REVIEW: NATURAL HAZARDS AND POLICY

Mitigation Emerges as Major Strategy for Reducing Losses Caused by Natural Disasters

Board on Natural Disasters*

The International Decade for Natural Disaster Reduction, a United Nations program for the 1990s, focused attention on the increasing losses caused by natural hazards and promoted actions to reduce their impacts. During this period in the United States, disaster managers and other officials increased emphasis on mitigation relative to response and recovery, especially in programs of the Federal Emergency Management Agency. Many other nations and international organizations undertook similar efforts. Beyond the Decade, efforts should focus on improving risk assessments; implementing mitigation strategies; improving technologies supporting warnings and the dissemination of, and response to, warnings; improving the basis for natural disaster insurance; and assisting developing nations.

Mounting losses in human casualties and property damage motivated the United Nations to declare the 1990s as the International Decade for Natural Disaster Reduction (IDNDR). Several disasters with large losses in the early 1990s underscored the need for this initiative. The natural hazards specified by the United Nations were earthquakes, windstorms, tsunamis, floods, landslides, volcanic eruptions, wildfires, grasshopper and locust infestations, and drought and desertification. To conduct the IDNDR, the United Nations established a secretariat in Geneva, Switzerland, a 25-member Scientific and Technical Committee (STC), and called on member states to form national committees, or designate focal points, to coordinate national-level activities. In the United States, the Subcommittee on Natural Disaster Reduction (*1*) coordinated federal agency programs under the National Science and Technology Council. In addition, the National Research Council, through the U.S. National Committee for the IDNDR and the Board on Natural Disasters (BOND) (*2*), provided an overview on U.S. activities and helped to link the public and private sectors. A World Conference on Natural Disaster Reduction held in Yokohama, Japan, during 1994 (*3*) reviewed Decade accomplishments and called for increased emphasis on implementation of scientific and technical knowledge for reducing disaster losses.

As the Decade enters it final stage, we review salient achievements and look ahead. It is clear that during the Decade there has been a significant shift in managing natural disasters, moving away from the traditional focus on response and recovery toward emphasis on mitigation, that is, preventive actions to reduce the effects of a natural hazard.

Natural Disaster Losses

Many nations experience fatalities and injuries, property damage, and economic and social disruption resulting from natural disasters. Hurricanes, tornadoes, floods, drought, earthquakes, and winter storms repeatedly ravage parts of the United States. Natural hazards were among the decade's defining events in the United States: the Northridge earthquake (1994), Hurricane Andrew (1992), fires in California (1993) and Florida (1998), flooding of the Mississippi River (1993) and the Red River in the north (1997) (Fig. 1), and widespread tornadoes in Oklahoma and Kansas (early May 1999) (Fig. 2). The direct losses of about $44 billion for the Northridge earthquake and $30 billion for Hurricane Andrew, which rank these events as the costliest in U.S. history, substantially impacted their regions and the insurance industry.

Not only have these recent U.S. natural disaster losses been substantial, but also the trend in annual losses has been markedly upward (*4*) (Fig. 3). Most of this increase cannot be attributed to increased occurrence of hazards. Although some types of events, for example heavy rains, have increased in frequency since the 1950s, others such as hurricane landfalls in the eastern United States have declined. Thus, it is difficult to attribute U.S. disaster loss increases in any significant measure to this factor. Instead, they can be attributed to several other factors. In the last several decades population in the United States has migrated toward the coasts, concentrating along the earthquake-prone Pacific coast and the hurricane-prone Atlantic and Gulf coasts, and the value of their possessions has increased substantially. Florida's population has increased fivefold since 1950, and now 80% of it lives within 35 km of the coast. Similarly, in California the population has increased from 10 million in 1950 to the current level of 33 million. In addition, population has concentrated in large cities, which serve as hubs for communications, transportation, commerce, and government and require complex infrastructures, some of which have aged to the point of unreliability. Many elements of these complex infrastructures are highly vulnerable to breakdowns that can be triggered by relatively minor events. Failure of a single span of the Bay Bridge disrupted traffic for several months in the San Francisco area after the Loma Prieta earthquake in 1989 (*5*). Less dramatically, failure to remove a ground connection shut down San Francisco's electrical power for most of a day in December 1998. In short, the United States has more to lose than ever before—some components of its infrastructure are highly vulnerable to damage and disruption, and

Fig. 1. Red River flowing over the Sorlie Bridge, Grand Forks, North Dakota, during the record flood in the spring of 1997. [Photo courtesy of the U.S. Geological Survey]

*The authors are members of the Board on Natural Disasters (BOND) of the National Research Council, 2101 Constitution Avenue, NW, Washington, DC 20418, USA. Members of BOND: Wilfred D. Iwan, *Chair,* California Institute of Technology, Pasadena; Lloyd S. Cluff, Pacific Gas and Electric, San Francisco, CA; James F. Kimpel, University of Oklahoma, Norman; Howard Kunreuther, Wharton School, University of Pennsylvania, Philadelphia; Stephanie H. Masaki-Schatz, Ranchos Palos Verdes, CA; Joanne M. Nigg, Disaster Research Center, University of Delaware, Newark; Richard S. Roth Sr., Northbrook, IL; Harvey Ryland, Institute for Business and Home Safety, Boston, MA; Ellis Stanley Sr., Los Angeles, CA; and Frank H. Thomas, Loudon, TN. National Research Council staff contributing to this article are Robert M. Hamilton, Patricia A. Jones, and Stephen D. Parker.

much of its population is located in areas at risk to natural disasters.

The earthquake that struck Kobe, Japan, in 1995 caused direct losses in excess of $100 billion, perhaps as much as $200 billion, and demonstrated the potential for disasters in the United States and other countries on a similar scale. Such a threat calls for action, but reducing potential losses for existing structures and systems by a substantial amount is costly, difficult, and perhaps impossible. Nevertheless, actions can be taken to avoid creating additional vulnerabilities and, in some cases, to reduce existing ones. This reality is helping to shape a new vision of the future among disaster managers and political leaders.

Emergence of Mitigation

The two basic approaches for reducing the impacts of natural disasters are mitigation and response. Mitigation includes all those actions that are taken before, during, and after the occurrence of a natural event that minimize its impacts, and response includes those actions that are taken during and immediately after the event to reduce suffering and hasten recovery of the affected population and region. Mitigation includes avoiding hazards, for example, by building out of a flood plain or away from seismically active faults, or by providing warnings to enable evacuation in the periods immediately preceding hazards such as floods, hurricanes, and tornadoes. It also includes reducing vulnerability through floodproofing of buildings or strengthening of structures to withstand the loads imposed by seismic shaking or wind. Response includes both the short-term emergency actions taken by police, fire, and other agencies as well as the longer-term actions taken to meet needs for food, shelter, rebuilding, and restoration of the affected community. Both elements are important in dealing with natural hazards, but in past practice just one—response—has predominated.

Mitigation planning should be incorporated in or carefully coordinated with land-use planning for community development. In this way, communities can find opportunities for accommodating development demands in areas less vulnerable to natural hazards. Comprehensive mitigation planning includes (i) determining the location and nature of the potential hazards, (ii) characterizing the population and structures (present and future) that are vulnerable to specific hazards, (iii) establishing standards for acceptable levels of risk, and (iv) adopting mitigation strategies based on an analysis of realistic costs and benefits.

In practice, mitigation may be difficult to implement, both politically and economically. Making progress in this endeavor requires incentives that are both appealing and feasible, long-term commitments by its champions, and an investment of financial resources by its backers, usually in the face of a highly uncertain threat. It is much easier to pass along the problem to the next generation. It is therefore encouraging that mitigation is receiving increased emphasis, a situation that has come about through a combination of circumstances.

In recent years, as natural disaster losses have mounted, U.S. disaster managers and other decision makers have recognized that singular reliance on the strategies of response and recovery portend continuously escalating costs along with the attendant disruptions associated with natural disasters. Although response and recovery are essential for humanitarian, economic, and political purposes, they must be accompanied by increasing attention to reducing losses through effective mitigation programs (*6*).

To this end, numerous governmental and nongovernmental organizations have shifted priorities. Most significantly, the Federal Emergency Management Agency (FEMA) has established a Mitigation Directorate, on a par with its Response and Recovery Directorate, and developed a National Mitigation Strategy (*7*). Moreover, FEMA has moved ahead aggressively with Project Impact to implement mitigation practices in 118 demonstration cities and communities, a federal investment of about $25 million a year. These efforts by FEMA build on substantial work by other federal agencies, such as the National Science Foundation, U.S. Geological Survey, and National Oceanic and Atmospheric Administration, which have funded research on hazard mitigation for more than 20 years to improve understanding of the nature of natural hazards and their effects. Also, the U.S. Army Corps of Engineers and Natural Resource Conservation Service conduct substantial mitigation efforts, especially for flood prevention.

Many private-sector companies have invested substantial resources to strengthen structures to withstand the effects of hazards. For example, the Institute for Business and Home Safety, an insurance industry–supported nonprofit organization, has promoted development of building materials that are more resistant to hazard-induced damage (hail-resistant roofing materials) and adoption and improvement of building codes. Many businesses have invested substantial funds to avoid damage and business interruptions, with notable success.

International Progress

Many organizations in the United Nations expanded or refocused activities in support of the Decade, although financial contributions specifically for the IDNDR (that is, in excess of regular budgets) amounted to only a few million dollars a year, with the largest contributions coming from Japan and several European countries. The United States contributed relatively little in funds, although the knowledge and expertise of U.S. scientists and engineers provided an important resource. Examples of important U.N. organizational activities include improved warning systems by the World Meteorological Organization, structural strengthening of hospitals by the World Health Organization/Pan-American Health Organization, and educational materials produced by the United Nations Educational, Scientific, and Cultural Organization. During recent years, the United Nations Development Program was assigned responsibility for promoting and coordinating mitigation in developing countries, and the World Bank established a Disaster Management Facility to assure that natural hazards are considered in development decisions. The Office of the Coordinator for Humanitarian Affairs and its predecessor organizations coordinated the efforts through the secretariat. Several international, nongovernment organizations also participated, notably the International Red Cross and the Red Crescent Society.

Activities by international professional societies also contributed significantly. For example, the International Association of Seismology and Physics of the Earth's Interior sponsored a global assessment of seismic hazards, and the International Association of Volcanology and Chemistry of the Earth's Interior organized increased monitoring of 17

Fig. 2. One of the many tornadoes that formed in central Oklahoma on 3 May 1999 during the largest tornado outbreak ever recorded in Oklahoma. [Photo courtesy of the National Oceanic and Atmospheric Administration]

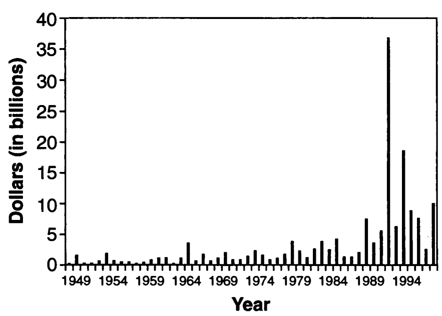

Fig. 3. Insured catastrophe losses in the United States, 1949 to 1998 (in 1998 dollars). [Source: Insurance Services Office, Incorporated, PCS division]

volcanoes, including Mount Rainier (Fig. 4) and Mauna Loa in the United States. The International Council for Science (ICSU; formerly the International Council of Scientific Unions) funded and sponsored about 10 projects, including ones dealing with landslides, drought, and tropical cyclones. The International Lithosphere Program examined the vulnerability of megacities.

The IDNDR plan called for special efforts at the national level, especially in developing countries, through national committees or focal points. Altogether, about 130 of these were formed, but less than half performed effectively. Some of them were quite successful in promoting new efforts; for example, the Australian National Committee and the federal agency Emergency Management Australia moved ahead in a broad range of mitigation activities in planning, hazards and risk assessment, and assistance to other countries in the southwestern Pacific region.

Goals for Beyond the IDNDR

The targets that were adopted for the IDNDR were for each nation to assess risks from natural hazards, complete mitigation plans, and establish warning and preparedness systems. In the United States, significant progress was made in this regard, but much remains to be accomplished. For example, the regions that are prone to the various hazards have been delineated at a national scale (*8*), but hazard assessments that are useful for local risk assessments have been completed for only a few regions. With regard to mitigation planning, FEMA's National Mitigation Strategy lays out a conceptual approach, but implementing the concepts is proving to be a slow process. As evidenced recently in Oklahoma and Kansas, warnings for weather phenomena have been improved with greater use of satellites and the Doppler radar system by the National Weather Service, but much additional research is needed to fully utilize the new information. For the decades beyond the IDNDR, efforts to reduce losses from natural disasters should move forward in all aspects of mitigation (*6*) with a focus in the following high-priority areas.

Improve risk assessments. Risk assessments are derived by first assessing the likelihood that a particular type of natural hazard will strike an area, including its frequency of occurrence and severity, and combining this information with both an inventory of structures that would be exposed to the hazard and with fragility data (estimates of the degree of damage that various classes of structures, for example, unreinforced masonry buildings in earthquake-prone areas, will suffer at specified levels of stress or exposure). Risk assessments are needed to increase public awareness of the threat posed by natural hazards and to guide allocation of resources [pp. 7–19 in (*3*); (*5*)].

Substantial progress has been made in recent years in modeling risk. There is broad interest in this tool not only as a means of describing disasters and estimating their costs, but also as a way to evaluate different disaster mitigation strategies. FEMA, in cooperation with the National Institute of Building Sciences, has developed Geographic Information System (GIS)–based earthquake loss estimation methodology called HAZUS (Hazards United States) for this purpose. This tool is currently being used to estimate earthquake losses nationally and in large metropolitan areas like San Francisco, Portland, Boston, and New York City. Efforts are underway to extend the GIS loss-modeling capability to flood and wind hazards. Risk-modeling techniques are increasingly being used to guide decisions by private as well as public entities, for example, to estimate probable maximum loss and average annual loss for the insurance sector. The confidence that can be placed in decisions made from risk modeling is strongly dependent on the level of uncertainty that is present in the models. Accurate hazard assessments are an essential starting point and need to be combined with comprehensive building inventories. The fragility data are often a particularly weak element in these models, which could be improved by more comprehensive field investigations after the disaster, data compilations, improvements in response analyses, and full-scale testing.

Implement mitigation strategies. Communities can often achieve significant reductions in losses from natural disasters by adopting land-use plans that avoid the hazards [pp. 21–39 in (*3*)] while at the same time achieving environmental and other goals. To cite one example, some cities in flood-prone areas that undertook to manage the hazard reduced flood-plain development to less than 25% of what would have occurred without the local planning programs, yielding $11 million in reduced property damage per year, with annual administrative and private costs of only $1.3 million (*9*). Few local governments, however, are willing to adopt land-use measures to protect against natural hazards unless they receive strong mandates from higher level governments (*10*). Land-use approaches require accurate identification of areas affected by hazards, but hazard-zone mapping may be too expensive for some municipalities. An additional complication is that hazards often span jurisdictional boundaries, which necessitates cooperation. For hazards land-use planning to be implemented, the public must find the hazards threat to be credible.

Building codes are also effective for reducing disaster losses [pp. 21–39 in (*3*); (*5*)]. A building code sets standards that guide the construction of new buildings and, in some cases, the rehabilitation of existing structures. Currently, building codes set minimum construction standards for life safety. However, maintaining the functionality of structures is also important and may be critical for certain classes of structures, for example those that are essential for public safety. Through Executive Orders (*11*) the federal government established seismic safety standards for federally funded new construction, and addressed seismic safety for existing owned and leased buildings. Some states have codes that are set at the state level but enforced at the local level, whereas other states let local governments set and enforce their own standards; however, more than half of the 30,000 communities in the United States have not adopted a building code at all. Of course, building codes are not effective unless they are enforced, which requires an ongoing inspection program, and many communities lack a sufficient number of inspectors. More than 25% of the damage from Hurricane Andrew could have been prevented if the existing building codes had been enforced (*12*). A "seal of approval" for structures that meet building codes has been proposed as a way to encourage improved building practices and to inform prospective buyers about structural safety (*13*).

Many structures that house low-income families are relatively unsafe with respect to natural hazards, either because of poor structural quality or risk-prone locations. Such families often cannot afford the costs of re-

Fig. 4. Mount Rainier at 4393 m, the highest peak in the Cascade Range, is a dormant volcano whose load of glacier ice exceeds that of any other mountain in the conterminous United States. This tremendous mass of rock and ice, in combination with great topographic relief, poses a variety of geologic hazards, both during inevitable future eruptions and during the intervening periods of repose. It is considered the most dangerous volcano in the Cascade Range because of the large population surrounding it. [Photo courtesy of the U.S. Geological Survey]

pair, reconstruction, or relocation. Equity considerations argue for providing this group with low-interest loans and grants. Because low-income victims are likely to receive federal assistance to cover uninsured losses after a disaster, subsidizing these mitigation measures can also be justified on cost-effectiveness grounds.

A community could also encourage its residents to engage in mitigation measures by providing them with tax or other financial incentives. For example, homeowners could get a tax rebate by undertaking a mitigation measure, thereby lowering the costs for disaster relief. Alternatively, property taxes could be lowered for the same reason. Unfortunately, communities often create monetary disincentives to invest in mitigation. A property owner who improves a home to make it safer is likely to have the property reassessed at a higher value and hence have to pay higher taxes. California has been cognizant of this problem and voters passed Proposition 127 in 1990 that exempts seismic rehabilitation improvements to buildings from being reassessed to increase property taxes. The city of Berkeley has taken an additional step to encourage home buyers to retrofit their newly purchased homes by instituting a transfer-tax rebate. The city taxes property transfer transactions at a rate of 1.5%, and up to one-third of this amount can be applied to seismic upgrades during the sale of property. Qualifying upgrades include repairing or replacing foundations, bracing basement walls, installing shear walls, anchoring water heaters, and securing chimneys. Since 1993, about 6300 houses have been improved, representing about $4.4 million in foregone revenues to the city (*14*).

In major urban centers ("megacities"), the vulnerability of infrastructure, telecommunications, and lifeline corridors makes it important to have backup or redundant systems to provide needed services should a disaster damage or destroy critical facilities. To illustrate this point, consider the crucial role of electricity in maintaining social and economic systems. Disaster damage to an electricity network may create havoc to a wide area as a result of indirect losses such as disruption of production in businesses, impaired hospitals and health facilities, and transportation problems due to nonfunctioning traffic signals, street lights, and safety alarms. The major mechanisms that society has developed to cope with electrical power failures are emergency or back-up generators and structural reinforcement of network facilities (*15*).

The economic, social, and political factors that influence the adoption of mitigation strategies are extremely complex (*16*). These include budget considerations, cultural norms, enforcement issues, and the tendency to maintain the status quo. In examining the range of mitigation measures to develop a strategy, one needs to target their adoption to specific situations. It is necessary to recognize that the opportunities for using certain measures will change as events unfold. For example, immediately after Hurricane Andrew in 1992 there was renewed interest in enforcing building codes, whereas before the event or even a few years after it occurred, the concern with mitigation was not a high priority on communities' agendas.

Improve technologies that support warnings and the dissemination of, and response to, warnings. Warnings are essential to prepare for a hazardous situation, such as an oncoming tornado, hurricane, or flood, and to move people out of harm's way, if necessary [pp. 41–61 in (*3*)]. To be most effective, warnings must be coupled with a forecasting system that provides prewarning data and with predetermined loss-reduction action plans. Warnings must specify the time, location, and severity of expected events with appropriate uncertainty bounds in a manner that allows actions to be taken for the survival of people and the protection of property and institutions. Some warnings are provided before a disaster ever develops in the form of maps that delineate hazard zones, signs posted in certain areas, or regulations that require real estate agents to inform potential property owners as to the nature of the hazard in their area. Other warnings, such as media announcements to evacuate hazardous areas, try to reduce losses just before the onset of an event.

Accurate and relevant information can be used to substantially reduce potential losses in many threatening situations (*17*), for example, airplanes can be directed around a volcanic ash cloud or property can be removed from an area about to be flooded. To be most effective, the information must be timely and in a form that is understandable by decision-makers. Recent advances in technology, such as high-speed computing and communications systems, combined with more comprehensive information resources and advanced GIS make a useful disaster information network feasible. It is now possible to rapidly integrate real-time data with archival data to produce information for critical decision making. For example, the dispersal pattern of fumes from a chemical spill can be predicted by using current weather data to identify threatened populations and evacuation routes. The foundation for such a network already exists, and moving ahead is largely a matter of coordination to set standards and protocols (*5*).

Improve the basis for natural disaster insurance. Insurance is a widely used financial instrument for protection against catastrophic loss [pp. 37–38 in (*3*)]. Insurance and financial institutions are increasingly active in formulating disaster policy and in promoting risk-reduction measures. By providing incentives for reducing vulnerability and by spreading risk, the efforts of the financial sector can reduce losses and moderate their economic impact.

Insurance should reward individuals who invest in hazard-reduction measures both before and after a disaster. Insured individuals should receive lower premiums for adopting mitigation measures before a disaster because the potential losses to the insurer are thus reduced. If they suffer losses to their structure, they will receive claim payments for the insured portion of their damage. Insurers also have the option of refusing to provide coverage unless the prospective policyholder undertakes certain protective measures to lower the potential losses from the risk in question.

One way to encourage communities to develop and enforce building codes and land-use management measures is to provide insurance premium reductions to all policyholders in the area based on the stringency of land-use regulations, building code standards, and inspection. The more effective a community program is in reducing future disaster losses, the greater the insurance premium reduction. Such a community rating system was created by the Federal Insurance Administration in 1990 as a way to recognize and encourage community flood plain management activities that exceed the minimum National Flood Insurance Program standards (*18*). This model could be applied to other hazards as well.

Assist disaster-prone developing nations. Countries that are highly vulnerable to natural hazards should implement modern approaches to disaster management [pp. 63–70 in (*3*)]. Earthquakes and volcanic eruptions threaten most countries around the Pacific Rim and throughout the Mediterranean, and the earthquake zone continues into the Himalayan region. Tropical cyclones cause extensive damage in the regions of the Pacific, Atlantic, and Indian oceans. As an illustration of the magnitude of these losses, according to its IDNDR National Committee, from 1989 through 1996 China experienced losses averaging 3.9% of its gross national product as a result of natural disasters. More recently, Hurricane Mitch rendered even greater relative devastation to Nicaragua and Honduras. Small island developing states repeatedly suffer losses on a similar scale. Many developing countries in the hazard-prone regions have limited resources for mitigating and recovering from the impacts of natural disasters and need scientific and technical assistance.

Scientific and technical assistance to developing countries, to the extent that it is available, is usually provided as equipment or training. All too often it is not long before the equipment sits idle and the trained personnel move on to other jobs. Another approach to assistance that has been successful in numerous cases, and that offers better prospects for building lasting capabilities in developing countries, is to establish partnerships between like-minded organizations in developing and industrialized countries [pp. 63–70 in (*3*)]. For example, a long-term cooperative endeavor between the U.S. Geological Survey's volcano hazards program and the Philippine Institute of Volcanology and Seismology developed collaborative relationships and expertise that were marshaled to predict the eruption of Mount Pinatubo, leading to evacuation of tens of thousands of people from around the volcano and departure of U.S. aircraft and personnel from Clark Air Base (*19*). Partnerships between academic institutions, government laboratories, and private organizations could greatly increase the capabilities of developing countries to cope with natural hazards, while at the same time extending American goodwill and providing American experts opportunities to pursue important studies in foreign areas.

It is essential that capabilities for disaster management be strengthened in developing countries, not only so the necessary expertise is available to implement programs, but also so knowledgeable people participate in policy discussions that lead to formulation of those programs. Unless someone is able to articulate in high-level discussions the opportunities for reducing disaster losses that modern disaster management methods offer, there is little chance that the issues will be appropriately framed. It must also be recognized that the inhabitants of hazardous areas in many developing countries are poor, and that their settlements often are illegal or self built with materials at hand. Building codes and warning systems are largely irrelevant, and thus special efforts must be made to reduce their vulnerability.

The United States provides developing countries with little assistance for natural disaster mitigation. To illustrate this point, consider the Office of Foreign Disaster Assistance (OFDA), an office within the U.S. Agency for International Development that is responsible for providing nonfood, humanitarian assistance in response to international crises and disasters. Within OFDA, the Prevention, Mitigation, Preparedness, and Planning Division (PMPPD) oversees projects designed to prevent or reduce the impact of disasters on people and economic infrastructure of foreign countries, whereas the Disaster Response Division deals with response. OFDA spent $155.4 million in fiscal year 1997, and 11% of this went to PMPPD. Although the OFDA projects are generally effective, and other federal agencies also conduct some related program activities, the relatively small amount of OFDA assistance reflects the rather limited international involvement of the United States in the IDNDR. Moreover, at the outset of the Decade, the U.S. representation at the United Nations played a passive role at best, and during the course of the Decade the United States has provided only minimal support for projects. International leadership, assistance, and cooperation in reducing natural disaster losses worldwide, however, could provide important benefits to the United States and support our foreign policy goals. More disaster-resistant communities abroad create American jobs by increasing exports and services. Disaster reduction promotes political stability. Cooperation advances the state of science and technology by providing access to data, information, and creative minds. In addition, cooperation facilitates the deployment of global observing systems for environmental monitoring.

Finally, in this era of globalization, the interests of all countries extend worldwide. As noted in the Subcommittee on Natural Disaster Reduction Strategic Plan (*20*), "because the U.S. has a global reach, it has a global vulnerability as well." For example, the Mount Pinatubo eruption caused direct losses to the United States of more than $1 billion and triggered a change in U.S. strategic presence in the western Pacific with the loss of air and naval bases. A proactive international program by the United States to reduce natural disaster losses is clearly justified for humanitarian purposes and to further foreign policy interests.

Several organizations in the U.N. system plan to continue IDNDR-related activities beyond the Decade, including the Office of the Coordinator for Humanitarian Affairs, the United Nations Educational, Scientific, and Cultural Organization, the World Meteorological Organization, the World Health Organization, and the United Nations Development Program. Several international programs also include natural disaster mitigation elements, such as the United Nations Commission for Sustainable Development, the Convention on Desertification, the Barbados Plan of Action for Sustainable Development of Small Island States, and the Framework Convention on Climate Change. Thus, there will continue to be numerous international venues for furthering the goals of natural disaster reduction.

References and Notes

1. *Reducing the Impacts of Natural Hazards: A Strategy for a Nation* (Office of Science and Technology Policy, Washington, DC, 1992).
2. National Research Council, *A Safer Future: Reducing the Impacts of Natural Disasters* (National Academy Press, Washington, DC, 1991); *Confronting Natural Disasters: An International Decade for Natural Hazard Reduction* (National Academy Press, Washington, DC, 1987).
3. ——, *Facing the Challenge: The U.S. National Report to the IDNDR World Conference on Natural Disaster Reduction* (National Academy Press, Washington, DC, 1994).
4. H. Kunreuther and R. Roth Sr., Eds., *Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States* (Joseph Henry Press, Washington, DC, 1998).
5. National Research Council, *Practical Lessons from the Loma Prieta Earthquake* (National Academy Press, Washington, DC, 1994).
6. ——, *Letter Report from the Board on Natural Disasters to Members of Congress Concerning the (Proposed) National Mitigation Strategy* (National Academy Press, Washington, DC, 1997).
7. *National Mitigation Strategy: Partnerships for Building Safer Communities* (FEMA, Washington, DC, 1995).
8. *Multi-Hazard Identification and Risk Assessment* (FEMA, Washington, DC, 1997).
9. R. Burby *et al.*, *Cities Under Water: A Comparative Evaluation of Ten Cities' Efforts to Manage Floodplain Land Use* (Institute of Behavioral Science, University of Colorado, Boulder, 1988).
10. R. Burby, *Cooperating with Nature: Confronting Natural Hazards with Land-Use Planning for Sustainable Communities* (Joseph Henry Press, Washington, DC, 1998).
11. *Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction*, Executive Order 12699, 55 Fed. Reg. 835 (9 Jan. 1990); *Seismic Safety of Existing Federally Owned or Leased Buildings*, Executive Order 12941, 59 Fed. Reg. 62,545 (5 Dec. 1994).
12. *Coastal Exposure and Community Protection: Hurricane Andrew's Legacy* [Insurance Research Council and Insurance Institute for Property Loss Reduction, Wheaton, IL (IRC), and Boston (IIPLR), 1995].
13. H. Kunreuther, in *Paying the Price: The Status and Role of Insurance Against Natural Disasters in the United States*, H. Kunreuther and R. Roth Sr., Eds. (Joseph Henry Press, Washington, DC, 1998), pp. 209–228.
14. *Incentives and Impediments to Improving the Seismic Performance of Buildings* (Earthquake Engineering Research Institute, Oakland, CA, 1998).
15. S. Chang, A. Rose, M. Shinozuka, *Infrastructure Life Cycle Cost Analysis: Direct and Indirect User Costs of Natural Hazards*. Proceedings of the U.S.–Japan Joint Seminar on Civil Infrastructure Systems, Honolulu, HI, 28 to 30 August 1997 (Multidisciplinary Center for Earthquake Engineering Research, Buffalo, NY, 1998). Technical Report MCEER-98-0017.
16. D. Mileti, *Disasters by Design: A Reassessment of Natural Hazards in the United States* (Joseph Henry Press, Washington, DC, 1999).
17. National Research Council, *Reducing Disaster Losses Through Better Information* (National Academy Press, Washington, DC, 1999).
18. E. Pasterick, in (*13*), pp. 125–154.
19. C. G. Newhall and R. S. Punongbayan, Eds., *Fire and Mud: Eruptions and Lahars of Mount Pinatubo, Philippines* (Philippine Institute of Volcanology and Seismology, Quezon City, and University of Washington Press, Seattle and London, 1996); in *Monitoring and Mitigation of Volcano Hazards*, R. Scarpa and R. I. Tilling, Eds. (Springer-Verlag, Berlin, 1996), pp. 807–838.
20. *Natural Disaster Reduction, A Plan for the Nation* (Office of Science and Technology Policy, Washington, DC, 1996).

21. The material presented here is based on work supported by the NSF, Federal Emergency Management Agency, and U.S. Geological Survey.