272	0	0	0	5,914
1963	0.23445	0	6,262	20	64	0	5,937	1,013	17,624
1964	0.23792	0	156	5,435	70	692	0	11,817	4,169
1965	0.24241	740	2,472	39,395	1,746	0	2	1,012	49
1966	0.24934	470	1,608	28,001	1,577	0	0	592	1,868
1967	0.25698	1,125	1,090	98,259	453	0	581	1,910	14,235
1968	0.26809	123	648	24,267	1,260	100	0	611	47
1969	0.28124	31,898	1,090	12,878	237	680	123,552	2,722	5,996
1970	0.29623	19	13,260	3,150	222	0	148	380	297
1971	0.31111	0	86	26,538	1,033	0	1,158	3,908	1,653
1972	0.32436	165,086	6,634	20,605	358	40	180,770	21,029	37,974
1973	0.34251	0	66,273	136,758	2,270	66,466	1,615	0	3,359
1974	0.37329	268	2,243	41,707	0	0	100	21,318	10,375
1975	0.40805	0	12,700	23,074	212	200	18,340	42,289	5,913
1976	0.43119	5,500	200	33,390	0	0	0	2,500	3,260
1977	0.45892	0	21,000	2,450	300	2,710	268,700	5,630	50,500
1978	0.49164	250	0	132,730	0	0	10,000	0	2,900
1979	0.53262	49,000	0	2,000,000	130	0	24,800	3,100	2,000
1980	0.58145								
1981	0.63578								
1982	0.67533								
1983	0.70214	0	40,100	0	500,000	0	30	16,943	0
1984	0.72824	206,015	50,500	51,500	50,500	51,600	55,055	1,500	229,000
1985	0.75117	55	1,550	38,650	0	0	290	0	1,050
1986	0.76769	6,665	15,150	34,100	479,000	0	800,000	20,351	600,000
1987	0.79083	3	95	546,515	250	10,500	1,510	30,150	125
1988	0.81764	0	5,165	2,226	0	0	0	11	1
1989	0.84883	16	11,482	341,098	15,403	50	39,363	320	1,010
1990	0.88186	3,000	18,059	386,886	56	15,657	3,472	58,770	8,930
1991	0.91397	2,934	13,109	188,766	6,005	19	984	227,634	908
1992	0.93619	3,460	204	199,356	24	2	7,371	176	5,791
1993	0.95872	763,380	5,070	56,990	160	7,550	0	2,080	620
1994	0.97870	20,399	51,039	1,721	0	1,502	16,169	160	5,397
1995	1.00000	12,270	1,264	85,050	1,500	5,150	66,759	250	8,595
1996	1.01937	360	2,740	407,066	312	5,123	153,516	370,060	224,172
1997	1.03925	100,541	23,479	136,472	10,100	170	898	54,675	18,391
1998	1.05199	50	25,427	163,407	4,485	23,805	2,381	3,120	35,506
1999	1.06677	619	554	612,634	1,314	1,036	255,062	2,371	363
2000	1.09113	0	230	25,130	679	1,845	1,368	488	11,003

Damage estimate available for large region, but not for individual state.

Damage in Thousands of Current Dollars

	Deflator	WI	WY
1955	0.20163	50	200
1956	0.20846	335	11
1957	0.21539	0	526
1958	0.22059	0	3
1959	0.22304	1,791	0
1960	0.22620	996	0
1961	0.22875	1,442	0
1962	0.23180	57	0
1963	0.23445	142	899
1964	0.23792	0	138
1965	0.24241	14,067	390
1966	0.24934	361	0
1967	0.25698	0	1,096
1968	0.26809	0	0
1969	0.28124	4,763	0
1970	0.29623	0	500
1971	0.31111	0	503
1972	0.32436	0	0
1973	0.34251	6,121	304
1974	0.37329	50	48
1975	0.40805	3,041	0
1976	0.43119	0	100
1977	0.45892	0	100
1978	0.49164	71,000	16,320
1979	0.53262	0	0
1980	0.58145		
1981	0.63578		
1982	0.67533		
1983	0.70214	0	0
1984	0.72824	6,000	0
1985	0.75117	2,300	40,000
1986	0.76769	80,000	250
1987	0.79083	2,992	16
1988	0.81764	32	0
1989	0.84883	160	1,602
1990	0.88186	31,159	44
1991	0.91397	180	2,160
1992	0.93619	29,305	0
1993	0.95872	903,660	0
1994	0.97870	62,052	0
1995	1.00000	675	0
1996	1.01937	218,025	181
1997	1.03925	93,346	192
1998	1.05199	82,825	22
1999	1.06677	9,305	0
2000	1.09113	74,298	20

Damage estimate available for large region, but not for individual state.