NATURAL HAZARD TRENDS IN THE UNITED STATES: A PRELIMINARY REVIEW FOR THE 1990s

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Natural Hazard Research

Working Paper #83

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PREFACE

This paper is one of a series on research in progress in the field of human adjustments to natural hazards. The Natural Hazards Working Paper Series is intended to aid the rapid distribution of research findings and information. Publication in the series is open to all hazards researchers and does not preclude more formal publication. Indeed, reader response to a publication in this series can be used to improve papers for submission to journal or book publishers.

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SUMMARY

This paper summarizes U.S. natural hazards trends in an effort to provide a "baseline" of data useful in assessing progress in the field and future needs. Using research performed in 1975 as a starting point, the nation's current status regarding common hazards such as earthquakes, hurricanes, tornadoes, floods, and drought are discussed as well as "newer" hazards such as urban stormwater runoff, arid lands floods, and urban-wildland wildfires.

It is difficult to estimate losses from hazards because the data is spotty, there is no uniform method of assessing damages or losses, and those methods that do exist generally do not address the indirect consequences of disaster. As a result, it is believed that current annual estimates of damages that range between $6-20 billion dollars may be too low.

Since 1975, there have been great advances in understanding the natural science and engineering aspects of earthquakes, floods, or severe weather. However, there has been uneven progress in striking a needed balance between the technological aspects of hazards and social analysis. We presently possess the technological means to reduce hazards, but have yet to find consistent and acceptable ways to implement them. Because solutions derived from natural science and engineering methods are not applied in a social vacuum, we believe that more attention needs to be given to social characteristics and trends that will affect hazardousness in the future.

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Introduction

Work began on this paper in 1990, as the United Nations, the U.S., and other countries adopted the concept of an International Decade for Natural Disaster Reduction. To monitor the progress of the U.S. Decade's efforts, we felt that it was important to establish a "baseline" of information on our country's current status of natural hazards research and applications. As the Decade has progressed, it has become clear that the effort to produce a thorough accounting of our status is a formidable task, best performed by a consortium of researchers and practitioners. Such a consortium has already been convened in the hope of producing a volume which will compliment the *Assessment of Research on Natural Hazards* published by White and Haas in 1975. We hope that this preliminary review of natural hazard trends in the U.S. will be of use to those who are in the process of conducting the second assessment.

Problem Statement

Where do we stand in the United States with respect to natural hazard losses, preparedness, and research? What trends in society and the environment might magnify or alleviate future hazard impacts, especially during the 1990s, a period dedicated to reducing natural hazard losses under the United Nations sponsored International Decade for Natural Disaster Reduction? How can we gauge progress in hazards reduction? Is the potential for truly great catastrophes increasing?

Answers to these questions must be qualified: there are few consistent and reliable data on hazard impacts in the U.S. or elsewhere, trends are difficult to discern with any reliability, and the domains of research and applications are far from unified, nor readily summarized. Natural hazards research and management are heterogenous fields divided among scores of disciplines and professional groups. Nevertheless, it is valuable to assess what we know, even in a limited fashion, as a baseline for measuring hazard reduction in the 1990s. By viewing the rough outlines of current hazard trends against the backdrop of similar assessment efforts in the early-1970s, we can gauge relative successes, and suggest areas needing special attention in the 1990s.

This paper is divided into five sections. The first describes national trends in hazard impacts, recognizing that the discreet nature of the most threatening events (e.g., earthquakes and hurricanes) make trend analysis uncertain. Part II attempts to assess preparedness and mitigation at the federal, state and local, and non-governmental levels. Part III describes impressions of the current state of hazard research as perceived by experts who were informally surveyed, as well as the observations of additional experts who met in 1992 to initiate the production of a second "assessment" volume (to compliment White and Haas, 1975). Part IV identifies social and environmental trends that might aggravate or reduce losses from natural hazards in the next decade or so, and explores the potential for catastrophic loss. Finally, Part V contains recommendations for the second assessment and guidelines for hazards work in the 1990s.

Part I: Magnitude and Trends of the Hazard Problem in the U.S.

Almost twenty years ago a group of researchers at the University of Colorado initiated the first broad assessment of trends, research, and applications related to natural hazards in the U.S. The resulting volume, *Assessment of Research on Natural Hazards* (White and Haas, 1975), and subsequent reports, monographs, and articles revealed the nation's understanding of, losses from, and vulnerabilities to a wide array of natural extremes, including earthquakes, hurricanes, and floods. The *Assessment* found the U.S. "becoming increasingly vulnerable to natural hazards, disaster-caused losses . . . rising and Federal assistance programs expanding" (p. 1). The *Assessment* further noted that:

> Natural hazard research in our nation is spotty, largely un-coordinated, and concentrated in physical and technological fields. While there has been a great deal of research directed at fields such as hurricane and tornado detection, weather forecasting and modification, flood control, earthquake engineering and prediction, hailstorm modification, water supply augmentation, [and] forest fire control, . . . relatively little is done in relation to the economic, social and political aspects of adjustment to natural hazards. (p. 5)

The *Assessment* authors felt that hazards work had focused on "technological solutions to the problems of natural hazards, instead of focusing equally on the social, economic, and political factors that lead to nonadoption of technological findings" (p. 1). Moreover, they argued that national trends would produce increasing hazard losses as coasts, floodplains, and seismic zones became further developed. The study also found that at that time few mechanisms existed to translate research into hazard-reduction programs. Technology transfer and awareness programs were found to be especially weak in terms of warning systems for short-term events such as flash floods, alternative adjustments to other hazards, and public awareness programs. The *Assessment* recommended a package of applied research to better illuminate the country's hazard problems.

Since the *Assessment*, much has been done to close the gaps in our understanding of social response to hazards, gaps that the *Assessment* argued were blocking the appropriate application of physical science and engineering solutions. Indeed, the *Assessment* itself was credited with having partially set the tone for hazard reduction programs that strike a better balance among the physical and social sciences, and engineering. Many weaknesses and needs identified by the *Assessment* have been addressed by new programs, institutions, laws, and even new agencies.

Yet, hazard losses continue to escalate, and it can be argued that the potential for truly catastrophic loss has increased. Such broad trends, however, are difficult to delineate. Hazard occurrence in the U.S. exhibits marked short-term and even multi-year fluctuations. For example, hurricane activity abated in the 1970s and early 1980s, and then rebounded in the late-1980s. While there is little evidence of long-term, cumulative trends in hazard frequency or magnitude, it does appear that U.S. property losses from all hazards (even in deflated dollars) are increasing, while fatalities are slowly declining.[1] Thus, the trends depicted by the White and Haas' *Assessment* continue to occur. While increased property loss is chiefly due to development of hazardous areas, e.g., coastlines, seismic zones, and floodplains, declining fatalities

[1] Note, however, that global hazard fatalities are increasing (Thompson, 1982; Mitchell, 1989b).

seem to be resulting from improved building practices, awareness programs, warnings systems, and emergency preparedness programs.

These trends reveal little, however, about the more subtle nature of hazardousness in the U.S. We do not know whether U.S. property losses are increasing as a proportion of gross national product, or of capital investment. If not, it might be argued that we are achieving relative success in hazard mitigation despite growing losses. However, the few studies that cast light on this issue suggest that proportional losses are increasing due to national investment patterns in which hazardous areas are developing more rapidly than the country as a whole (White and Haas, 1975; Petak and Atkinson, 1982). But, the authors of these studies recognize that the lack of consistent hazard loss data make such conclusions tentative.

Trends in Selected Hazards

Hazards loss data are notoriously poor and comparisons from year to year, useful if any trend is to be discerned, must be made cautiously. Generally, data are better for repetitive hazards, such as floods and tornadoes, than for more singular events such as earthquakes and droughts. Long, quiet episodes between major hazard events also make any trend difficult to assess. The discussion here focuses on a selection of natural hazards, both those with more continuous data from which some trends might be assessed, and episodic hazards such as earthquakes and droughts. Examples of estimated losses associated with well-known hazard events are listed in Table 1.

Earthquake: Earthquake loss data are difficult to assess, and less effort has been made to track earthquake losses than other major hazards such as hurricanes. Recent events, however, broadly define the range of current losses and point to what might be expected in the future. The major U.S. earthquakes of the past few decades have had relatively modest impacts. The 1964 Alaskan event caused an estimated $300 million loss (in 1964 dollars), quite significant for the time but not catastrophic for the community of Anchorage, where researchers concluded that the earthquake "had little long-term human impact" (Haas, 1973, p. 91). The 1989 Loma Prieta earthquake in northern California resulted in perhaps over $7 billion in public and private losses (Piacente, 1989), but these losses were generally confined to the region. However,

Table 1. Recently Estimated Annual U.S. Losses Due to Weather Hazards (millions of dollars). From Riebsame et al., 1986, and Mason and Mattson, 1990.

Hazard	Deaths	Cost	Source Date
Flood	163		1986
	88		1985
		3,175	1986
		1,000	1983
		2,000	1982
		3,000 +	1981
		1,700 +	1980
		1,000 +	1978
Hurricane	33		1986
	23		1985
(wind & storm surge)		796	(in 1982$)
		1,800	1982
		441	1979
Tornado	98		1986
	76		1985
		300	1983
		200	1982
		2,000	1982
		75	1979
Lightning	97		1986
		200	1983
		100	1981
		100	1979
Hail (total)		750	1983
(crops)		680	1983
(property)		70	1983
(crops)		667	1985
		284	1979
Cold	454		1981
	398		1984
Heat	175		1980
	212		1984
	40		1985
Winter Storm	30		1985
		630	1982
Snowfall		3,000	1982
Snow (urban)		100 +	1975
Frost		800	1982
Windstorm	82		1980
(not tornado)	71		1985
		1,200	1982
Drought		800	1982

Loma Prieta was not the "big one" expected to occur in California within the next few decades.

The most obvious trend in earthquake loss *potential* is continued rapid population growth in seismically active zones, especially Los Angeles, San Francisco, Seattle, Salt Lake City, Memphis, and St. Louis (Figure 1). Even New England, a region that witnessed population out-migration in the 1970s, saw a resurgence of growth in the 1980s, placing more people at risk from the potentially energetic seismic area around Boston.

Hurricane: Despite fewer strong hurricanes making U.S. landfall during the late-1970s and early-1980s, hurricane property losses per storm increased (Riebsame et al., 1986). That trend has certainly continued with Hurricanes Hugo (1989), Bob (1991), Andrew (1992), and Iniki (1992). Hugo's insured losses of $4.5 billion are "believed to be less than half of what was perhaps more than $10 billion in total destruction" (Kerr, 1992b). In August 1991, Hurricane Bob struck New England as a very strong Category II hurricane, causing 17 fatalities and massive damage to property and public facilities. President Bush signed major disaster declarations for six states, and total damages were estimated at $1.5 billion (National Weather Service Eastern Region, 1991; Thomas, 1992). Estimates for Hurricane Andrew, which struck south Florida on August 24, 1992, include $16.5 billion in insured losses—Allstate alone expects $1.2 billion in claims, which is four times what it paid for Hugo (Kerr, 1992a; Steinmetz, 1993). And Iniki, which struck the island of Kauai in Hawaii on September 11, 1992, inflicted damage to 90-95% of the island's homes (with major damage to 10,000 homes) and placed 8000 residents in shelters. Expected costs are estimated to be between $1-1.6 billion in damages (Mydan, 1992; National Public Radio, 1992; Steinmetz, 1993).

Beginning in 1983 (with Hurricane Alicia) there has been least one hurricane landfall per year, but even with this recent increase in storms, fatalities have remained low as most of the storms have been of modest intensity and because warning and evacuation programs have proven effective (Caribbean UNDRO, 1989). The technical success of storm-surge modelling and evacuation planning was especially demonstrated when Hurricane Hugo—the most severe hurricane to cross the U.S coastline since

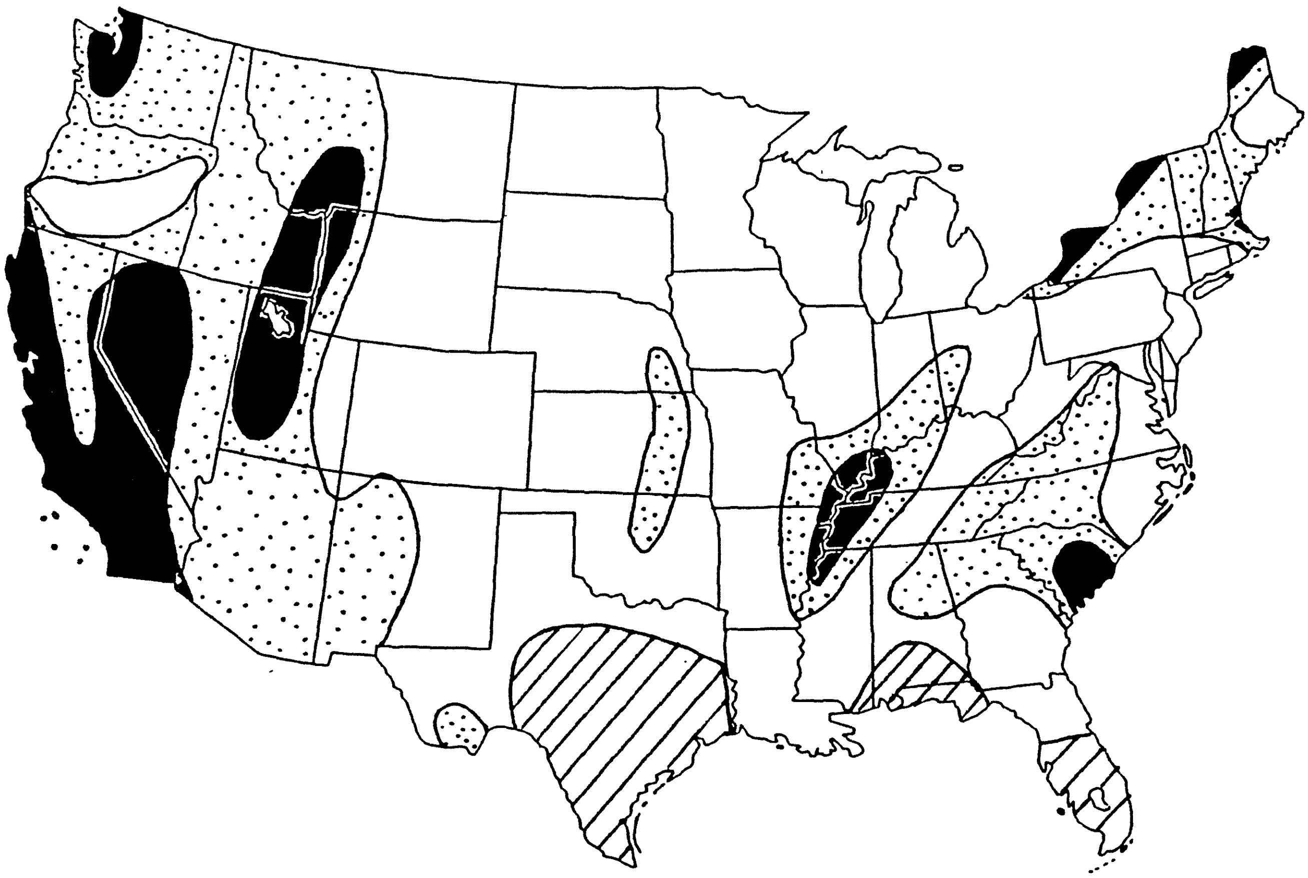

Figure 1. Seismic Risk Map of the United States.*

Zone 3 = □ - Major damage (Intensity VIII and higher)

Zone 2 = □ - Moderate damage (Intensity VII)

Zone 1 = □ - Minor damage (Intensity V-VI)

Zone 0 = □ - No damage

* Adapted from Algermissen, 1969. Intensity scales are Modified Mercalli.

Camille in 1969 (until Andrew)—moved inland near Charleston, South Carolina, in 1989. And in the case of Hurricane Andrew, researchers at the National Meteorological Center in Camp Springs, Maryland, successfully inaugurated the use of their global weather forecasting model to predict the hurricane's path. However, there has been no progress in forecasting changes in hurricane intensities (Monastersky, 1992), which is unfortunate given the fact that intensity levels dramatically alter the amount of devastation faced by impacted communities.

Hugo also demonstrated the increasing amount of gross monetary loss that can be caused by individual hurricanes. The intense eyewall and on-shore winds, where most of the storm surge and near-shore wind damage occurred, hit north of Charleston in a less-developed segment of coastline. However, the hurricane maintained high wind speeds well inland, causing total wind and water damage amounting to between $6-7 billion. Table 2 illustrates the difference this single event made in the decade's damage figures for hurricane losses. Such a large loss ranked Hugo with Camille ($1.3 billion) and Agnes ($8 billion, including the Pennsylvania floods) as one of the most costly hurricanes in U.S. history. Now Andrew can also be added to that list. Initial survey reports from Hugo did highlight the less-recognized vulnerability of inland areas to storms that move inland quickly and lose energy slowly (Golden, per. comm., 1990).

Tornado: The annual number of reported tornados have remained fairly constant over the past three decades with approximately 750 per year (NA, 1989) while the

Table 2. Hurricane/Tropical Storm Landfalls and Associated Damages Along the U.S. Coast: 1986-1989*

Year	1986	1987	1988	1989
Landfalls	6	7	6	11
Damages (M)	17	8	59	7,670
Average Loss Per Landfall	2.8	1.1	9.8	697

* From Case, 1988, 1990; Lawrence 1987, 1989.

number of associated deaths have been falling. However, property losses have been increasing. Extrapolating from the figures in Table 3, these trends will probably continue. Increases in property loss are probably due to simple demographics—more people and development in tornado-prone zones. Building codes and standards that mitigate wind damage may not be keeping pace with development, which leaves many buildings susceptible to tornado damage (Perry et al., 1989). The fewer deaths are probably due to improved forecasting and warning systems.

Flood: Fortunately for this review there exists a recent assessment of floodplain management in the U.S. that evaluates flooding impacts and trends (Interagency Task Force, 1992). Overall, flood losses are increasing and, unlike other meteorological hazards, flood fatalities are also increasing (Riebsame et al., 1986), probably largely due to flash floods in mountainous regions during the 1970s and 1980s. While riverine or "slow rise" flood forecasts are quite reliable in the U.S., it is not feasible within technical, economic, and political constraints to provide this level of safety in all of the thousands of small, flash flood-prone basins in the U.S. (Gruntfest, 1987). Thus, perhaps some 300 small- to medium-sized communities face the threat of a disastrous

Table 3. Tornado Sightings, Deaths, and Damages 1986-1989

Year	1986	1987	1988	1989
No. of Tornados	764	656	702	856
No. of Deaths	15	53	29	50
No. of Category 6†	66	32	48	60
No. of Category 7††	9	6	17	18

* From *Storm Data* (NA, 1986, 1987, 1988, 1989)
† $500,000-5 million in losses
†† $5 million and greater in losses

flash flood. While some communities have well-developed flood warning systems—such as Gatlinburg, Tennessee, or Manitou Springs, Colorado—the next large-fatality flash flood is more likely to hit a community that lacks an effective warning system, simply because such ill-prepared communities are the more numerous. A good example of this is the flash flood of June 14, 1990, in Shadyside, Ohio. In that case, because there was no recorded history of flash flooding on the two creeks involved, the "public awareness of the possibility of a flood of this magnitude was essentially nil" (U.S. Department of Commerce, 1991, p. vii). This fact, coupled with the extremely rapid development of flooding conditions and underestimation of rainfall intensity by radar, resulted in at least 26 fatalities, the destruction of 80 residences and numerous vehicles, and additional damage to 251 homes and businesses in Belmont County. Although the National Weather Service issued a flood watch approximately two hours before the flood occurred, the weather office that had warning responsibilities in Belmont had neither radar nor ground truth reports that would have indicated the magnitude of the rainfall event (U.S. Department of Commerce, 1991). The public became aware of the flood watch mainly via commercial radio and television—the same medium by which the Shadyside Police and the County Emergency Management Coordinator became aware of the danger. National Oceanic and Atmospheric Administration Weather Radio proved ineffective. A report on the flood that was issued in January, 1991, concluded that, "due to the very fast onset of the flash flood near Shadyside, a local flood warning system would have needed to have been in place to provide sufficient lead time for residents to take protective actions" (U.S. Department of Commerce, 1991, p. viii).

Drought: Drought occurs in some part of the U.S. every year, but the large droughts that attract national response occur roughly once a decade. There are no consistent drought-loss data comparable to that for hurricanes or floods, but evidence suggests that the nation is becoming more sensitive to drought—a vulnerability made evident during 1988 (Grigg and Vlachos, 1990; Riebsame et al., 1991). Water systems developed since the 1930s have not kept pace with demand in several areas, especially the northeast and mid-atlantic regions, and rapid development in the far west has stressed that region's water supply (see U.S. Water Resources Council, 1978; Waggoner, 1990).

In many river basins, water management rules have not been updated to account for social and environmental conditions that have emerged since systems were first developed (U.S. Army Corps of Engineers, 1988), and many major water systems lack drought contingency plans (Vlachos, 1990). Separate studies of the 1980-81 mid-Atlantic drought concluded that similar meteorological conditions caused more problems in the 1980s than they did in earlier droughts due to aging infrastructure, increased demand, and reliance on above-normal precipitation for normal water system function (Weisman, 1985).

A comprehensive assessment of the 1987-89 drought found that the lack of timely monitoring, information dissemination, and responsive management, exacerbated by the increased vulnerability of many parts of the U.S. to decreased precipitation, worsened the natural resource and economic impacts of the drought (Riebsame, et al., 1991). The federal government estimated that total agricultural loss in the 1988 growing season alone was $16 billion, while Riebsame et al. suggest that the total loss, including ecological damage and human morbidity and mortality, is at least twice that figure.

Some Emerging Hazards Deserving Attention

Increasing societal vulnerability associated with human use of seismic zones, floodplains, and the coasts is an obvious, though difficult to mitigate, result of economic development. Other, more subtle hazard situations also deserve attention, such as increased stormwater runoff, and wildfire hazards at the margins of urban development.

Urban Stormwater Runoff: Continued urban and suburban expansion has changed the nature of runoff/flood characteristics in many U.S. basins. Urbanization generally increases total and peak runoff, the frequency of extreme runoff events, and the transport of pollutants and sediment. Moreover, Schilling et al. (1987) argue that urban stormwater management systems in the country are deteriorating due to lack of investment and planned maintenance. Basin urbanization and wetland loss increase the nation's slow-rise and flash-flood hazard. Increasing urban stormwater runoff also aggravates environmental problems such as sedimentation, biological pollution, and toxic loads. Integrated systems for urban drainage are just developing in some localities, and this promises to be a key water problem over the next fifty years (e.g., Hill, 1987).

Arid-Lands Floods: The far western U.S. has developed faster than any other region over the last two decades, a fact that raises concern over catastrophic loss during an earthquake in California, Utah's Wasatch Front, or the Puget Sound area. But, in terms of repetitive losses, the chief problem in this arid and semi-arid region is flooding. The flood hazard in arid lands is inherently more difficult to define than it is in humid regions. "Floodplain" means little to the residents of metropolises such as Las Vegas and Salt Lake City, which have been built on the shifting channels of alluvial fans. Floods and landslides in 1983, caused when a long-term period of above-normal precipitation was topped by rapid snowmelt, illustrated the west's vulnerability to such hazards. Nearly $250 million in losses were associated with the 1983 floods and landslides (Anderson et al., 1984), two phenomena intimately linked in arid lands. Flash flooding due to heavy thunderstorms also continues to be a primary hazard in arid lands, as evidenced by recent events in Cheyenne, Wyoming, and Las Vegas, Nevada.

Urban-Wildland Wildfire: Recent intense wildfire seasons have increased public concern over fire hazards, but the oft-cited Yellowstone fires of 1988 may actually have diverted attention from the more serious problem of wildfires in the zone where suburban development intermingles with rural areas and wildlands. The "urban-wildland" interface, especially in the southeast and west has been the scene of increasing fire losses as the normal fire ecology of forests intersects with low-density suburbanization and second-home or recreational developments. In 1985 more than 85,000 fires swept over three million acres, destroying or damaging more than 1400 structures and killing 44 people. Even more fires occurred in 1986 (100,000) but these killed fewer people (nine fire fighters) and caused somewhat less property damage than the previous year's record high. The summer of 1988 produced more acreage burned than ever before (roughly six million), but much of this land was in wilderness and park preserves and relatively little developed property was damaged. The fall of 1991 produced one of the most devastating urban-wildland fires to date. In October, what has become known as the Oakland-Berkeley firestorm caused 25 fatalities, 150 injuries, left 5000 homeless, and destroyed: 1) 3354 single family homes with an estimated value of $1.2 billion dollars, 2) 456 apartment units, and 3) 2000 vehicles. An additional $100 million was spent on: relief costs, repairs to gas and electric facilities, fire suppression, post-fire erosion control in an effort to prevent flooding, and emergency watershed protection. Unfortunately,

> an estimated 7,000,000 Californians are living in established hillside settlements or in new, rapidly growing communities in urban-wildland areas. These areas are known to be extremely hazardous. The inhabitants of these hazardous areas are at risk of not only losing their homes, but even their lives from a wildland fire. It is no longer a question of if a conflagration will occur in these areas, it's a question of where, when, and how great the losses will be. (Federal Emergency Management Agency, 1992a, p. 13)

With increasing construction of primary or secondary residences in near-wildland sites (Bethea, 1987) all over the country, increased property losses and fatalities can be expected.

A Problem of Measurement

The brief review presented above does not claim to explore the full range of natural hazards (especially more subtle ones such as expansive soils and heat waves), or to fully assess their impacts on the U.S. Unfortunately, the national toll from natural hazards is perhaps the least well-measured element of the country's economy. Hazards do not occupy the financial scale of major economic sectors such as manufacturing or services, nor do they retain the attention given more immediate policy issues such as national security, health care, or education. Yet, the economic and social disadvantages of natural hazard vulnerability—some of which can be reduced—may be roughly proportional to other major social and public policy issues such as the trade deficit, productivity losses associated with problem behaviors such as smoking or drug use, and decaying infrastructure.

From the early-1970s *Assessment*, to the recent report on the status of the nation's floodplains, analysts have lamented the poor state of hazards data collection. Indeed, critics of the 1970s assessment called for more detailed, empirical analysis. Rossi, Wright, and Wright, in particular, criticized the *Assessment* for failing to provide a more empirically-based assessment of the actual hazard situation in the U.S. (1981, p. 149). Yet, they also noted that the *Assessment* made explicit the "thinness" of hazards data in the U.S.—a fact that obviously limited the *Assessment's* ability to detail hazard risks and losses. Rossi et al. (1981) strongly advocated the need for a more discriminating analysis of hazard trends, one that would, for example, indicate the relative roles of populations at risk, investments, and event timing and magnitude in relation to increasing flood deaths. Moreover, they felt that the focus on loss *per se* (as opposed to loss as a proportion of investment or gain from use of land), tended to overstate the hazard threat in the U.S.—raising the question of whether we even had a meaningful yardstick for measuring hazard effects (see Howe et al., 1990).

Unfortunately, we cannot answer the critical question of whether losses are growing as a proportion of gross national product/gross domestic product or of investment, nor can we judge the efficiency of investments in various hazard-reduction activities, such as improved warnings or relocation projects, without better data.

Not only do we have only a rough notion of the status of hazard losses in the U.S., we know little about the economic and social structure of loss. Previous studies have shown the difficulty of accounting for hazard impacts as they propagate into the economy (Green et al., 1983), even at the local level. Monroe and Ballard (1983) offered a methodology for assessing disaster effects as they spread through a community, into surrounding areas, and propagated through time and the economy. Their paper was one of the first to attempt to estimate an earthquake's impact on a community's economy by virtue of its adverse effect on personal income and employment, rather than focusing on structural damage. A "domino effect" was described: the normal operation of commuting/transportation systems and service/production facilities are interrupted causing decreased levels of employment and effective wages, and hence leading to decreased retail sales. Along with a loss of government income from sales taxes, falling personal income levels further diminished tax revenues at the very time that government expenditures swell due to aid payments and repairs necessitated by the disaster. Finally, due to the adverse economic environment, out-migration exceeds in-migration, the population base declines, and the tax base is further reduced. While Monroe and Ballard's study is more comprehensive than most, it still neglects non-economic losses, and thus may still underestimate overall costs to society.

Recent hazard events illustrate this last point. While considerable attention was focused on the exact death toll of the Loma Prieta earthquake (eventually placed at 62), less effort was made to assess the number of people injured or the costs of those injuries. Early estimates put the injured list at 3757, roughly 60 times the fatality rate, and close to the 1:50 ratio of deaths to injuries suggested by White and Haas (1975) for hurricanes. If this magnification factor holds for most hazards, and assuming that the social costs of injuries are at least as much as deaths (they may be greater, considering that injured persons require more medical attention and follow-up treatment), then we are seriously underestimating the cost of direct effects of hazards on people.

Studies of inequities in hazard vulnerability are also rare. However, different recovery capabilities and evidence of inequitable distribution of aid began to emerge following Loma Prieta (Phillips, 1990; Phillips and Ephraim, 1992) and Hurricane Hugo (Rubin and Popkin, 1991). Poor, non-English-speaking, homeless, and otherwise disenfranchised citizens appear to receive less, and less timely, assistance. A similar situation may be emerging following Hurricane Andrew, where "people living in devastated areas like Perrine and Richmond Heights, most of them black and many of them poor, are questioning why more affluent neighborhoods got more press attention and, at least initially, more relief supplies" (Rohter, 1992, p. E3).

Additionally, the potentially large costs of hazard-caused environmental degradation or long-term adverse health effects (both psychological and physical) have only recently been addressed (Brabb, 1984; Green et al., 1988; Showalter and Myers, 1992). By way of illustration, it has been suggested that the 1988 drought's largest impacts were not the immediate losses of crops and water supply (perhaps $16 billion), but rather the longer-term effects on wetlands, waterfowl, soil, and forests—all of which express drought stresses over periods of years rather than days and weeks (Riebsame et al., 1991). Similarly, while Hurricane Hugo's winds caused immediate damage to 36% of South Carolina's woodlands, flattening a large area of the Marion National Forest with a loss of perhaps 6.7 million board feet of lumber valued at $1 billion, there was un-measured further impact on wildlife, recreation, environmental quality, and other benefits of the forest, as well as the creation of an unusual fire danger.

The Bottom Line

The 1970s *Assessment* estimated that total U.S. direct natural hazard losses were (in early 1970s dollars) roughly $4.5 billion. More recent estimates of annual natural hazard losses in the U.S. include: 1) $4 billion from floods; $2 billion from landslides; $2 billion from tornados and hurricanes; $1 billion from volcanic eruptions, wildfires and tsunamis; and $1 billion from earthquakes, for a total of some $10 billion dollars per year according to Hays (1990); 2) a conservative estimate of $6 billion per year according to the Committee on Earth and Environmental Sciences Subcommittee on Natural Disaster Reduction (CEES/SNDR, 1992); and 3) as much as $8 billion per year in 1970, topping $17 billion per year (all in 1970s dollars) according to Mason and Mattson (1990; see Table 4). Riebsame et al. (1986), whose analysis included less well-measured impacts of extremes of heat and cold and often-neglected hazards such as crop damage due to hail, estimate that annual costs from weather and climate hazards *alone* run to $20 billion a year in the U.S., with deaths numbering in the thousands (Table 1).

These direct dollar losses, impressive on their own, mask long-term effects on businesses, health, and the environment. Indeed, Yetter (1990) concludes that "most business and industrial organizations do not survive as business entities when they fall victim to major emergencies, natural disasters or some other form of severe business interruption" (p. 6). Using major fire losses as an example, he found that 43% of businesses suffering a major loss never recover and of those that do, only 23% last

Table 4. A Comparison Between Annual Natural Hazard Losses for the Year 1970 and Projected Losses in the year 2000 (for selected hazards).†

Type Hazard	# Lost Housing Units		Dollar Cost per Capita*		Annual Cost (millions)	
	1970	2000	1970	2000	1970	2000
Hurricane	56,406	95,994	8.36	22.92	1,697.2	5,869.2
Tornado	36,212	52,119	8.12	20.38	1,656	5,219.1
Riverine Flood			13.57	12.4	2,758.3	3,175.3
Earthquake	20,485	22,868	3.83	6.07	781.1	1,553.7
Expansive Soil			3.93	3.89	798.1	997.1
Landslide			1.82	3.4	370.3	871.2
Severe Wind	547	748	.06	.19	18	53.4
Tsunami	234	335	.07	.16	15	40.4
Total	113,884	172,064	39.76	69.41	8,094	17,779.4

† Adapted from Petak and Atkinson, 1982; Mason and Mattson, 1990.
* All costs are in 1970 dollars.

beyond three years. In other words, businesses suffering a major loss have a "mortality rate" of 87% within three years of the event, while the average three-year mortality rate among U.S. businesses is 34% (Dun and Bradstreet, 1987). Losses to those who had been employed by such companies must be significant in terms of time spent searching for a new job, with possible relocation costs, and the broader costs to society of unemployment and retraining. And none of these dollar estimates can pretend to gauge the emotional effect on families due to loss of loved ones, homes, or income—these psychological costs of hazards have been neglected in most analyses (for an exception, see Glittenberg, 1989). In addition, regional economic ties that span the nation ensure that the "economic effects of a major [disaster] will not be limited to the impacted region alone. Hence, there will be ripple effects. The real question, however, is about their scope, intensity, and duration" (National Research Council, 1992, p. 145; see also Federal Emergency Management Agency, 1992b).

Part II: The Potential for Future Loss Reduction

The Status of Hazard Mitigation and Preparedness

As with questions regarding hazards impacts, questions pertaining to society's capability to prepare for, respond to, recover from, and mitigate natural disasters can be answered only with the understanding that consistent, comprehensive study of the topic has not been attempted.

What is clear is that hazard reduction activities are addressed by a large number of organizations, agencies, and individuals. In fact,

> the present hazard management system, to a large degree, consists of an array of independent programs undertaken by a host of different local, state, and federal authorities—many with conflicting responsibilities—as well as by many private organizations. (National Academy of Sciences, 1989)

The major participants involved with hazards reduction include government agencies, not-for-profit and professional organizations, university researchers, private/commercial enterprises, and volunteer groups. Each has conducted studies or implemented projects or programs to reduce the nation's susceptibility to losses from natural disasters. Coordination among the groups has been quite successful in some instances, for example in the creation of the National Flood Insurance Program (NFIP), which includes a cooperative effort between federal and local government as well as involvement from the private sector (the insurance industry). Coordination has been less successful in other instances—as seen in the continued tension between programs at different government levels as well as the continued need for better communication between researchers and practitioners.

While no comprehensive assessment exists today of all participants in hazards reduction in the U.S., it is possible to discuss the major actors involved: federal, state and local, and non-governmental organizations.

The Federal Level

At the federal level, no fewer than a dozen agencies share responsibility for preparedness, response, recovery, and mitigation of natural disasters. They include the Federal Emergency Management Agency (FEMA), U.S. Army Corps of Engineers (Corps), U.S. Geological Survey, National Institute of Mental Health, Tennessee Valley Authority, U.S. Environmental Protection Agency, Departments of Transportation and Agriculture, National Oceanic and Atmospheric Administration (NOAA), National Science Foundation, National Institute of Standards and Technology, and the U.S. Bureau of Reclamation. The activities of these agencies encompass a broad range of projects from hazard assessment and disaster response to the implementation of structural and nonstructural methods to reduce damages.

In the past 20 years the federal response to natural hazards has been substantial. A variety of programs use different approaches to address disaster problems. For example, the National Flood Insurance Program focuses on regulation to mitigate future flood losses, and on insurance to provide relief from flood damage. The National Earthquake Hazards Reduction Program relies on research and technology transfer to encourage seismic safety. NOAA has emphasized improving its ability to predict severe weather and then translating that data to local emergency managers. Executive orders ensure that federal agencies set good examples for development that occurs in floodplains (e.g., EO 11988 issued in 1979) and in seismically active areas (e.g., EO 12699 issued in 1990). Amendments to the Disaster Relief Act adopted in 1988 allow the federal government to provide financial assistance to state and local governments that want to incorporate mitigation elements into their post-disaster reconstruction projects (as opposed to simply rebuilding damaged facilities to their "pre-disaster" condition).

A significant change in federal level hazard reduction programs has been the emergence of interagency efforts to deal with natural disasters and comprehensive emergency preparedness. While there was little in the way of interagency cooperation fifteen years ago, there is now a trend toward frequent interaction (Tubbesing, 1989). The creation of FEMA is, perhaps, an example of this for it was established in 1979 to bring together a number of programs formerly housed in separate agencies. FEMA's appearance signaled that the federal approach to disasters would attempt to coordinate mitigation, preparedness, response, and recovery activities.

Other examples of cooperative efforts include the Interagency Hurricane Evacuation Program. Initiated to bring the talents of the Corps, NOAA, and FEMA together to assess, plan for, and respond to hurricane hazards, it also served as an interagency effort to conserve funds. The creation of post-disaster interagency hazard mitigation teams is another example of this trend. These teams travel to disaster sites to identify opportunities for mitigation in the recovery process, and to designate lead agencies and potential implementation tools to take advantage of these opportunities. A third example is the development of the Federal Catastrophic Disaster Response Plan. Headed by FEMA and originally focused solely on earthquakes, this planning effort includes participation of all federal agencies able to provide expertise and assistance in the event of a disaster that exceeds local and state response capabilities. The American Red Cross cooperates as a full partner in this planning process. Plans, of course, do not guarantee effectiveness. For example, following Hurricane Andrew, the U.S. General Accounting Office (GAO) examined the adequacy of federal strategies for dealing with catastrophes and found them deficient (U.S. General Accounting Office, 1993).

State and Local Level

Identifying state and local capabilities to deal with natural disasters is more difficult than identifying federal level capabilities. Fifty states and thousands of communities face different hazard threats. They have varying levels of authority to deal with hazards, and each has its own style of coping with disaster.

It is possible to point to exemplary state and local level loss reduction programs. For example, in California the creation of substate organizations (e.g., Bay Area Regional Earthquake Preparedness Project, Southern California Earthquake

Preparedness Project) to promote earthquake awareness and preparedness appears to be an effective model for dealing with a multi-jurisdictional hazard threat. Floodplain management programs in some states (e.g., Wisconsin, Illinois) have more stringent development requirements than the minimum standards imposed by the National Flood Insurance Program. Communities like Tulsa, Oklahoma, and Denver, Colorado, are frequently cited as examples of outstanding stormwater management programs.

In some cases, a local and state-level capability assessment has been conducted on a hazard-by-hazard basis. In 1989, for example, the Association of State Floodplain Managers (ASFPM) published a report describing state and local floodplain management activities undertaken in 1987-88. The report provides a complete picture of state floodplain management activities in the country, and gives examples of typical local level programs (Association of State Floodplain Managers, 1990). The ASFPM now updates these activities every three years and has just published the report covering the period from 1989-1992. In a similar fashion, the National Coordinating Council on Emergency Management conducted a survey of all the states to determine their level of earthquake preparedness (NA, 1990). While these examples shed some light on state and local mitigation capabilities, they cannot provide a comprehensive picture.

Trends as Revealed by CHIP. The Federal Emergency Management Agency has developed a system called the Hazard Identification, Capability Assessment, and Multi-Year Development Plan (HICA/MYDP—now referred to as CHIP), which is a data base designed to determine the status of emergency preparedness at the state and local level (Grier, per. comm., 1990). Each state emergency management agency and all local governments that receive financial support from FEMA are required to submit information to the data base. The data base is most useful for developing state by state profiles, but also lends itself to providing a broad outline of the responsibilities and capabilities of state and local emergency management agencies.

At the state level, all respondents shoulder the principal responsibility for emergency preparedness, while most claim principal responsibility for emergency response and disaster assistance and recovery activities. Ninety percent of the states have made provisions for contingency funding in the event of an emergency, and slightly more than half have entered into mutual aid agreements with neighboring states in the event that they simultaneously suffer from the same disaster. Annual budgets for state emergency management agencies in 1988 ranged from more than $17 million in California to less than $350,000 in Maryland, with the average figure at slightly more than $2.5 million. FEMA provides approximately half the funds for these budgets.

Lead responsibility for hazard mitigation plans rests with the state emergency management agency in 73% of the states, and the vast majority of states address hazard mitigation in their state emergency operations plans. Most states have ongoing public education and awareness programs to inform both the public and the media about hazards and protective measures on a regular basis. Half the states extend this program to assist local school boards in incorporating emergency management information into school curricula.

In terms of local level capabilities, CHIP collates data from some 3000 (mostly county level) local jurisdictions. All of them have legal authority for emergency management. Most (94%) have developed multi-hazard emergency operations plans, but fewer than half have established disaster contingency funds. About 60% of the jurisdictions report they have developed a hazard mitigation plan, and 80% do have a public education program to alert citizens to hazards or warnings, and to disseminate protective measures. About two-thirds of the jurisdictions have maps of their hazardous areas.

The data base includes information about local jurisdictions' perception of vulnerability to significant threats from 11 different natural hazards. Eighty-one percent list winter storms as a significant threat; 73% floods; 69% tornadoes; 53% drought; 48% wildfire; 33% earthquakes; 29% hurricanes; 9% landslides; 3% volcanoes; and 2% avalanche and tsunamis.

The information in the CHIP data base is a valuable resource for examining the ability of state and local governments to deal with disasters. However, it does little to answer questions regarding the effectiveness of the programs that have been established.

Non-governmental Organizations

Non-governmental entities, composed of the volunteer community, not-for-profit or professional organizations, the private sector, and academia, play an important role in reducing the impacts of hazards in the U.S.. Non-governmental entities not only move to alleviate immediate individual needs of disaster victims, but undertake long-term studies and projects to reduce society's general vulnerability to disasters.

In times of disaster, it is the individual victim who appears most vulnerable and in need of assistance because homes are destroyed, valuables lost, injuries or death suffered. To meet this need, a volunteer community has emerged to alleviate and mitigate the suffering experienced by disaster victims. Characterized by the American Red Cross, which was established by an Act of Congress in 1905, this community ministers to the needs of victims in the immediate post-impact time period. Basic needs such as food, clothing, shelter, and first aid are met by these groups. Longer term needs that are fulfilled include counseling, advocacy, temporary housing, reconstruction assistance, and, in some instances, financial aid.

The volunteer community is composed of the many formal organizations, informal groups, and individuals that respond in time of disaster. An umbrella group—the National Voluntary Organizations Active in Disaster (NVOAD)—serves as a coordinating body for the volunteer community to foster more effective service, through mitigation and response, for the benefit of people affected by disaster. As one of its activities, NVOAD publishes a directory of organizations active in disaster. It lists 18 different groups that, nationwide, have thousands of members who are prepared to help in time of need.

However, systematic analysis of volunteer organizations has not been done. In a case study of volunteer networks in the St. Louis metropolitan area, Gillespie et al. (1986) confirm that organized volunteers are a critical resource in disaster preparedness. They recommend that local governments develop more sophisticated systems for identifying, recruiting, motivating, and rewarding volunteers.

The hazard reduction role of not-for-profit or professional organizations has been growing and can be expected to continue. In 1985, the COSMOS corporation investigated the role of professional associations in the natural hazards field (Burke and Moore, 1985). Twelve major organizations were identified with direct links to natural hazards, and another 25 with related interests. The roles played by these organizations range from information exchange to setting standards for hazard reduction to lobbying. Several conduct research to advance the state-of-the-art of their profession, or to assess the status of knowledge implementation (e.g., such as the studies referenced above conducted by the ASFPM and NCCEM). Most conduct regular workshops or conferences to provide training in the specialized fields of hazard management and to offer networking opportunities. Nearly all have newsletters to provide information to their members. Other activities undertaken by professional associations include technical publications, scholarships or fellowships, and the maintenance of directories of experts.

The private sector role in hazard reduction is probably quite large, though private sector and public-private approaches to hazard mitigation are poorly recorded. Involvement by the private sector ranges from consulting firms that specialize in various aspects of hazard reduction such as contingency planning or site-specific risk assessments to companies that manufacture and market flood warning and other hazard-related equipment. The insurance industry has a keen interest in the losses caused by catastrophic disasters, and has long worked to improve educational programs aimed at informing the insured of their risks to hazards. A recent initiative by the property-casualty insurance industry is the formation of a Committee for Natural Disaster Loss Reduction (NA, 1992), which the organizers hope will eventually develop into the Insurance Institute for Hazards Reduction and will function in an industry support role similar to the Insurance Institute for Highway Safety. Another example of private sector involvement in the hazards arena is BICEPP—the Business and Industry Council for Emergency Planning and Preparedness. BICEPP is a nonprofit, private sector association based in southern California that encourages business organizations to work together to prepare for and deal with emergencies.

Academic institutions also play a role in improving the nation's ability to cope with disasters. They provide homes for hazards researchers as well as training in fields relevant to hazards reduction. (Though only one university—the University of North Texas—has a resident undergraduate program in emergency management.) The Information Sources list in the *Natural Hazards Observer* (NA, 1993) includes 25 institutions of higher education with hazard-related programs or services, and new programs continue to emerge across the country. For example, a new Hazards Research Center has been established at the University of Louisville, and a Center for Disaster Medicine is now housed at the University of New Mexico.

It appears that the U.S. has a reasonable ability to deal with disasters. In fact, one of the underlying premises of the International Decade for Natural Disaster Reduction (IDNDR) is that enough knowledge already exists, and only needs to be properly applied, to significantly reduce damages from natural disasters. The critical question is whether or not the individuals, agencies, institutions, and organizations described in the preceding sections are willing to apply the knowledge and devote the resources required to achieve loss reduction.

Part III: The Views of Some Experts in the Field

In a preliminary attempt to better ascertain the status of U.S. natural hazards vulnerability, we elicited the opinions of nine hazard experts[2] in the form of an informal survey conducted in 1990. The following discussion draws heavily upon their combined insights.[3]

Despite the variety of hazards addressed (severe thunderstorms, hurricanes and other coastal hazards, earthquakes, expansive soils, landslides, flash floods), responses were surprisingly uniform in several respects. The experts consistently expect escalating property damage over the next decade, and increasing population was unanimously cited as the major culprit for increased loss, as people continue to move

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[2] J. Golden (hurricane); G.B. Grigg (coastal hazards); E. Gruntfest and C. Huber (flooding); D.E. Jones, Jr. (expansive soils); C. Kisslinger (earthquake); W.L. Read (severe storms); D.N. Swanston (landslides); and G.F. Wieczorek (landslides).

[3] Please note that in the interest of avoiding discontinuity in the following paragraphs, exact quotes from the experts' personal communications are enclosed in quotation marks but are not cited individually.

into and further develop hazard-prone areas. A good example of this is a recent Supreme Court case, *Lucas v. South Carolina Coastal Council*. Plaintiff David H. Lucas purchased two lots on the Isle of Pine in December, 1986,

> from the development company where he had previously served as a contractor, manager, and part owner. He must therefore have been quite familiar with the instability of the inlet shoreline that borders his lots [which] over the past 40 years, has wandered back and forth across his present lots. Although they are now 'dry land,' they were covered with four feet of water by Hurricane Hugo in 1989. Only three years before he bought the lots, emergency sandbagging and shore protection were required to defend neighboring homes from erosion. (Platt, 1992, p. 8)

Because a 1988 South Carolina Beachfront Management Act (BMA) had drawn a no construction or rebuilding baseline on the landward side of Lucas' lots, he sued the state for unlawful taking of his property. The Supreme Court, by a 6-2-1 majority, reversed and remanded the South Carolina Supreme Court's decision that had upheld the constitutionality of the BMA against the "takings" challenge. It is feared that the ruling will invite

> landowners to challenge public land-use regulations of many types. . . [and] will be invoked throughout the nation to dissuade heads of state and local officials from regulating private property . . . [hovering] like a huge black cloud over the environmental management landscape in coming years. (Platt, 1992, p. 9)

Other factors cited by the experts as responsible for escalating property losses included the increasing value of the properties effected, dependence on "vulnerable lifelines and critical facilities," increasing street and highway milage, inflation, and the "lack of, or diminishing power (although this is locally variable) of public agencies charged with implementing . . . land use policies."

On the other hand, our respondents noted that hazard areas can be recognized and risks reasonably well assessed along all the country's coastlines and that floodplain delineation and mapping has also improved. Progress has also been made in the delineation of earthquake hazards, but local seismic hazard delineation is not yet sufficient to guide micro-zonation in most areas. Our ability to delineate and forecast landslides has also much improved.

Unfortunately, we continue to have a limited ability to define the flash-flood hazard to various locales, and increasing urban and local flooding problems have perhaps reduced the effectiveness of warnings geared to conventional water courses. Technological improvements in detection components generally have not been matched by improved human awareness and response.

According to our survey of experts, human lives are considered to be less at risk from all hazards, except flash floods, due to advances in forecasting and structural/non-structural mitigation. Unfortunately, as populations increase and "expand into increasingly unstable terrain in search of dwelling sites and recreation" it will become increasingly difficult to keep loss of life from climbing. Flash floods pose a particular problem because they are difficult to forecast and because their occurrence is being changed by urbanization and land development where newly impervious surfaces increase runoff volume and speed. Indeed, a large proportion of flash flood deaths occur in urban areas, chiefly in automobiles.

In an initial draft of this paper, we wrote that, "most of the respondents expect that the nation should expect to experience at least one major catastrophic event from their category in the coming decade—in addition to less 'spectacular' occurrences. Because a single severe event has the potential to disrupt the socioeconomic health of the nation, this expectation must be given serious consideration." This statement seems to be supported by recent circumstances surrounding Hurricane Andrew's impact on southern Florida and Hurricane Iniki's on Kauai in Hawaii. Radio news reports broadcast shortly after those events indicated that aid earmarked for rebuilding Los Angeles following the riots of June 1992 might be diverted to the communities devastated by these hurricanes. In additions, insurance rates are expected to rise nation-wide through 1995 on all types of property (including automobiles) as insurance companies attempt to replenish their capital (Steinmetz, 1993).

In coastal areas increasing density of ocean front construction generally increases the value of ocean front property but may also increase erosion rates. In earthquake-prone areas, failures of buildings, other structures, and lifelines are the principal cause of death, injury, and economic loss. Expansive soil problems add to the nation's economic losses by a current (conservative) estimate of between $11.5-12.0 billion dollars in annualized improvements damage. Development of urban areas with high landslide potential is especially problematic: losses in 1985 reached $1.5 billion in direct property losses alone. On the positive side, landslide losses associated with road building decreased during the 1980s because of the near completion of the interstate highway system.

Ideas From Estes Park

During July 8-11, 1992, approximately 65 hazards researchers and practitioners gathered in Estes Park, Colorado, to attend the Assessment of Research and Applications of Natural Hazards Workshop. The gathering was chaired by Dennis Mileti, director of the Hazards Assessment Laboratory at Colorado State University, and included participants from federal, state, local, university, and private organizations. White papers on a variety of natural hazards subjects summarized the participant's perceptions of the status of their particular areas of research, and noted general conclusions and research needs. The white papers addressed earthquakes, hurricanes (and their economic impacts), tsunamis, extreme winds, landslides, flash floods, and drought; lifelines in earthquakes; geomorphic hazards of the fluvial system; coastal construction; land use planning and development management; information systems and knowledge transfer; warnings and warning response; building practices; the ex-post evaluation of hazards intervention programs; insurance; awareness and education; wildfires and the urban-wildland interface; applications; public/mental health medical effects and issues; emergency response and relief; impacts of human activities on natural hazards; post-impact emergency measures; the natural/technological hazards interface; volunteers and recovery; risks to cultural property; and climate change. A summary paper distributed at the workshop described specific research needs for the future. From this paper, some general conclusions can be offered.

Hazards researchers need more, and more reliable, data. Research is needed at large scales, such as large populations or at national levels. Special populations (e.g., the physically challenged) need more in-depth study, as do the mechanisms of death, injury, and illness due to specific natural disasters. Cross-cultural research, and non-hazard-specific research is needed, as well as data on how people develop, and react to, their perceptions of hazards. A clear definition of what constitutes a "victim" is needed, since people not directly impacted by a disaster can yet be victimized by it. How response is effected by socioeconomic status, lifestyle choice, and/or the media must also be addressed.

Despite much discussion over the years, we still ^\ ((^^^U^^^Sr ways to assist the transfer of findings from the "research lab" to the people who use the information, and to find ways to more effectively implement what we already know (for instance, is the advice regarding this subject, and available in Gori [no date] and Kockelman [1989], being heeded?). A corollary to this problem is the need to better communicate scientific knowledge to the decision maker. We also need to find better ways to encourage participation in hazards research by those who have knowledge in unique areas—to incorporate all facets of the professional community into the research effort, such as architects, engineers, planners, and fire managers.

A particularly difficult problem involves identifying and somehow quantifying the local, regional, and aggregated costs and benefits of various mitigation strategies (perhaps demonstration projects would be beneficial in this). Post-audits can assist the assessment of direct and indirect loss, as well as contribute ideas for reducing future loss. A risk assessment framework is needed to identify the risks to people and property in any particular geographic area. We also need to find ways to utilize new technological advances such as remote sensing, geographic information systems, and doppler radar.

Part IV: Social and Environmental Trends that Will Affect Future Hazardousness

The history of hazards policy in the U.S. is one of reaction rather than anticipation, not only in response to hazards themselves, but to the social and

Erratum
Page 29, Paragraph 2
Sentence should read:

"Despite much discussion over the years, we still need better ways to assist the" environmental trends that increase hazard vulnerability. This section explores the trends that will affect hazardousness in the future, with the goal of improving the anticipatory, rather than reactive, element of hazards reduction.

What Does Hazards Theory Say About Trends?

Natural hazards research originated in the U.S. with White's (1942) investigation into the human occupancy of flood-prone areas, which revealed that the "technological fix" of activities such as dam building was actually increasing flood losses. With a general rejection of the use of quantitative methods to explain human spatial behavior as it relates to natural hazards, research in the late 1950s and early 1960s followed a behavioral approach based on a theory of rational decision making—a human ecology-bounded rationality model—which implied that irrational decisions by people with respect to hazards were partly due to imperfect perception of the hazard, incomplete knowledge, or inflexible decision making (Marston, 1983; Emel and Peet, 1989). Later research took a more radical approach, focusing on the locational constraints imposed by a society's cultural, economic, and political structure, pointing out that different people and nations experience different levels of vulnerability that are dependent on their relative levels of wealth (Susman et al., 1983; Tierney, 1989). In order to speculate about long-term trends in hazard vulnerability, the evolution of systems in both the physical and social realm must be considered—a study of the "co-evolution", as it were, of nature and society.

Calls have also been made to concentrate less on the emergency period following disaster and instead to give "full credit to the ongoing societal and man [sic]-environment relations that prefigure" disaster (Stallings, 1988, p. 576). This call is being heeded, if for no other reason, because of increasing costs of relief and recovery, hence mitigation is moving from structural (e.g., dam-building) to non-structural (e.g., land-use regulations, insurance) measures (Riebsame et al., 1986).

It is possible to discern two theories about hazard-society interaction. In one view, a self-correcting process operates in which society and environmental hazards are adjusted toward some acceptable equilibrium (Kates, 1971; Burton et al., 1978). This process is composed of numerous small or large "adjustments" which reduce impacts.

Alternatively, some researchers argue that the cumulative process of social development inevitably leads to greater vulnerability and growing potential for catastrophe; a view encapsulated in White's (1985) "perilously changing world" and Perrow's (1984) "normal accidents". Analysts subscribing to this second view find little evidence of an emerging equilibrium between social development and hazards. Rather, they envision an open-ended process leading to increased, rather than decreased, hazardousness. This interpretation reflects a fundamental belief about human development and the effectiveness of social response to environmental challenges, and renders moot the questions of whether risks are multiplied as society and technology evolve, or whether increasingly sophisticated societies are better able to mitigate hazards through increasingly sophisticated planning (e.g., drought contingency planning) and technologies (e.g., new weather radars).

Perhaps the two views on this issue simply reflect optimistic and pessimistic attitudes about the relationship between society, technology, and the environment. Susman et al. (1983) argue that hazardousness and "vulnerability [are] increasing due to human changes, and in the largest fraction of the world's inhabited area these changes are clearly bound up with 'development' or its failure" (p. 267). Burton and Kates (1986) clearly assume the mantle of optimism, as evidenced in the title of their essay: "The Great Climacteric: The Transition to a Just and Sustainable Human Environment," describing themselves as closer to the realm of opinion that is "possibilist in its attitude toward nature, optimistic in its view of technological advance and the sufficiency of resources" (p. 341). But, optimism and pessimism are not a firm foundation for analysis and prediction. If we are to judge progress in natural hazards reduction over the next decade we must have some objective sense of trends that may either exacerbate or lessen hazardousness.

Whither Hazardousness in the 1990s?

Though we cannot yet determine, unambiguously, whether nature-society relationships in the late-twentieth century are becoming more or less hazardous, we can identify broad social and environmental trends that may exacerbate or decrease hazard impacts in the future (Table 5). Among those that obviously increase risks are

Table 5. Social and Environmental Trends Affecting Hazardousness

SOCIAL TRENDS	
Lessening Effect	Aggravating Effect
Improved building technology Better detection/warning systems Improved health care systems	Increased hazard zone occupancy Aging population Aging Infrastructure Third World urban in-migration More hazardous facilities Resource exploitation in sensitive areas
ENVIRONMENTAL TRENDS	
Lessening Effect	Aggravating Effect
Warming climate in northern areas due to greenhouse effects Reduced use of some pesticides Clean-up of toxic sites	Sea-level rise Mid-latitude drying due to greenhouse effects Forest destruction Soil erosion Wetland loss Loss of genetic diversity

population growth, rapid coastal development and more intense re-development, industrialization and the spread of hazardous facilities, encroachment of agriculture into cold and dry marginal lands, urban sprawl, and extraction of resources from sensitive environments (e.g., Alaska's North Slope).

Increasing social vulnerabilities may also be intrinsic to trends such as rural-to-urban migration and the further development of mega-cities such as Los Angeles, as well as continued development of recognized hazard zones such as river deltas and seismic areas. Less obvious trends that could exacerbate future hazards include deteriorating infrastructure and the country's aging population profile; further resource exploitation in sensitive zones such as the Great Plains, the arctic, and continental shelves; and a decreasing genetic diversity in food crops.

Several environmental trends might also exacerbate future natural hazards. Rising sea levels will intensify coastal storm surges and increase erosion from successive storms. The greenhouse effect—climate warming due to human enrichment of atmospheric carbon dioxide and other trace gases—may in some areas increase drought severity and frequency. Deforestation and wetland loss may exacerbate flooding.

But some environmental trends may also reduce hazards; for example, climate warming might decrease the severity of winter storms and frosts. And no doubt some social developments will work to ameliorate hazards. Improved building design will protect lives and property, better health care will heighten people's tolerance of some hazards, and scientific and technological advances will provide better and earlier hazard detection and warning. However, the net effect of these environmental and social trends cannot be determined at present with the information and tools at hand.

Overall, there seems little doubt that average annual losses along coastlines will increase with development and shoreline erosion. Earthquake losses are also expected to be greater in the future than in the past. No significant reduction in soil expansion losses are foreseen over the next ten years (unless courts or statutes force builders and developers to integrate an understanding of the potential problems of expansive soil into their work). Landslide costs will undoubtedly increase and regional short-term climatic patterns or events (e.g., El Niño) will cause wide fluctuations in annual hazard figures. Increased urbanization in the sunbelt will also escalate future flash flood losses where many communities are highly vulnerable; the upcoming decade may even witness events comparable to the Rapid City and Big Thompson floods of 1972 and 1976.

Growing Catastrophe Potential?

Some hazards researchers and practitioners believe that the potential for truly catastrophic natural disasters is increasing in the U.S. as society populates and develops hazardous areas (White and Haas, 1975). In some respects this is a truism: if a major hurricane directly hits Miami or New Orleans or a significant earthquake strikes Los Angeles or Salt Lake City, the results could well be catastrophic, perhaps costing $50 billion in direct losses and causing up to 20,000 deaths. The expert opinions described earlier support the notion that fundamental development trends in the U.S. will inevitably lead to increased, and hence potentially catastrophic, loss.

Hazard losses are skewed to extreme events, and a corollary question to the issue raised earlier regarding losses as a proportion of gain, is whether the potential for truly catastrophic loss is increasing even while routine losses remain roughly proportional to at-risk investment. Simple logic, and the fact that little progress has been made in reducing hazard-zone occupance over the last two decades, suggests that the potential for catastrophe is indeed escalating, highlighted by a few particular potentialities: a major western or central U.S. earthquake; a severe, multi-year drought; or a poorly-forecast, "sneaky" hurricane that catches Miami, New Orleans, or perhaps part of the northeastern metropolises unprepared (meaning un-evacuated—evacuation times for large coastal cities run from 24 to 36 hours; see Ruch, 1981).

We may even be fueling this potential through certain hazards research and applications priorities. For example, a large proportion of earthquake research is devoted to the design of seismically-safe new buildings. Yet, most of the buildings affected by the next large earthquake, assuming it occurs within the next decade or so, will lack either new or retro-fit earthquake design. More work is needed on retro-fit, but it garners less attention than new design. Moreover, the single most effective approach to hazard reduction, land use planning with hazards in mind, has perhaps received less attention than any other adjustment. Despite some gain in floodplain regulation under the NFIP, even here we find little overall affect on the investment at risk (Mason and Mattson, 1990). Indeed, much of the flood loss in the U.S. is repeat loss. It may be, simply, that land use controls rub against American values, and that we will not be able to curb development of hazard zones. Nevertheless, this approach must receive closer scrutiny in the 1990s.

Part V: Recommendations for Evaluating Hazard Trends in the 1990s

The planning that led to the U.S. Decade for Natural Disaster Reduction seems to reveal that while the hazards community has a good intuitive notion of hazard reduction needs, empirical and analytical support for programmatic priorities is weak. Support for this stance was illustrated by the response to a call for a "social" basis for the "Meso-Scale Research Initiative," which seeks to improve weather forecasts in the U.S.

The initiative went through several planning iterations in federal and university institutions, but was weakened by a lack of clear social and economic rubrics that showed its utility. A workshop of social scientists was convened, and they called for a more integrated link between social and natural science analysis, noting that investments and developments in physical science and technology, without a foundation in social trends and needs, can lead to misplaced resources (Environmental and Societal Impacts Group, 1991). Unfortunately, the workshop participants also noted that the few standing federal efforts to assess the social implications of weather and climate extremes had been discontinued, and that little attention was given to such studies in the first place unless funding for physical science and technology seemed threatened.

This predicament exists in many areas of hazards-related research and development. Superficially, it does seem logical to spend money on the natural science and engineering aspects of earthquakes, floods, or severe weather, especially when it is difficult to identify the needed balance between these technological aspects and social analysis. However, solutions derived from natural science and engineering methods are not applied in a social vacuum. Because in many areas the balance between the technical and social sciences has yet to be identified, more attention needs to be given to social characteristics and trends that will affect hazardousness in the future.

As we proceed with the Decade for Natural Disaster Reduction, we need to further encourage what Mitchell (1989a) describes as a change in the interpretation of hazards—from simple acts of nature, to a focus on people as contributors and modifiers of hazards. Mitchell also notes that research has evolved from response to risks arising from physical systems, to factors that effect exposure to risk, and to differing potential for loss and recovery. Hazards are now seen as a combination of risk, exposure, vulnerability, and response, with the old remedy of modifying physical risk giving way to modification of exposure and vulnerability. The definition of hazards is also changing to encompass technological threats, global warming, climate change, and other environmental threats, while the conceptualization of hazards is being extended to include the contexts in which they are found. Contexts are important because they color interpretation and can make it difficult to grasp commonalities among different theoretical explanations. Two contexts in particular are extremely important. First, real world problems are not necessarily bounded. Different types of hazards overlap with one another, and hazards overlap within the full range of the social infrastructure. Second, there exists a dichotomy between unified global and fragmented local perspectives. We live on one earth peopled by many worlds differentiated by religion, class, ethnicity, language, political systems, and historical experience. Because hazards research cannot be addressed in isolation from other problems and processes, it will be necessary in the future to search for broader theoretical explanations of hazards and to increase the use of existing knowledge by hazard managers (Mitchell, 1989a).

It is this latter issue—the use of available knowledge by hazard managers—that we perceive to be the critical step in reducing the nation's vulnerability to damage from disasters. As White (1992) writes, there have been and will continue to be obstacles to putting research findings into practice. However, there are several reasons why a new effort should be undertaken to assess the status of hazards research and practice: 1) the volume of research findings is much larger; 2) the number of competent individuals and institutions pursuing such research has multiplied; and 3) social conditions have radically changed since the 1975 *Assessment*.

The authors of the new assessment are faced with many challenges. They will need to decide what specific hazards they wish to assess and then will need to conduct thorough literature reviews in order to identify (since 1975) other assessment efforts, data surveys, or retrospective syntheses of related research. From such reviews it may be possible to better describe the nation's vulnerability to hazards, and to describe major mitigation efforts that are attempting to reduce loss. This could include governmental, private, non-profit, and interagency cooperative programs, as well as pertinent technological advances.

Because of the enormous scope of this undertaking, it may be advisable for the second assessment authors to initially confine their research on topics such as those described in the section, "Ideas From Estes Park," to a regional scope, with the eventual goal of combining the research into a portrait of the nation's status. Selected case studies of efforts performed within the regions could provide "hands-on" information regarding current practices, successes, failures, constraints, and opportunities. And such efforts should be undertaken with full recognition of the contexts within which the original studies took place. As concluded by those who met in Estes Park, we agree that there is a critical need to transfer knowledge from researchers to the people who use it—to find ways to more effectively implement what we already know. This goal cannot be accomplished without the active participation of those who must implement our findings. Thus, analysis of the case studies should also include input from professionals such as architects, engineers, planners, and fire managers. These are the people who can tell us why they did or did not implement earlier recommendations, and without their participation it will be more difficult for future research results to substantially alter the vulnerability of the U.S. public.

Another question that will need to be addressed is how closely the second assessment should mirror the strategy for the U.S. Decade for National Disaster Reduction (USDNDR) as outlined by the Committee on Earth and Environmental Sciences Subcommittee on Natural Disaster Reduction (CEES/SNDR). For instance, the researchers who met at Estes Park purposefully chose a broad range of hazards upon which to focus second assessment research. Alternatively, the USDNDR has a much narrower focus: drought, earthquakes, floods, hurricanes and other severe windstorms, insects and diseases (pestilence) (which was not listed among the Estes Park research interests), landslides, tsunamis, volcanic eruptions, and wildfires (CEES/SNDR, 1992). The CEES/SNDR document splits the goals of the USDNDR into four parts: strategic priorities, integrating priorities, research elements, and application elements. The research elements are in turn separated into three categories: physical and biological nature, management systems, and human interactions. Being social scientists, we are particularly interested in the human interactions section which is described as including: behavior, health, and communications; institutional opportunities and constraints; and economics. Our earlier statement that it is difficult to obtain funding for research into these issues is borne out by the document's description of the agency budgets (in "focused" or "contributing" dollars[4]) for fiscal year 1990. As Table 6 illustrates, of the $205.6 million "focused" dollars, only $4.8 million (2.3%) is allocated for human interaction research, and of the $115.2 "contributing" dollars, only $600,000 (0.6%) is allocated for human research. The bulk of the funds are earmarked for the category "physical and biological nature," which includes research into climate, weather, hydrologic systems, solid earth processes, and ecosystem processes. Thus we see confirmation at the national level that the "predicament" we described earlier still exists—that it seems more acceptable to spend money on the natural science and engineering aspects of earthquakes, floods, or severe weather, than on the social implications of these hazards. Hopefully, the second assessment authors may be able to reiterate the need for a more balanced approach.

Since its inception, hazards research has had a strong practical and applied focus, brought about by the simple desire to reduce human loss and suffering. This applied focus does not, as some might claim, preclude the further development of theory. Theories, hypotheses, and facts coexist in a fluid and dynamic environment, and since 1975 the facts have definitely changed. The empirical evidence garnered from studies

Table 6. Comparison of Budgets Allocated for the Three Research Elements Outlined by the CEES/SNDR (in millions).*

	Physical/Biological Nature	Management Systems	Human Interactions	Total
Focused Dollars	154.0 (74.9%)	46.8 (22.8%)	4.8 (2.3%)	205.6
Contributing Dollars	97.4 (84.5%)	17.2 (14.9%)	0.6 (0.6%)	115.2

(* From CEES/SNDR, 1992, pp. 70, 72.)

4 'Focused dollars' are spent "on agency programs, activities, or new initiatives that address the explicit goals and objectives of the U.S. strategy" while 'contributing dollars' are "committed to agency activities or new initiatives that are justified on a basis other than specific natural hazards research and applications but that contribute substantially to the goals and objectives of the U.S. strategy" (CEES/SDNR, 1992, p. 68).

such as those we are supporting for the second assessment will be able to inform hazard theory, which, following adjustments to reflect current realities, may then be better poised to guide research into the 21st century.

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