

# Federal Financial Exposure to Catastrophic Risk

by

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**PRELIMINARY DRAFT - Please do not cite without permission**

## I. Introduction

In the aftermath of the terrorist attacks of September 11, 2001, Congress passed supplemental appropriations of over \$26 billion for redevelopment, clean-up, and aid to attack victims and their families. By the standards of the time, the nature and extent of the expenditures were unprecedented. However the new standard would be broken only a few years later, when Congress appropriated emergency funds for over \$80 billion in disaster assistance in the aftermath of four hurricanes including Katrina.

Viewed in the context of federal disaster policy over the last century, the responses to September 11 and Hurricane Katrina---far from being isolated spasms of generosity---fit well with a long-term trend of an increasing federal role in disaster assistance (e.g., Moss (1999), (2002)). Kunreuther and Miller (1985) noted:

The role of the federal government with respect to hazards has been changing ... there has also been a realization that government has been viewed as the protector of risks in ways that would have been unthinkable 50 years ago. Even 30 years ago there was a reluctance by local communities to rely on federal relief for recovery purposes.

The “reluctance” of years past seems little in evidence now. The response of Missouri Governor Mel Carnahan to calls for fiscal restraint in the aftermath of the Mississippi River flooding in 1993<sup>1</sup> (“This is not the time for debating the fine points of long-term policy!”) seems more representative of local opinion today. Moreover, as federal generosity has increased, so has exposure to disasters: Development has been steadily increasing in catastrophe-prone areas, so the property at risk is far greater now than at any time in the past. The combination of rising standards for federal assistance and the growing private exposure suggests that the “stealth entitlement” of federal disaster assistance has grown large enough to merit a deeper assessment.

Following Governor Carnahan’s exhortation, we make no attempt in this paper to dissect the

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<sup>1</sup> Cited by Moss (1999), page 259.

“finer points” of public disaster policy. Instead, we set ourselves the more concrete (though perhaps less ambitious) objective of assessing the federal exposure. In other words, if we take as given the current generosity of federal disaster policy and the current state of development in catastrophe-prone areas, what is the taxpayer’s expected annual bill for disaster-related expenditures? And what could the bill be in a “bad” year?

The numbers we estimate in answering the foregoing questions are significant. Based on the historical relationship between catastrophe damages and federal expenditures, together with prospective assessments of future catastrophe damages from 1) a leading catastrophe modeling firm, Applied Insurance Research (AIR) and 2) the projection of historical catastrophe loss data from Property Claims Services (PCS), we estimate the average expected bill for disaster assistance related to hurricanes, earthquakes, thunderstorms, and winter storms to be about \$20 billion. In a “bad” year, corresponding to a catastrophic event of severity expected only once every century, the bill could exceed \$100 billion. Conservative methods guide both estimates, so more liberal assumptions (e.g., extrapolating recent growth in federal generosity to the future, instead of assuming no change) would yield considerably higher estimates.

Even the conservative estimate of \$20 billion is far higher than the Federal Emergency Management Agency (FEMA) regular budget for disaster relief. Regular appropriations for the Disaster Relief Fund (the main vehicle for federal relief) averaged about \$1 billion over the fiscal years 2001-2005, while supplemental appropriations to the Disaster Relief Fund averaged \$16.5 billion over the same period.<sup>2</sup>

The rest of this paper is organized as follows. Section II offers background, including details on federal disaster policy. Section III discusses the methodology used for 1) assessing the relationship between federal disaster relief and catastrophe damages and 2) estimating the prospective distribution of aggregate catastrophe losses for the United States. Section IV discusses the results, including the effects of modifying assumptions. Section V concludes with a discussion of the policy implications of our findings.

## II. Background

The federal government’s implicit exposure to catastrophic risk stems from *ad hoc* disaster relief distributed to individuals, business, and communities; direct exposure of government facilities and service provision operations to disasters; and government insurance programs such as the National Flood Insurance Program (NFIP) and the Terrorism Risk Insurance Program (TRIP).

### *Disaster Relief*

Historically, disaster relief expenditures have been the most significant component of federal catastrophe exposure. One consequence of the seemingly *ad hoc* nature of the relief is that only a small portion of anticipated relief expenditures are contained in the budget. However, although the full extent of the federal obligation to assist may not be explicitly enumerated by legislation,

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<sup>2</sup> GAO Report 07-139: “Budget Issues: FEMA Needs Adequate Data, Plans, and Systems to Effectively Manage Resources for Day-to-Day Operations.”

history suggests that federal action is inevitable after major disasters: Indeed, assistance seems discretionary in name only. In the words of Moss (1997, p. 334):

Disaster spending has become a political sacred cow. ... Again and again in the aftermath of disasters, representatives from the affected states have insisted that their constituents deserve no less than what other victims received and that the particular nature of their disaster might justify even more. Federal catastrophe coverage has thus been subject to a ratcheting-up process ...

The Stafford Emergency Assistance and Disaster Relief Act of 1988, and its antecedents beginning with the Disaster Relief Act of 1950, guide the process for federal relief in the aftermath of catastrophes. The act formally requires the federal government to offer aid when state and local resources are overwhelmed by a major catastrophe. The Stafford Act designates FEMA to give declaration recommendations to the President after a disaster and the Homeland Security Presidential Directive (HSPD)-5 makes the Secretary of Homeland Security “responsible for coordinating Federal resources within the United States to prepare for, respond to, and recover from terrorist attacks, major disasters, and other emergencies” (DHS 2006).

If the President makes a declaration, then FEMA is charged with overseeing the response both directly and by administering funds to other federal agencies. The money comes from the Disaster Relief Fund (DRF), a “no-year” account (i.e., any dollars appropriated remain available until expended) which receives annual appropriations, though is largely reliant on supplemental appropriations from Congress in the event of major catastrophes.

The other sources of significant federal spending on disasters are the Small Business Administration (SBA), which makes subsidized disaster loans to households and businesses, and the USDA which dispenses disaster loss funds to farmers. Most funding for the SBA is provided through its annual appropriations from Congress. The President may make a Major Disaster declaration or an Emergency declaration. The latter is less significant and aims for federal costs not to exceed \$5 million. If the President makes a more substantial Major Disaster declaration, some types of available federal aid actually have Stafford Act mandated *floors* on the federal share of expenditures. These mandated floors include 75% of eligible costs for “Essential assistance” and “Debris Removal” and 100% of “Housing assistance”.<sup>3</sup>

### *Insurance Programs*

The U.S. federal government plays significant roles in disaster insurance markets. In particular, it essentially acts as the major underwriter of residential flood insurance (through the NFIP, administered by FEMA); it also effectively acts as the country’s largest reinsurer of terrorism risk through the TRIP.

In the case of the TRIP, the maximum exposure is laid out by statute. In 2007, the federal government is technically liable for up to \$61.625 billion of terrorism losses, of which some

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<sup>3</sup> Bea, Keith. “Federal Stafford Act Disaster Assistance: Presidential Declarations, Eligible Activities, and Funding.” *CRS Report for Congress*. Order Code RL33053. April 28, 2006.

fraction may be recouped from the industry.<sup>4</sup> Of course, it is possible that the government's implicit exposure under this program may be higher than the limits laid out in the statute. To date, no actual losses have been paid under TRIP.

The NFIP boasts about \$1 trillion in exposures nationally. Although it is described as a "self financing" program, the NFIP has borrowing rights at the Treasury when losses exceed its resources. This borrowing authority was increased dramatically to \$20.8 billion to cover claims incurred in Hurricane Katrina, although the NFIP still plans to eventually pay back its loans from the Treasury (Watermark 2006).

Other federal insurance programs are also exposed to catastrophe losses. Notably, the U.S. Department of Agriculture insured \$50 billion of crop value in 2006 through the Federal Crop Insurance Corporation.<sup>5</sup>

#### *Exposures to Federal Facilities and Operations*

Federal government property, such as military bases or VA hospitals, can be susceptible to direct physical damage from catastrophes. The federal government is also bound to provide certain everyday public services, including providing Social Security and Medicare benefits, and running federal law and order institutions. The prompt resumption of these services post-disaster can entail significantly higher than normal operational costs.<sup>6</sup>

#### *Additional Sources of Exposure*

The aftermath of a major catastrophe will entail significant economic disruption for the affected region, and potentially for entire national industries. Lost jobs, reduced wages, and lower output will all result in a lower tax base. This means less federal revenue at a time of increased federal spending. Government post-disaster aid will contribute to rebuilding the tax base, and thus over the long run, will lessen the size of indirect exposure created by lost tax revenues.

Next we describe our collection and analysis of data on federal disaster expenditures and catastrophe losses.

### **III. Data and Methodology**

As noted above, *ad hoc* disaster assistance has historically been the most important source of direct federal financial exposure to catastrophes. Hence, the remainder of the paper focuses on

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<sup>4</sup> The figure of \$61.625 billion is obtained by multiplying the federal coinsurance share for 2007 (85%) by \$72.5 billion (calculated as the maximum insured loss amount of \$100 billion less the aggregate industry retention of \$27.5 billion).

<sup>5</sup> Source: Federal Crop Insurance Corporation *Summary of Business Report for 2004 through 2007* (as of 1-29-07).

<sup>6</sup> "Hurricane Katrina: What Government is Doing." Department of Homeland Security. Sept. 24, 2006.

that component of exposure. The basic approach is to use data on disaster damages and disaster assistance to project the distribution of expected federal disaster relief expenditures.

There are three basic steps to this analysis. The first step is to document the relation between catastrophe damages and federal relief expenditures over the period 1989 to 2006 to estimate the amount of federal relief expenditures likely to be “produced” by catastrophe losses. The second step is to develop a prospective annual catastrophe loss distribution for the United States. The third and final step, performed in the results section, is to apply the estimated ratio of federal relief expenditures to catastrophe damages (obtained in the first step) to the estimated catastrophe damage distribution (obtained in the second step) to produce an estimated annual federal disaster expenditure distribution for the United States.

#### *Data on the Relation between Catastrophe Loss and Federal Disaster Relief*

We combine loss estimates for recent catastrophes with figures for emergency supplemental appropriations to assess the generosity of post-disaster federal aid.

We analyze catastrophes with at least \$1 billion in total damages (in nominal terms) between 1989 and 2006. The main source for total damage estimates is data from the National Oceanic and Atmospheric Administration’s (NOAA) National Climactic Data Center. For each catastrophe, we also identify insured losses using the Insurance Services Office’s (ISO) Property Claims Services (PCS) and National Flood Insurance Program (NFIP) payouts. Our selection criterion yields 53 events, with the majority being hurricanes and tropical storms. Also included are the Loma Prieta, Northridge and Nisqually earthquakes<sup>7</sup>, the Oklahoma City and September 11<sup>th</sup> terrorist attacks<sup>8</sup>, and various significant floods, storms, and wildfires.<sup>9</sup> As the NOAA relates, unlike with private and NFIP insured losses, where every dollar paid out in claims is recorded, there is no federal agency tasked with keeping track of total losses resulting from catastrophes in the US.

NOAA bases their estimates on compilations of statistics from “Storm Data (NCDC publication), the National Weather Service, the Federal Emergency Management Agency, other U.S. government agencies, individual state emergency management agencies, state and regional climate centers, and insurance industry estimates.”<sup>10</sup> The figures from the NOAA and the others

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<sup>7</sup> Total losses for Loma Prieta and Northridge earthquakes, described as overall losses in the entire affected region, come from “Megacities – Megarisks: Trends and challenges for insurance and risk management.” Munich Re. 2005. Total losses for the Nisqually Earthquake come from Meszaros and Fiegenger. “Effects of the 2001 Nisqually Earthquake on Small Businesses in Washington State.” U.S. Dept. of Commerce Economic Development Administration. Oct. 2002.

<sup>8</sup> Oklahoma City Bombing total damage from “Governor, Finance Director Release Bomb Damage Estimates.” Press Release from the Office of Governor Frank Keating. <http://www.state.ok.us/osfdocs/nr5-18.html> September 11<sup>th</sup> total damage figure from Bram, Orr and Rapaport. “Measuring the Effects of The September 11 Attack on NYC.” FRBNY Economic Policy Review. November 2002. (New York City) and Nanto, Dick K. “9/11 Terrorism: Global Economic Costs” CRS Report for Congress. RS21937. Oct. 5, 2004. (Pentagon)

<sup>9</sup> NOAA damage estimates are used for all events except the three earthquakes, the Oklahoma City bombing, and the September 11<sup>th</sup> terrorist attacks.

<sup>10</sup> The National Oceanic & Atmospheric Administration (NOAA) describes their estimates of total costs as “the costs in terms of dollars and lives that would not have been incurred had the event not taken place. Insured and uninsured losses are included in damage estimates. Economic costs are included for wide-scale, long-lasting events

we use for total damages represent the largest loss estimates we observed from reputable sources. They always at least encompass insured and uninsured property damages. For longer duration events, like the 1993 Mississippi Flood, Droughts, and the Earthquakes in our sample, our sources include attempts at estimating additional economic costs, such as reduced agricultural output. In the case of September 11<sup>th</sup>, our total loss figure explicitly includes economic costs associated with labor losses. The catastrophes, with the associated estimates of total and insured losses, are summarized in Figures 1a and 1b.

The gap between insured and total losses is, of course, significant. In the case of earthquakes, this can be attributed mainly to low rates of earthquake insurance purchase; similarly, in the case of hurricanes and tropical storms, significant amounts of damage can result from flood---and many households are either uninsured or only partially insured against flood. Deductibles, coinsurance, and uninsured damages (e.g., certain “economic costs” described above) further contribute to insured losses being substantially below our estimate of total losses. For the entire sample of 53 events, the insured to total loss ratio averages 45%.

For federal expenditures, we only use figures for emergency supplemental appropriations for disaster assistance. This is legislation outside of the regular annual budgeting process. By our estimates, it accounts for about 80% of all federal disaster spending over the period, as we discuss below. The money can go to any agency involved in relief, but the majority is provided through FEMA’s Disaster Relief Fund. The appropriations include funds for, “disaster relief, repair of federal facilities, and hazard mitigation activities directed towards reducing the affects of future disasters.” Not included are funds for, “counterterrorism, law enforcement, and national security.”<sup>11</sup>

It should be noted that the narrow focus on supplemental appropriations ignores some elements of federal financial exposure to disasters. We do not include the budgeted portion of federal disaster spending, which covers annual appropriations to FEMA’s disaster relief fund, much of the Small Business Administration’s subsidized disaster loans program, and reconstruction projects which take place long after the fact. Also not included are farm and economic supplemental appropriations through the USDA for specifically agricultural disasters, like droughts. Total USDA spending on farm disaster aid totaled \$54.4 billion over this time horizon.<sup>12</sup> We also treat NFIP losses as insurance payments and thus exclude them from the expenditure data. While the program was close to being self-financing through 2004 (at which point, the NFIP had aggregated only a \$200 million deficit) the picture, of course, looked far different after record flood losses of the 2005 Hurricane season. Other special items are also excluded: For example, in the case of the 2001 terrorist attacks, we have not included the billions in compensation distributed through the Victims’ Compensation Fund. In summary, our

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such as drought.” The estimates are from Lott and Ross. “Tracking and Evaluating U.S. Billion Dollar Weather Disasters, 1980-2005.” *NOAA’s National Climactic Data Center, Asheville, North Carolina*. 2006. Updated estimates (1/22/2007) obtained <http://www.ncdc.noaa.gov/oa/reports/billionz.html>.

<sup>11</sup> Murray, Justin. “Emergency Supplemental Appropriations Legislation for Disaster Assistance: Summary Data FY1989 to FY2006.” CRS Report for Congress. RL33226. Jul. 10, 2006.

<sup>12</sup> Chite, Ralph M. “Emergency Funding for Agriculture: A Brief History of Supplemental Appropriations, FY1989-FY2006.” CRS Report for Congress. Apr. 3, 2006.

figures for total federal disaster expenditures capture a fair portion, but not all, of the non-budgeted federal exposure to disaster risk; furthermore, our expenditure figures do not attempt to capture exposures that are already reflected in the budget.

Figure 2 shows the ratio of federal expenditures to total losses. The appropriation legislation for disasters is usually part of larger bills, and often money is earmarked for multiple recent disasters. This fact, combined with the large number of hurricanes in the sample, make drawing inferences by catastrophe type difficult. Instead we focus on all the events together. The ratio of aid to total losses has a mean of 32% and a median of 30%, and the ratio of aid to uninsured losses has a mean of 96% and a median of 64%. In aggregate, the 53 events, in nominal terms, comprise about \$447 billion in total losses, \$200 billion in insured losses, and \$169 billion in emergency spending. We draw on the Congressional Research Service analysis of appropriations, the text of the aid legislation, and date of catastrophe occurrence to assign aid to catastrophes.<sup>13</sup>

It is illuminating to consider the ratios for the aggregate sample figures, which are presented in Table 1. These correspond to 45% insured/total losses, 38% aid/total losses, and 69% aid/uninsured losses. While there is significant volatility in the aid ratios across the sample, there is some evidence of an increase in generosity over time: Emergency federal aid/total losses for 9/11 and surrounding natural disasters was 62%, even though federal aid did not breach 50% of total loss for any of the previous events in the sample. Yet, in 2005, we observe four hurricanes, (including Katrina) where federal aid exceeded 50% of total losses.

To obtain a more comprehensive picture of federal government spending on disaster aid, we tabulate annual total federal disaster spending and compare it to annual catastrophe losses for fiscal years 1989-2006. The data are presented in Table 1 and Figure 3. In addition to the emergency supplemental appropriations discussed above, we include regular annual appropriations to FEMA's disaster relief fund, USDA emergency funding for agriculture disasters<sup>14</sup>, and the subsidization cost of SBA disaster loans.<sup>15</sup> Annual catastrophe losses are comprised of NOAA's billion dollar weather events, the Loma Prieta, Northridge, and Nisqually earthquakes, and the Oklahoma City and September 11<sup>th</sup> terrorist attacks. Over this span, we observe \$209 billion in total disaster spending and \$483 billion in catastrophe losses,<sup>16</sup> for a coverage ratio of 43%. Annual coverage ratios are partially misleading due to the time lapse between event occurrence and subsequent disaster spending, but we do display them in Figure 3.

We now proceed to discuss projections of the catastrophe loss distribution for the entire United States, which will form the other half of the estimate of the federal government's catastrophe loss exposure.

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<sup>13</sup> Appropriation legislation is sometimes explicit in assigning particular dollars to a particular catastrophe or set of catastrophes, in which case the allocation is straightforward. In other cases, legislation appropriates funds for unspecified catastrophes in the future, in which case the date of occurrence is relevant for assignment.

<sup>14</sup> Funding for "market loss payments to compensate for low farm commodity prices" is excluded.

<sup>15</sup> SBA costs are only included for 1999-2006 due to data availability. Emergency supplemental figures are adjusted to avoid double counting for some SBA disaster loan subsidies and DRF original appropriations.

<sup>16</sup> The main distinction between the catastrophe losses used in this calculation relative to those used previously relates to the inclusion of drought losses. This augmentation is necessary due to the inclusion of the USDA expenditures.

### *Data on the Aggregate Catastrophe Loss Distribution for the United States*

The prospective catastrophe loss distribution for the United States is obviously difficult to estimate precisely, but a rough sense of its character is essential for our exercise. We use two methods to project the distribution.

The first method starts with the prospective distribution of catastrophe losses from a leading catastrophe modeling firm, Applied Insurance Research (AIR). We make adjustments to AIR's distribution to account for uninsured losses (e.g., such as flood losses incurred in hurricanes).

The second method starts with ISO's Property Claims Services database, which contains data on insured losses from U.S. catastrophes spanning more than five decades. We then adjust the historical figures to account for changes in property exposure and insurance penetration rates, and we also make adjustments to account for uninsured losses.

In both methods, we restrict our attention to natural catastrophes, such as hurricanes and earthquakes. This leads to a conservative estimate (in the sense of being smaller than what is likely) of catastrophe exposure in two respects. First, we omit man-made catastrophes such as terrorist attacks or nuclear power accidents. Second, our methodology almost certainly neglects to fully reflect catastrophe exposure from flooding, since our data sources are focused on privately insured losses. While we have made adjustments to events in the data to reflect the presence of uninsured flood losses, these adjustments are applied only to events that produced significant insured losses (such as a tropical storm). Such a methodology almost certainly understates flood exposure by failing to account for events with significant flooding but insignificant wind involvement.

### *Aggregate Catastrophe Loss Distribution based on the AIR Model*

Catastrophe modeling is recognized globally as the standard technique for risk assessment and management. It is utilized by insurers and other firms exposed to catastrophic risk in pricing, risk selection and underwriting, loss mitigation, reinsurance decision making, and overall portfolio management. AIR Worldwide, which provided the catastrophic loss estimates discussed here, is one of the three global leaders in catastrophe modeling. Although catastrophe modeling began in the 1980s, the development of the technology accelerated following Hurricane Andrew in 1992 and the Northridge earthquake in 1994.

The AIR model is a stochastic simulation model that incorporates mathematical representations of the natural occurrence patterns and characteristics of hurricanes, earthquakes, and other catastrophes.<sup>17</sup> The model incorporates meteorological and seismological data, actuarial loss data, and information on property values, construction types, and occupancy classes (classifications that indicate what the structure is being used for, such as residential, retail, etc.). In most major geographical areas, the AIR maps insurer exposure to catastrophic losses to the level of the individual building structure. Incorporated in the model are property characteristics and insurance coverage parameters. Thus, the model provides simulated loss distributions for

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<sup>17</sup> The discussion of the AIR model is based on Clark (2004).

individual insurers in finely divided geographical areas.

The structure of the AIR model is shown in Figure 4a. The simulations begin with event generation, which entails random generation of events in terms of their location, frequency of occurrence, and severity. The simulations incorporate probability distributions based on historical data for each variable that defines the events. By sampling from these distributions, a large stochastic catalogue of simulated event scenarios is generated. This process is represented schematically in Figure 4b for the simulation of hurricanes.

To estimate the damage potential of natural hazards, the model estimates their physical parameters not only at the source, but also at the sites of the affected building inventory. The local intensity part of the model's hazard module is designed to capture how intensity changes as the simulated catastrophe propagates or travels over the affected area. Detailed scientific and geophysical data and algorithms are employed to model the local effects of each simulated event.

The damage estimation, or vulnerability, component of the model superimposes the local intensities of each simulated event onto a database of exposed properties and estimates the expected level of damage to buildings and their contents. Loss estimates are based on region-specific damage functions for many different construction types and occupancies. Total damage estimates can be generated for the entire insurance industry, individual insurer policy portfolios, or for individual buildings.

In the final component of the model, insured losses are calculated by applying specific insurance policy conditions to the total damage estimates. Policy conditions include deductibles by coverage, coverage limits and sublimits, coinsurance, and other policy conditions. The output of the model is an estimated loss distribution for a specific insurance portfolio and location, often presented as an exceedence probability curve which plots the probability of exceeding various loss amounts.

For purposes of the present study, AIR provided expected average losses and the higher percentiles, in aggregate and by occurrence, for hurricane, earthquake, winter storm, and severe thunderstorm. For all perils except earthquake, the estimates project insured losses, while the earthquake projection addresses insurable losses. As a result, AIR estimates of insured losses for perils other than Earthquake will differ from total losses because of deductibles, policy limits, and uninsured losses. Accordingly, we adjust losses for the hurricane and thunderstorm perils upward assuming a 47.7% insured to total loss ratio to account for the historical relation between insured losses and total property losses in hurricanes identified in the preceding section. The intention is, to the extent possible, to adjust the AIR output to a basis consistent with the total loss estimates used in the previous section. However, we do not attempt to adjust the earthquake losses to reflect uninsured economic costs absent from the AIR calculations. As a result, the loss estimates should be lower than those that would be fully consistent with the "total losses" used in the previous section. Hence, our ultimate projections of total loss exposure from the AIR model are conservative---and may ultimately yield estimates of federal exposure that are lower than the truth.

Table 2 summarizes the average annual aggregate and occurrence losses produced by adjusting

the AIR losses as described. In addition, we list the 99<sup>th</sup> percentile for all cases---the amount of loss corresponding to that expected with a frequency of once per century.<sup>18</sup> The estimates show an annual aggregate expected average total loss of \$63.9 billion. For All Perils, there is a one percent chance of an annual loss of at least \$281.6 billion dollars (without attempting the adjustment to hurricane and thunderstorm losses described above).<sup>19</sup>

#### *Aggregate Catastrophe Loss Distribution based on PCS and NFIP Data*

In this section, we discuss the estimation of catastrophe loss distributions using the PCS data on insured catastrophe losses. PCS reports losses at the state level, beginning in 1949, for various types of catastrophes. We adjust the data for changing exposure levels, as explained below, to provide estimates of the losses that would have resulted from the historical catastrophes recorded by PCS if today's property values had existed at the time of the events. Maximum likelihood estimation is used to fit the adjusted losses to underlying parametric loss distributions. In this fashion, we can project expected losses and various percentiles to compare with the figures provided by AIR.

#### *Data Considerations*

Property Claims Services (PCS), a division of the Insurance Services Office (ISO), compiles data on insured losses from catastrophes. Currently, PCS defines a catastrophe as an event that causes \$25 million or more in damages and affects a significant number of policyholders.<sup>20</sup> The PCS loss estimates are for personal and commercial property along with vehicle losses covered by comprehensive coverage.<sup>21</sup> The data are collected by canvassing the insurance industry following major loss events and conducting supplemental field research in some instances.<sup>22</sup> PCS maintains data from 1949 through the present, broken down by state and by type of event. Because most insurance policies do not cover flood damage, we supplement the PCS data with information on flood losses from the NFIP.

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<sup>18</sup> Note that the figures for the percentiles for the All Perils category do not contain adjustments for the historical relation between insured losses and total property losses, as we do not have detailed information on the composition of the All Perils distribution. The average, however, does reflect the adjustment.

<sup>19</sup> This figure represents the 99<sup>th</sup> percentile of the distribution of the sum of insured losses for all perils except Earthquake, and insurable losses for Earthquake. Since we do not have the composition of the All Perils distribution, we cannot make the referenced adjustments without making further assumptions. In the case of the average, however, the adjustments yielded an increase of about 50%; a similar impact on the 99<sup>th</sup> percentile would suggest a figure above \$400 billion.

<sup>20</sup> The monetary threshold used by PCS to define a catastrophe has been adjusted over time. From 1949 to 1981, the dollar threshold was \$1 million; from 1982 to 1996, the threshold was \$5 million; and since 1997 the threshold has been \$25 million.

<sup>21</sup> Auto losses generally represent 10% or less of total losses from catastrophes (email from Gary Kearny of PCS).

<sup>22</sup> PCS generally combines two methods to develop the best estimate of insured catastrophe losses. First, PCS conducts confidential surveys of insurers, agents, adjusters, public officials, and others to gather data on claim volumes and amounts. PCS analyzes the data and combines it with trend factors to determine a loss estimate. PCS also maintains a database containing information on the number and types of structures for every U.S. state. Using that information, PCS can estimate the number of insurable risks in a specific geographic area. Combined with survey information, the structure data forms the basis for the PCS damage estimates. For large or unusual events, PCS resurveys the affected insurers to obtain updated information. PCS estimation methodology is described in more detail in Property Claims Services (2006).

In this study, we develop models based on the PCS and NFIP data by fitting probability distributions to the data. We then estimate the loss quantiles to measure exposure to loss from various perils.

Prior to fitting probability distributions, it is important to adjust the PCS loss data for changes in the amount of property exposed to loss. The reason for this adjustment is that the value of property exposed to loss in the United States has expanded dramatically during the period 1949 through 2006. Consequently, events from prior decades would be likely to cause much greater damages if they occurred today. To adjust the data for changes in property values, we created a housing value index for each state using the U.S. Census Bureau's decennial census data on housing values.<sup>23</sup> Values for years between the decades are calculated based on logarithmic interpolation; values for 2001-2006 are calculated based on the annual growth rate that prevailed from 1990 to 2000.

Because PCS focuses on insured losses from catastrophic events, we also adjust the PCS data to estimate the total (insured and uninsured) losses from each event. These adjustments differ by peril because the proportion of property covered by insurance varies significantly by peril. For example, earthquake insurance take-up rates in California are substantially smaller than homeowners insurance take-up rates in the Southeast. Adjustments are also applied to the NFIP data to estimate total as well as insured losses from floods. These adjustments are described in detail below.

For a hurricane or tropical storm loss, we scale up the losses by a constant factor, the inverse of the insured-to-total loss ratio for the hurricanes and tropical storms in our federal expenditure sample (with NFIP losses not included in the insured figure). For some of the approaches described below, we will treat NFIP losses separately: For these cases, we reduce the hurricane scale factor by the estimated component of uninsured hurricane loss which is attributable to flood. This component is the NFIP flood payout for a given hurricane, scaled by our estimated NFIP annual take-up rates. The annual loss payout numbers from NFIP are exposure-adjusted based on the total US housing value. The take-up rates are also estimated: We use the known take-up rate for 2004 of 49% in SFHA's and then use the ratio of NFIP policies to U.S. households as a basis for projecting historic take-up rates and a take-up rate for 2005. That is, in the absence of better data, we assume that the proportion of households in SFHA's has remained constant over time. (We are in the process of searching for better data on take-up rates.) The inverse of the take-up rate is the annual scale factor for converting insured loss to total loss.

Similarly for earthquakes, we use known take-up rates for earthquake insurance since 1996 for California (available from the California Department of Insurance), and project earlier take-up rates based on the relationship between annual California earthquake premium data (also from the California Department of Insurance), California aggregate housing value, and the known take-up rates since 1996. We apply the inverse of these known and estimated take-up rates to the PCS insured earthquake loss for the year it occurs to get a total loss figure.

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<sup>23</sup>The use of a housing value index implicitly assumes that the value of commercial property and automobiles exposed to loss has expanded at the same rate as the value of residential property. Because population growth in a geographical region is likely to be accompanied by corresponding growth in commercial activity and the number of automobiles, this is likely to be a reasonable assumption.

## Statistical Methodology

The objective of the estimation is to provide estimates of the severity of loss from specific perils and also the total annual claims distribution by peril and overall for all types of catastrophes. Two principal types of estimation procedures are conducted: (1) Estimation of the total claims distribution by estimating frequency and severity distributions and compounding these distributions to obtain the distribution of total claims. (2) Fitting of distributions to annual aggregate claims. The compounding approach is more likely to give accurate results, but the aggregate annual approach provides useful supplemental estimates.

The compounding approach begins by estimating a total claims distribution for each of the major catastrophe perils on which PCS maintains data. The estimation has three phases: (1) Estimate the severity of loss distribution using maximum likelihood estimation. (2) Estimate the frequency of loss distribution, also using maximum likelihood. (3) Compound the frequency and severity distributions to estimate the total claims distribution using Fourier transforms.<sup>24</sup> The final step in the analysis is to compute an overall catastrophe total claims distribution by summing the distributions from the individual perils. The step also utilizes Fourier transforms. For this draft, only the severity distributions by peril and an overall severity distribution have been estimated: In the annual aggregate approach, distributions are fitted to the aggregate losses per year both by peril and for all types of catastrophes combined.

In estimating severity distributions in the compounding approach and estimating total claims distributions in the aggregate annual loss approach, three different distributions are used, which have been shown to provide good models of loss distributions in prior research (e.g., Cummins, Lewis, and Phillips, 1999). The distributions – the lognormal, the Pareto, and the Burr 12 – are specified as follows:

The lognormal: 
$$f(x) = \frac{1}{x\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{\ln(x)-\mu}{\sigma}\right)^2}, \quad x > 0$$

The Pareto: 
$$f(x) = \alpha\lambda^\alpha (\lambda + x)^{-\alpha-1}, \quad x > 0$$

The Burr 12: 
$$f(x) = a | q x^{a-1} b^{-a} \left[1 + \left(\frac{x}{b}\right)^a\right]^{-q-1}$$

As mentioned, the parameter estimates are obtained using maximum likelihood estimation.

## Results

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<sup>24</sup> The Fourier transform approach is discussed in Klugman, Panjer, and Willmot (2004).

Summary statistics on catastrophe losses are presented in Table 3, which have been adjusted for changes in housing exposures (but not to account for differences between insured losses and total losses). All data are from PCS except the flood data, which were obtained from the National Flood Insurance Program. Hurricanes have the highest average loss severity, \$8.8 billion, and annual flood loss has the highest median severity, \$1.275 billion. Hurricanes also have the highest standard deviation of loss. As expected, the observed losses are highly skewed for all perils.

The trends in the total number of catastrophic events and the total insured losses are shown in Figure 5. The loss amounts have been adjusted to 2006 property values, and catastrophes that would not have caused at least \$25 million in losses at 2006 property value levels have been deleted for purposes of preparing this figure. Even though Hurricane Katrina was the largest loss event recorded during the sample period, based on the housing value-adjusted loss data there were five previous events of approximately equal or greater magnitude. In 1950, a major wind and thunderstorm event caused substantial property losses from Maryland to Maine. If a similar event occurred at present, the estimated losses would be greater than \$227 billion. In 1954, Hurricane Carol caused major damage ranging from New Jersey to Maine with particularly large losses in Massachusetts and New York. The same year, Hurricane Hazel caused devastating losses ranging from South Carolina to New York. If those storms occurred today, it is estimated that Carol and Hazel would cause losses of \$132 billion and \$125 billion, respectively. A storm of the magnitude of Hurricane Gloria, which struck several Northeastern states in 1985, would cause estimated losses of \$65 billion if it occurred today. By contrast, insured losses from Hurricane Katrina were “only” \$44 billion.

Parameter estimates for several of the estimated distributions are shown in Table 4, along with log likelihood function values. Estimates are shown both for insured and total losses. The last column of the table shows the best fitting distribution based on an approximate likelihood ratio test.<sup>25</sup> The results show that the Burr 12 and lognormal generally fit the data better than the Pareto, as expected given the relative lack of flexibility of the Pareto.

As an example of one of the estimated distribution, the severity distribution of total losses from hurricanes and tropical storms is shown in Figure 6. The likelihood ratio results show that the lognormal provides the best fit to this set of data but not at a high level of statistical significance. The graph bears this out but suggests that all three distributions fit the data reasonably well, with the Pareto perhaps overestimating the probability in the tail of the distribution.

Table 5 presents the means and upper percentiles of the estimated loss distributions for the models whose parameters are shown in Table 4. The percentiles shown are the 50<sup>th</sup>, the 75<sup>th</sup>, the 90<sup>th</sup>, the 95<sup>th</sup>, the 99<sup>th</sup>, and the 99.9<sup>th</sup>. The latter three percentiles would correspond to event “return periods” of 20, 100, and 1000 years, respectively.

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<sup>25</sup> The likelihood ratio test results are only approximate because the distributions estimated are not nested in the sense that they can be obtained by imposing parameter restrictions on the distribution with the largest number of parameters. The significance tests are based on a Chi-square distribution with 1 degree of freedom. The likelihood test statistic is  $2 \cdot [\log(L:\text{distribution 1}) - \log(L:\text{distribution 2})]$ , for pairwise tests of the distributions.

Focusing on the 99<sup>th</sup> percentile, the best fitting severity distribution for hurricanes (the lognormal) shows that a once in 100 year event would cause insured losses of \$131 billion and total losses of \$273 billion. For annual flood losses, the lognormal and Burr 12 are about the same in terms of goodness of fit and give comparable loss estimates at the percentiles. For example, at the 99<sup>th</sup> percentile, the Burr 12 predicts insured losses of \$7 billion and total losses of \$23.6 billion, compared to corresponding estimates of \$8 billion and \$22.5 billion from the lognormal.

In terms of annual aggregate losses from the mega-perils (hurricanes, earthquakes, and floods) combined, all distributions fit the insured loss data about equally well, with the lognormal having the largest log likelihood value, whereas the Pareto clearly provides the best fit to the total losses. Based on the Pareto estimates, the 99<sup>th</sup> percentiles of the insured and total loss distributions are \$376 billion and \$1.032 trillion, respectively. These estimates suggest very large exposure to catastrophic losses for both the government and the insurance industry.

## **IV. Results**

The AIR model projects expected annual catastrophe losses of \$56 to \$64 billion; this is roughly comparable to the projections from the PCS data, which indicate annual average losses of \$50 to \$60 billion (based on the lognormal distribution). For the 99<sup>th</sup> percentile, the AIR model indicates a loss of \$282 billion, which is again comparable to the figures from the PCS methods--which indicate a range from \$226 billion to \$303 billion, depending on the distribution chosen.

Reasonable estimates of the recent relation between federal aid and losses, based on the analysis presented, range from 30% to 50%---with figures at the higher end of the range supported by generosity observed in recent events such as the 2005 hurricanes, and by the aggregated ratios of aid to losses over the period. It is true that the aggregates are skewed to some degree by the larger events that have happened in recent years, but even a straight average, by event, of the ratio of aid to loss yields a figure in excess of 30%.

Thus, our analysis suggests that an expected annual federal exposure in the neighborhood of \$15 billion to \$30 billion, with the exposure in a bad year (once in a century) in the neighborhood of \$70 billion to about \$150 billion.

## **V. Concluding Remarks**

The tremendous growth in federal disaster spending observed over the 20<sup>th</sup> century has continued in more recent years. The \$82 billion in emergency federal spending on Katrina and other proximate hurricanes in 2005 exceeded the FY2005 budget of all but 5 government agencies.<sup>26</sup>

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<sup>26</sup> The agencies were HHS (Medicare), Social Security, Defense, Treasury (Debt Interest), and Agriculture (CRS RL33228).

Even the much maligned congressional earmarks totaled only about \$50 billion in 2005.<sup>27</sup> Our analysis shows that the expected annual expenditure on disaster assistance---an estimated \$20 billion---is quite significant. While this estimate is obviously not precise, different assumptions or methods seem unlikely to alter the basic inferences about the significance of the annual cost.

FEMA's current annual budget falls far short of expected annual federal disaster assistance, most of which is financed through supplemental appropriations on an "as needed" basis. Over our sample period (FY1989-FY2006), FEMA's Disaster Relief Fund received original appropriations for less than \$15 billion, while experiencing outlays of over \$58 billion.<sup>28</sup>

This budgetary treatment may not be unusual, but the lack of transparency with respect to acknowledging the commitment and accounting for its size is unfortunate in at least two respects. First, the costs and benefits of the disaster assistance program currently cannot be weighed against other national priorities. Second, federal disaster policy itself cannot be optimized without understanding the commitment and the dollars involved. For an example of the latter point, if a scaling back of the federal disaster assistance program is not politically realistic, federal subsidization of state and local mitigation expenditures may be in the taxpayer's interest--at least in the short run.

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<sup>27</sup> CRS Appropriations Team. "Earmarks in Appropriation Acts: FY1994, FY1996, FY1998, FY2000, FY2002, FY2004, FY2005." *Congressional Research Service Memorandum*. January 29, 2006.

<sup>28</sup> Bea, Keith. "Federal Stafford Act Disaster Assistance: Presidential Declarations, Eligible Activities, and Funding." *CRS Report for Congress*. Order Code RL33053. April 28, 2006.

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Figure 1a  
 Sample of Major Disasters: 1989-2006

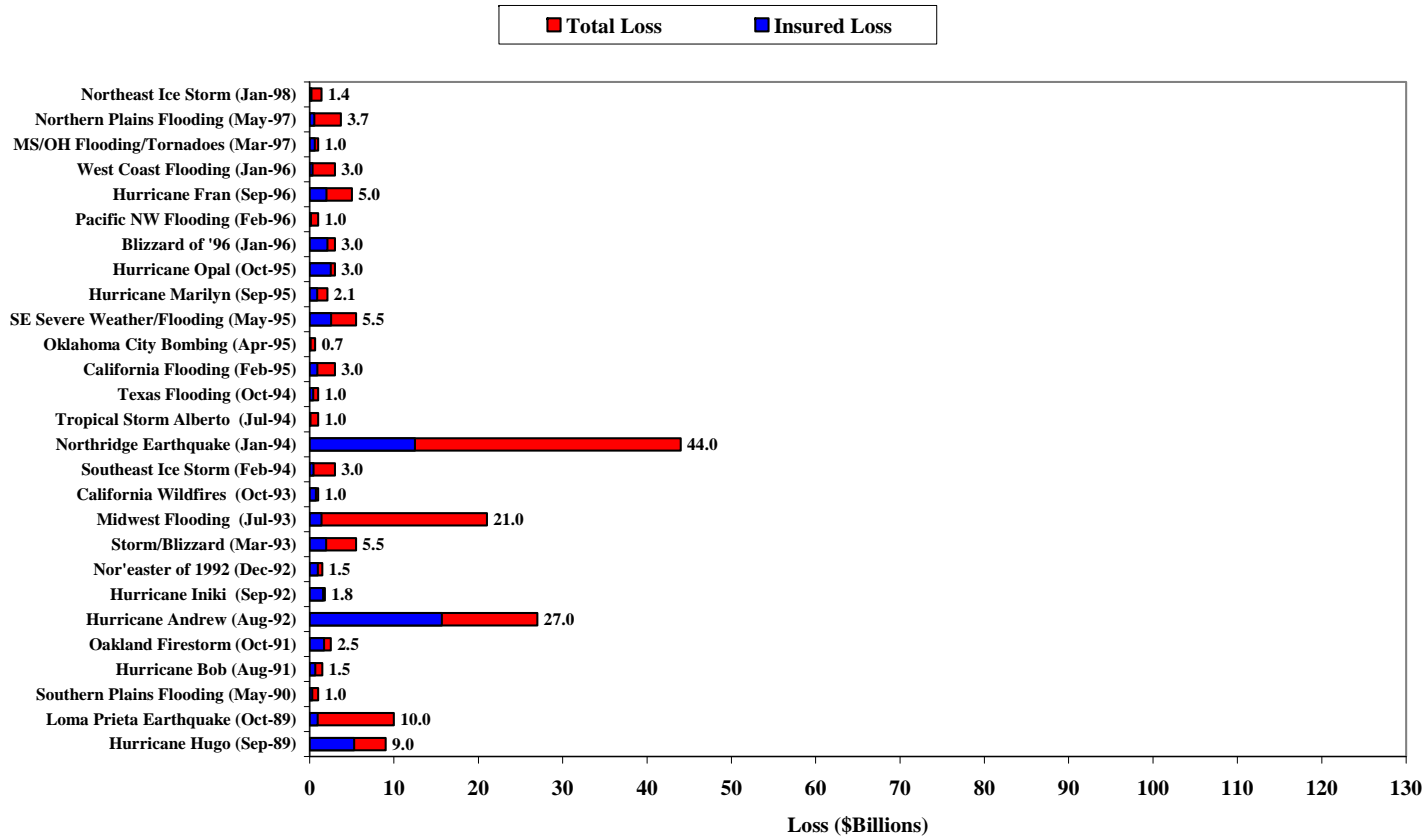


Figure 1b  
Sample of Major Disasters: 1989-2006

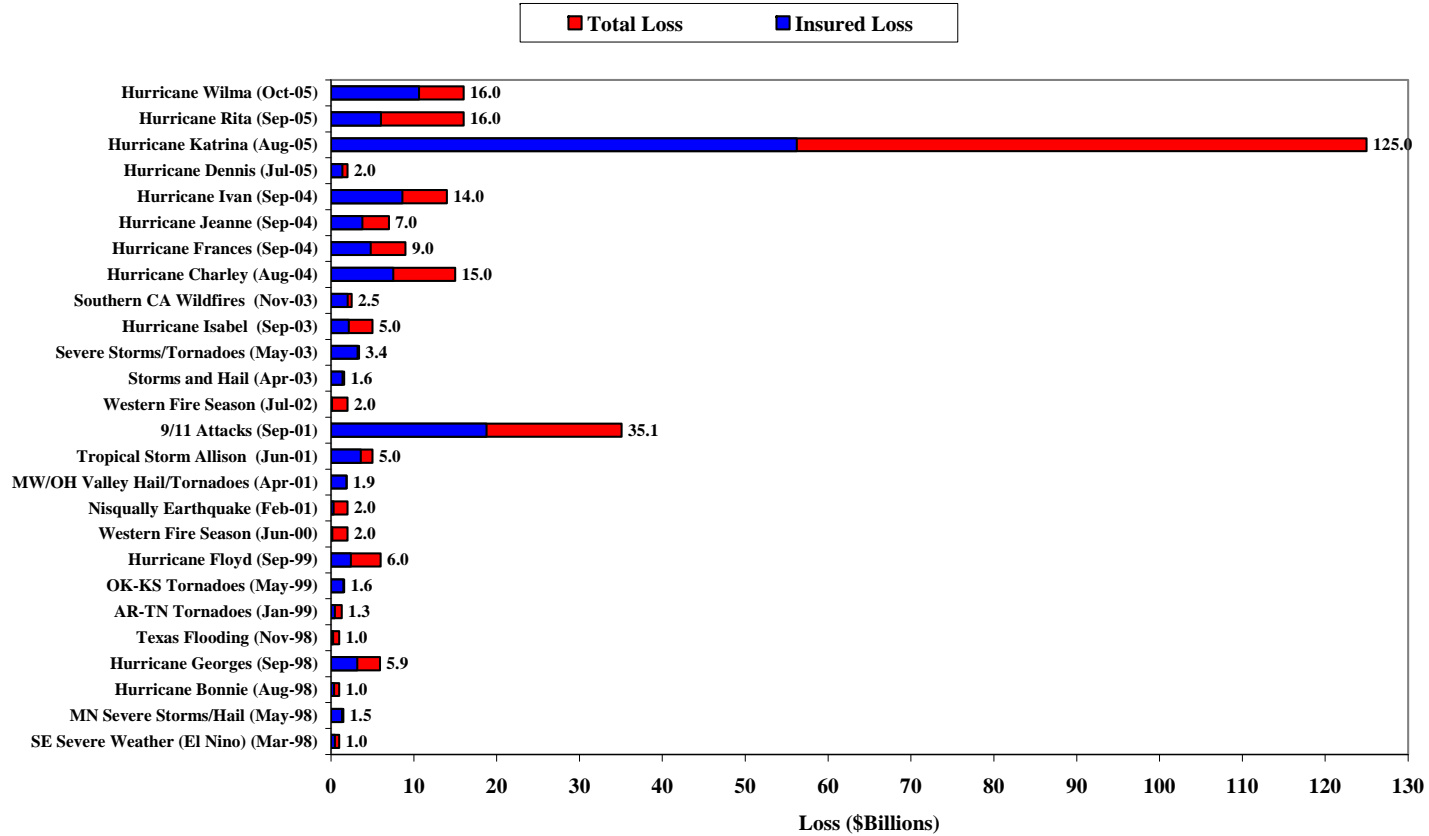
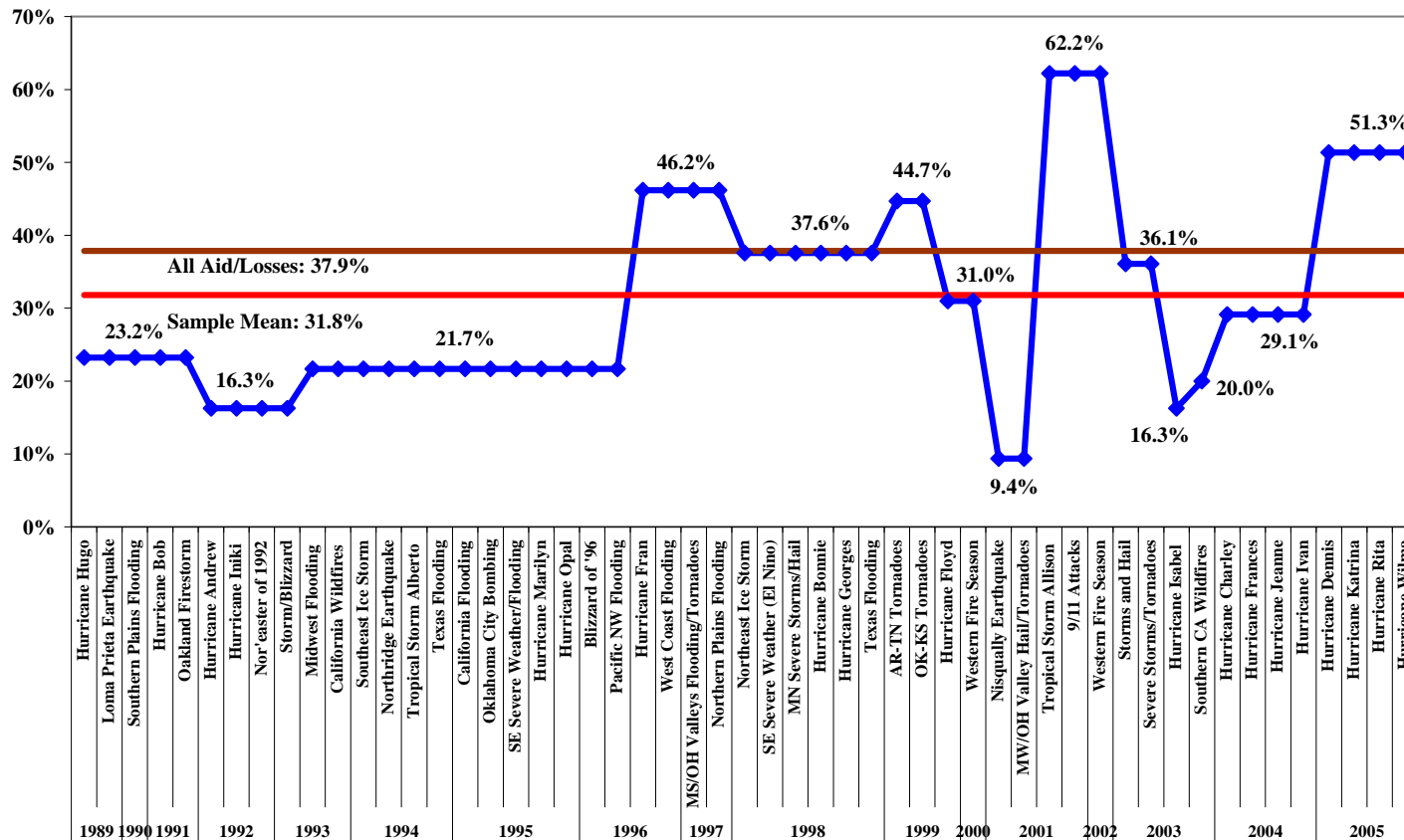


Figure 2  
Federal Aid Ratios: 1989-2006



Table|1

Summary of Catastrophe Loss and Federal Aid

1989-2006

Values in \$Billions

Emergency Supplemental Appropriations

Aggregate		By Event		
<b>Number of Events</b>	53		Mean	Median
<b>Total Loss</b>	446.9	<b>Aid to Total Loss</b>	31.8%	30.1%
<b>Insured Loss (including NFIP)</b>	200.2	<b>Insured Loss to Total</b>	47.2%	45.0%
<b>NFIP</b>	24.1	<b>Aid to Uninsured Loss</b>	96.0%	64.1%
<b>Federal Aid</b>	169.2			
<b>Aid to Total Loss</b>	37.9%			
<b>Insured Loss to Total</b>	44.8%			
<b>Aid to Uninsured Loss</b>	68.6%			

Total Federal Disaster Spending

Aggregate		By Year		
<b>Number of Years</b>	18		Mean	Median
<b>Total Loss</b>	483.1	<b>Aid to Total Loss</b>	48.9%	51.9%
<b>NFIP</b>	25.2			
<b>Federal Aid</b>	209.9			
<b>Aid to Total Loss</b>	43.5%			

Figure 3  
Total Federal Disaster Spending: FY1989-FY2006

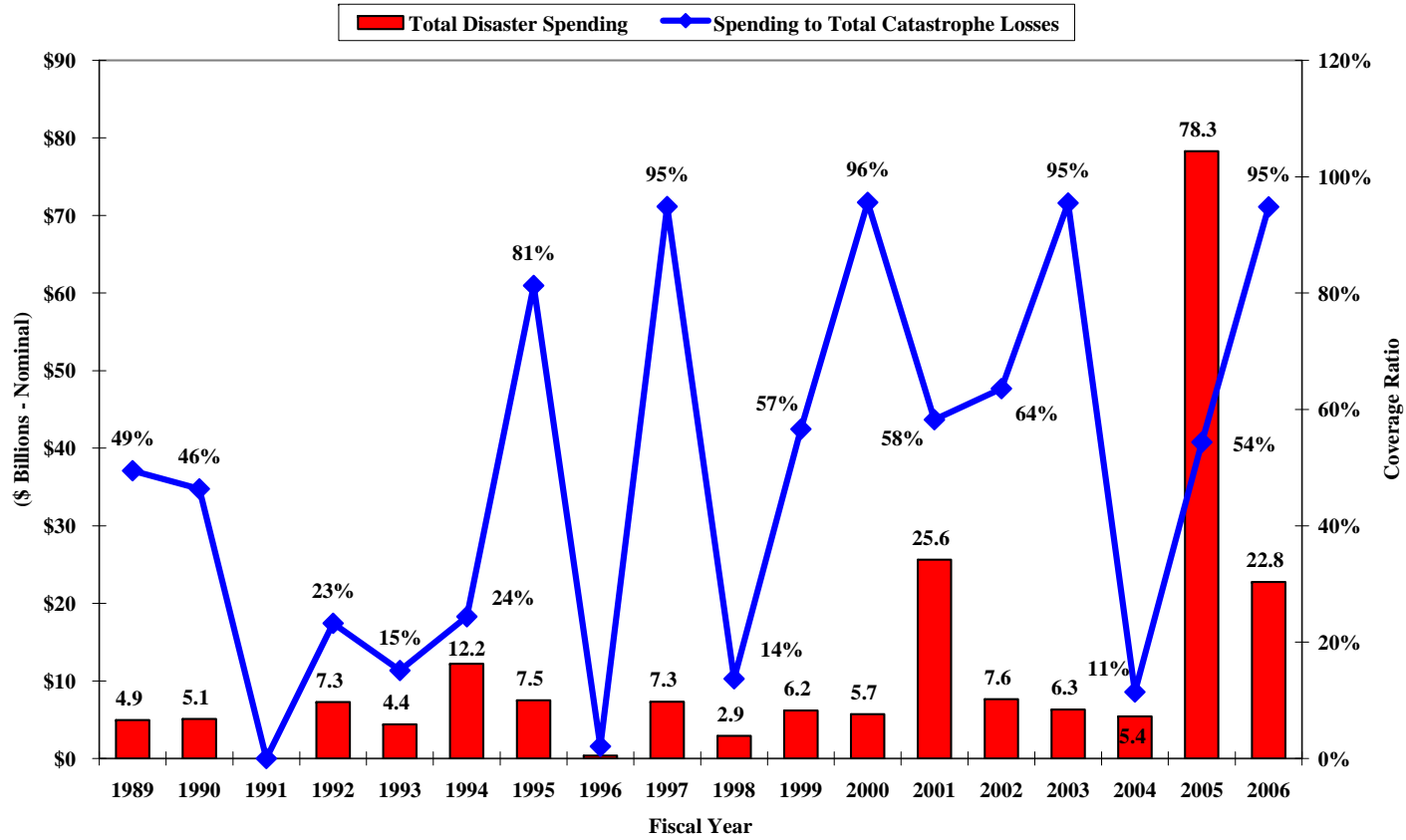


Figure 4a: The Structure of the AIR Simulation Model

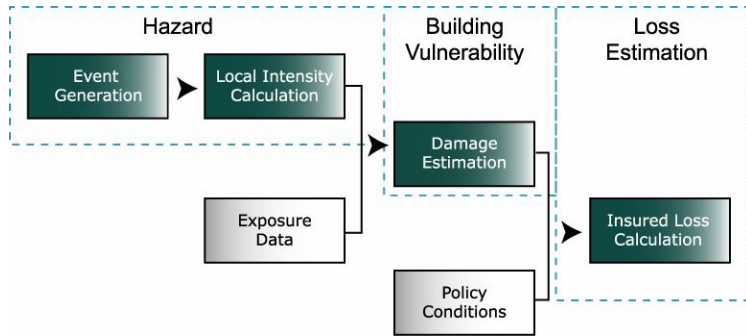


Figure 4b: Simulating a Stochastic Catalogue of Storm Events

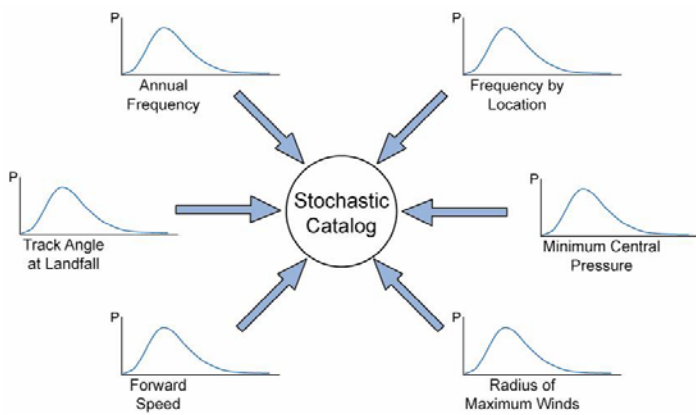


Table 2

**AIR based projections of US catastrophe loss exposure**

Hurricane and severe thunderstorm scaled by 47.7% insured to total loss ratio.  
 Perils include hurricane, earthquake, winter storm, severe thunderstorm, and implicitly, flood.

Amounts in \$billions

**All Perils (Standard Hurricane Model)**

	<b>Aggregate</b>	<b>Occurrence</b>
<b>Expected Average Loss</b>	56.0	36.9
<b>99th Percentile</b>	272.6	234.6

**All Perils (Near Term Hurricane Sensitivity)**

	<b>Aggregate</b>	<b>Occurrence</b>
<b>Expected Average Loss</b>	63.9	43.1
<b>99th Percentile</b>	281.6	240.3

**Table 3**  
**PCS Data 1950-2006**

Summary Statistics - Exposure Adjusted Insured Loss  
 Values in \$Billions

<b>Cat Type</b>	<b>N</b>	<b>mean</b>	<b>median</b>	<b>SD</b>	<b>CV</b>	<b>skewness</b>	<b>min</b>	<b>max</b>	<b>P75</b>	<b>P90</b>	<b>P95</b>	<b>P99</b>
Wind and Thunderstorm Event	1,150	664	163	6,806	1,025.41	32.40	2	227,673	370	923	1,845	5,534
Winter Storm	128	1,382	312	2,908	210.44	3.92	17	18,619	1,147	3,437	6,180	16,383
Hurricane	85	8,830	1,220	22,158	250.93	4.23	11	132,032	5,435	29,601	44,357	132,032
Fire - Other	47	1,390	146	4,401	316.54	4.73	12	26,197	429	2,202	7,863	26,197
Flood	28	1,801	1,275	2,355	130.75	4.37	187	13,101	1,842	2,818	3,672	13,101
Wildland Fire	18	572	254	822	143.64	3.06	35	3,534	681	1,227	3,534	3,534
Earthquake	15	1,785	79	5,748	322.06	3.81	16	22,450	504	2,317	22,450	22,450
Tropical Storm	15	808	178	1,705	211.06	2.70	58	6,011	290	3,719	6,011	6,011
Riot	11	2,952	1,044	6,574	222.69	3.20	6	22,581	1,613	3,074	22,581	22,581
Utility Service Disruption	1	221	221				221	221	221	221	221	221
Volcanic Eruption	1	260	260				260	260	260	260	260	260
Water Damage	1	971	971				971	971	971	971	971	971

Figure 5  
 PCS Aggregate - Threshold of \$25 million by event

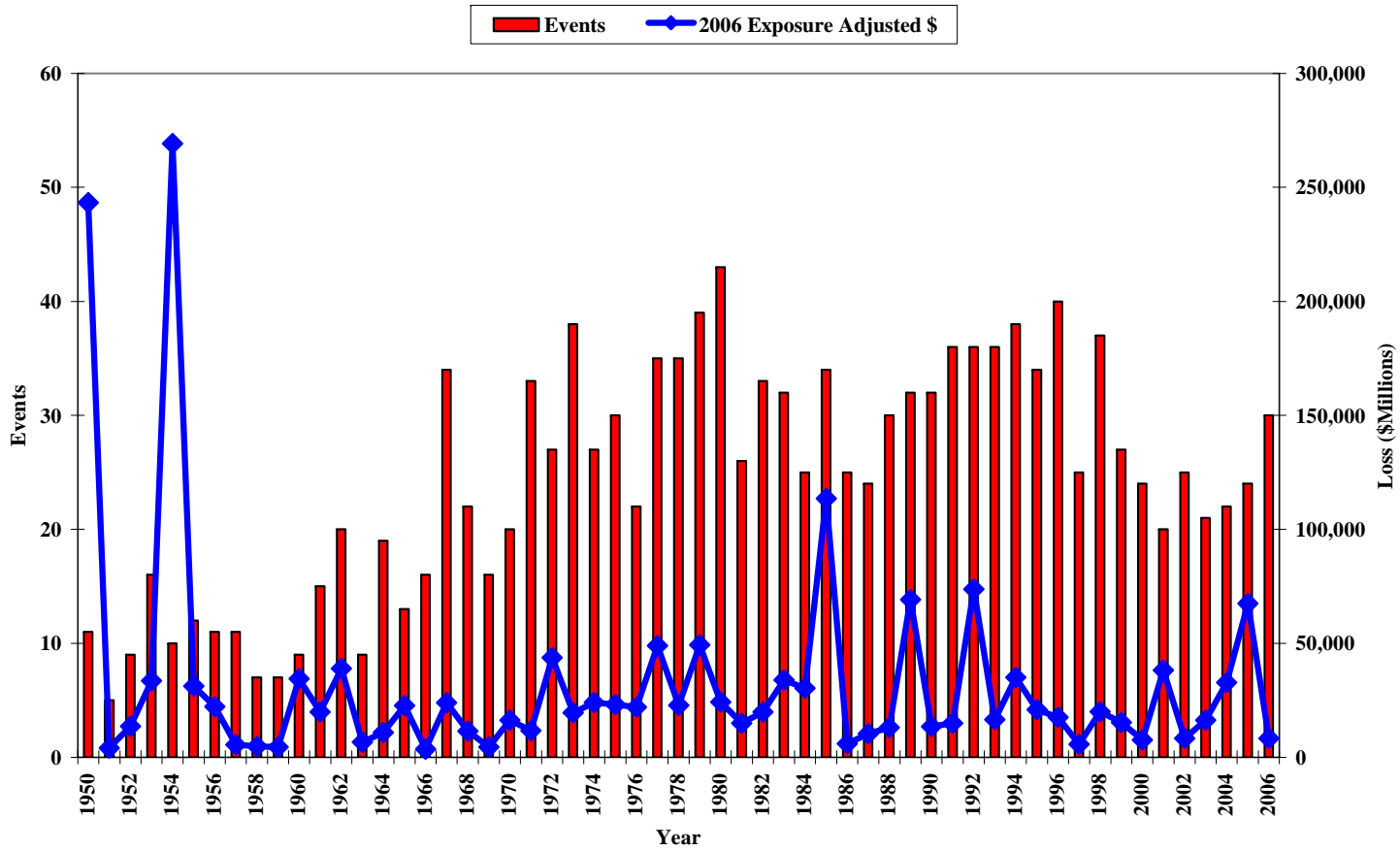


Table 4  
Maximum Likelihood Parameter Estimates and Log Likelihood Function Values: PCS and NFIP Loss Data

Catastrophe Type	Loss Type	N	Lognormal			Pareto		
			mu	sigma	log(L)	alpha	lambda	log(L)
Hurricane/Tropical Storm (HTS)	Insured	100	20.686	2.112	-2,285.208	0.577	3.22E+08	-2,287.371
	Total	100	21.420	2.112	-2,358.605	0.577	6.71E+08	-2,360.768
Earthquake (EQ)	Insured	15	18.684	1.988	-311.853	0.645	5.10E+07	-311.072
	Total	15	21.169	1.749	-347.209	0.741	7.69E+08	-346.648
Annual Flood (F)	Insured	28	20.940	0.802	-619.866	3.227	4.29E+09	-624.938
	Total	28	21.982	0.797	-648.894	2.459	8.59E+09	-654.657
Wind and Thunderstorm (WT)	Insured	1,150	18.965	1.337	-23,775.917	1.696	3.36E+08	-23,797.698
Winter Storm (WS)	Insured	128	19.799	1.535	-2,770.743	1.104	4.24E+08	-2,774.122
Annual Aggregate - HTS, EQ, F	Insured	28	22.195	1.604	-674.419	1.027	4.29E+09	-675.555
	Total	28	23.091	1.491	-697.473	0.960	8.59E+09	-675.555
Annual Aggregate - HTS, EQ, F, WT, WS	Insured	28	23.790	0.754	-697.962	5.490	1.37E+11	-703.516
	Total	28	24.288	0.797	-713.438	6.344	2.75E+11	-718.192
Annual Aggregate - HTS, EQ, WT, WS	Insured	56	23.622	0.927	-1,398.037	3.230	6.87E+10	-1,405.069
	Total	56	24.316	0.940	-1,437.704	1.922	6.87E+10	-1,445.930
Aggregate Occurrence - HTS, EQ, WT, WS	Insured	1,393	19.162	1.514	-29,247.880	1.242	2.68E+08	-29,248.099
	Total	1,393	19.922	1.503	-30,295.214	1.203	5.37E+08	-30,294.457

Table 4 - Continued

Catastrophe Type	Loss Type	N	Burr12			log(L)	Max log(L)
			a	b	q		
Hurricane/Tropical Storm (HTS)	Insured	100	0.775	1.07E+09	1.074	-2,288.514	-2,285.2
	Total	100	0.780	2.15E+09	1.053	-2,361.869	-2,358.6
Earthquake (EQ)	Insured	15	0.890	1.34E+08	1.021	-311.783	-311.1
	Total	15	1.237	1.07E+09	0.755	-346.464	-346.5
Annual Flood (F)	Insured	28	1.839	2.15E+09	2.015	-619.730	-619.7
	Total	28	2.057	4.29E+09	1.301	-648.873	-648.9
Wind and Thunderstorm (WT)	Insured	1,150	1.554	1.16E+08	0.710	-23,756.171	-23,756.2
Winter Storm (WS)	Insured	128	1.738	1.35E+08	0.418	-2,770.216	-2,770.2
Annual Aggregate - HTS, EQ, F	Insured	28	1.032	4.29E+09	1.011	-675.538	-674.4
	Total	28	1.204	8.59E+09	0.868	-698.256	-675.6
Annual Aggregate - HTS, EQ, F, WT, WS	Insured	28	2.667	1.72E+10	0.719	-698.110	-698.0
	Total	28	2.166	3.44E+10	0.976	-714.121	-713.4
Annual Aggregate - HTS, EQ, WT, WS	Insured	56	2.008	1.72E+10	0.935	-1,397.253	-1,397.3
	Total	56	1.976	3.44E+10	0.936	-1,436.981	-1,437.0
Aggregate Occurrence - HTS, EQ, WT, WS	Insured	1,393	1.118	2.68E+08	1.192	-29,237.051	-29,237.1
	Total	1,393	1.152	5.37E+08	1.139	-30,277.340	-30,277.3

Table 4 - Continued

Catastrophe Type	Loss Type	N	Likelihood Ratio Tests				Best Fit
			LN - Pareto	Burr - LN	Burr - Pareto	Chi-Sq(5%,1)	
Hurricane/Tropical Storm (HTS)	Insured	100	4.326	-6.612	-2.286	3.84	LN**
	Total	100	4.326	-6.528	-2.202	3.84	LN**
Earthquake (EQ)	Insured	15	-1.562	0.14	-1.422	3.84	Pareto
	Total	15	-1.122	1.49	0.368	3.84	Burr12
Annual Flood (F)	Insured	28	10.144	0.272	10.416	3.84	Burr12 or LN**
	Total	28	11.526	0.042	11.568	3.84	Burr12 or LN**
Wind and Thunderstorm (WT)	Insured	1,150	43.562	39.492	83.054	3.84	Burr12**
Winter Storm (WS)	Insured	128	6.758	1.054	7.812	3.84	Burr12 or LN**
Annual Aggregate - HTS, EQ, F	Insured	28	2.272	-2.238	0.034	3.84	LN
	Total	28	-43.836	-1.566	-45.402	3.84	Pareto**
Annual Aggregate - HTS, EQ, F, WT, WS	Insured	28	11.108	-0.296	10.812	3.84	Burr12 or LN**
	Total	28	9.508	-1.366	8.142	3.84	Burr12 or LN**
Annual Aggregate - HTS, EQ, WT, WS	Insured	56	14.064	1.568	15.632	3.84	Burr12 or LN**
	Total	56	16.452	1.446	17.898	3.84	Burr12 or LN**
Aggregate Occurrence - HTS, EQ, WT, WS	Insured	1,393	0.438	21.658	22.096	3.84	Burr12**
	Total	1,393	-1.514	35.748	34.234	3.84	Burr12**

Note: \*\* indicates the distribution provides a significantly better fit than the other distributions based on an approximate Chi-square likelihood ratio test. LN = lognormal.

Table 5  
Upper Percentiles of PCS and NFIP Loss Distributions

Values in \$Millions

Catastrophe Type	Loss Type	Lognormal Distribution		Percentiles					Best Fit
		mean	50.0	75.0	90.0	95.0	99.0	99.9	
Hurricane/Tropical Storm (HTS)	Insured	8,962	963	4,004	14,431	31,083	131,102	658,094	LN**
	Total	18,672	2,007	8,342	30,065	64,758	273,139	1,371,071	LN**
Earthquake (EQ)	Insured	939	130	497	1,663	3,424	13,270	60,592	Pareto
	Total	7,208	1,562	5,081	14,690	27,732	91,333	347,438	Burr12
Annual Flood (F)	Insured	1,713	1,242	2,133	3,471	4,646	8,024	14,807	Burr12 or LN**
	Total	4,837	3,521	6,027	9,778	13,062	22,485	41,333	Burr12 or LN**
Wind and Thunderstorm (WT)	Insured	421	172	425	956	1,554	3,865	10,734	Burr12**
Winter Storm (WS)	Insured	1,289	397	1,117	2,837	4,956	14,107	45,571	Burr12 or LN**
Annual Aggregate: HTS, EQ, F	Insured	15,771	4,357	12,853	34,033	60,952	181,852	619,244	LN
	Total	32,436	10,673	29,178	72,134	123,991	342,516	1,069,879	Pareto**
Annual Aggregate: HTS, EQ, F, WT, WS	Insured	28,534	21,474	35,709	56,437	74,221	124,077	220,718	Burr12 or LN**
	Total	48,538	35,330	60,479	98,114	131,064	225,616	414,746	Burr12 or LN**
Annual Aggregate: HTS, EQ, WT, WS	Insured	27,894	18,151	33,919	59,545	83,389	156,845	318,429	Burr12 or LN**
	Total	56,517	36,333	68,495	121,194	170,527	323,597	663,528	Burr12 or LN**

Table 5 - Continued

Catastrophe Type	Loss Type	Percentiles						Best Fit
		50.0	75.0	90.0	95.0	99.0	99.9	
Hurricane/Tropical Storm (HTS)	Insured	748	3,237	17,094	57,577	941,699	50,951,842	LN**
	Total	1,560	6,745	35,622	119,983	1,962,359	106,176,043	LN**
Earthquake (EQ)	Insured	98	387	1,760	5,254	64,269	2,284,143	Pareto
	Total	1,191	4,225	16,428	43,054	383,807	8,599,447	Burr12
Annual Flood (F)	Insured	1,028	2,302	4,467	6,565	13,584	32,195	Burr12 or LN**
	Total	2,797	6,505	13,321	20,456	47,300	133,971	Burr12 or LN**
Wind and Thunderstorm (WT)	Insured	170	425	970	1,629	4,741	19,398	Burr12**
Winter Storm (WS)	Insured	370	1,064	2,989	5,971	27,052	220,762	Burr12 or LN**
Annual Aggregate: HTS, EQ, F	Insured	4,135	12,256	36,090	75,012	375,792	3,573,269	LN
	Total	9,093	27,813	85,960	186,050	1,032,112	11,446,359	Pareto**
Annual Aggregate: HTS, EQ, F, WT, WS	Insured	18,436	39,354	71,387	99,430	179,971	345,135	Burr12 or LN**
	Total	31,749	67,165	120,332	165,974	293,318	541,997	Burr12 or LN**
Annual Aggregate: HTS, EQ, WT, WS	Insured	16,444	36,824	71,437	104,981	217,159	514,408	Burr12 or LN**
	Total	29,833	72,620	158,940	257,791	685,592	2,430,672	Burr12 or LN**

Table 5 - Continued

Catastrophe Type	Loss Type	Burr 12 Distribution						Best Fit
		50.0	75.0	90.0	95.0	99.0	99.9	
Hurricane/Tropical Storm (HTS)	Insured	943	3,736	14,486	36,051	265,748	4,292,735	LN**
	Total	1,963	7,793	30,454	76,405	575,995	9,643,115	LN**
Earthquake (EQ)	Insured	130	441	1,491	3,406	21,022	267,916	Pareto
	Total	1,489	4,103	12,108	26,046	147,935	1,744,060	Burr12
Annual Flood (F)	Insured	1,325	2,138	3,248	4,198	7,028	13,622	Burr12 or LN**
	Total	3,616	5,865	9,262	12,484	23,636	56,549	Burr12 or LN**
Wind and Thunderstorm (WT)	Insured	160	369	911	1,736	7,529	60,738	Burr12**
Winter Storm (WS)	Insured	310	891	3,205	8,337	76,439	1,818,914	Burr12 or LN**
Annual Aggregate: HTS, EQ, F	Insured	4,228	12,198	35,106	71,963	350,678	3,216,261	LN
	Total	10,149	26,821	73,200	146,991	701,361	6,375,035	Pareto**
Annual Aggregate: HTS, EQ, F, WT, WS	Insured	20,621	33,412	56,268	81,557	189,777	630,950	Burr12 or LN**
	Total	34,941	58,331	97,654	138,820	302,571	902,587	Burr12 or LN**
Annual Aggregate: HTS, EQ, WT, WS	Insured	18,026	31,660	56,091	83,086	199,164	681,210	Burr12 or LN**
	Total	36,051	63,882	114,184	170,158	413,334	1,440,290	Burr12 or LN**

Figure 6  
Hurricane/Tropical Storm - Total Loss

