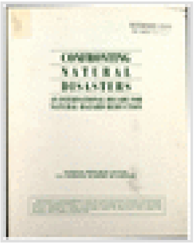

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CONFRONTING NATURAL DISASTERS:

AN INTERNATIONAL DECADE FOR NATURAL HAZARD REDUCTION

Advisory Committee on the
International Decade for Natural Hazard Reduction
Commission on Engineering and Technical Systems
National Research Council (U.S.).
U.S. National Academy of Sciences

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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FOREWORD

The images of death and destruction from natural disasters are constantly thrust before us: a typhoon in South Korea, landslides in Europe, tornadoes in the United States, an earthquake in Mexico, poisonous gas releases in Cameroon. This report counters with its own image of a less hazardous world, attained by sharing knowledge we already have about reducing the impacts of natural hazards, and by cooperating in research to extend this knowledge.

The time has come to view natural hazards as a world problem, but one that scientific and technological advances now provide a unique opportunity to address. The establishment of an International Decade for Natural Hazard Reduction, beginning in 1990, would be a potent first step in reducing the impacts of natural hazards through coordinated research, data gathering, and information sharing.

The thrust of this report is that much that is already known is not universally applied and that there is vast opportunity to advance our knowledge of hazard reduction if we pool resources. If we are to achieve a less hazardous world, we must approach the problems of research and application on an international basis. Anything less is to accept the frightful toll that natural hazards now inflict.

I hope that you will read this report with a view toward action and that you will share my enthusiasm for the International Decade for National Hazard Reduction. A safer world awaits our resolve to act together.

Frank Press, President

National Academy of Sciences

PREFACE

This report outlines the concept of an International Decade for Natural Hazard Reduction (IDNHR): the need for such an effort, the benefits it might confer, the kinds of projects it might include, and how it might be organized. The report is intended not only for those now in the hazard reduction field, but also for the broader audience of policy makers and the interested public who will provide the motive force behind any successful attempt to reduce hazard-related losses.

There is widespread interest in establishing an IDNHR. The scientific and technological community believes that the time is right for a coordinated international program on hazard reduction and, conversely, that if nothing is done, natural disasters will become increasingly severe. There is a growing confidence that important advances in coping with natural hazards are within reach of every nation if a global effort is mounted. It is too optimistic to expect that natural disasters can be completely eliminated during such an effort, but it is reasonable to expect that a strong program can markedly reduce injuries, deaths, and property damage due to natural hazards.

The concept of a cooperative international program to reduce natural hazards was first presented by Dr. Frank Press, president of the U.S. National Academy of Sciences, in a speech at the Eighth World Conference on Earthquake Engineering in 1984. In his keynote address to the International Association for Earthquake Engineering (IAEE), he proposed an International Decade for Natural Hazard Reduction, beginning in 1990.

After the conference, as copies of the speech circulated, international interest began to build, not only with respect to reducing the toll of earthquakes, but also with respect to other natural hazards.

Interest in establishing an IDNHR continued to grow and led to the appointment of a National Research Council Advisory Committee on the International Decade for Natural Hazard Reduction, whose charge was to evaluate the potential for such an effort and how best it might be realized. The committee was composed of natural hazard experts from many disciplines and was drawn from academia, the private sector, and government agencies.

The committee benefited from the input received from Canada and Mexico, our neighbors to the north and south, and from Japan, our partner in many recent cooperative research projects. The present report is the outcome of the deliberations of the committee, and is intended to introduce the concept of an IDNHR to a broad audience. It is not the report's purpose to synthesize or critique the extensive literature on hazard mitigation, but rather to point to opportunities for reducing global risk from natural hazards through the application of science and technology. The principal sources used by the committee in its deliberations appear in the Appendix. In addition, the Appendix contains a list of suggested readings of a more general nature for readers wishing to pursue the subject.

It soon became clear that launching an endeavor as complex as the IDNHR takes time and careful prior planning. As the IDNHR will address a number of natural hazards, contributors from many disciplines will be involved, and participation from a number of countries can be expected.

Further, in each country many government and professional agencies will need to begin coordinating their activities so that national and international programs can be organized.

Nonetheless, it will require prompt action to initiate the IDNHR in 1990. The committee believes that concerted action now by the world community can yield results quickly and set the tone for major reduction in the impacts of natural hazards in the future.

The committee has been greatly aided by many people and organizations. On behalf of the committee, I express gratitude for this help. For myself, I wish to thank all the committee members, the liaison members, and the National Research Council staff members who have inspired and facilitated the task at hand.

George W. Housner, Chairman
Advisory Committee on the
International Decade for Natural Hazard Reduction

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AN INTERNATIONAL DECADE FOR NATURAL HAZARD REDUCTION: A SUMMARY

THE NEED FOR AN IDNHR

Throughout history, natural disasters have exacted a heavy toll of death and human suffering. Natural hazards such as earthquakes, landslides, tsunamis (tidal waves), hurricanes, tornadoes, floods, volcanic eruptions, and wildfires have claimed more than 2.8 million lives worldwide in the past 20 years, adversely affecting 820 million people. Since 1949, at least 17 individual disasters have killed more than 10,000 people each; on two occasions--in Bangladesh and China--single disasters took more than a quarter-million lives.

Accompanying the loss of life has been devastating economic loss and the hardships it entails for survivors. A single hazardous event can destroy crops, buildings, highways, ports, and dams. It can severely disrupt community lifelines--the systems that provide food distribution, water supply, waste disposal, and communication locally and with the rest of the world. In the last two decades, property damage estimated at $25-100 billion resulted from natural disasters; total losses are much higher, reflecting shattered economies and disrupted social structures in the wake of a disaster. For example, tropical cyclones have caused worldwide losses of an estimated $6-7 billion annually. The comparable loss for landslides exceeds $5 billion. These figures merely hint at the human impacts of a natural catastrophe. Mudflows from the eruption of Colombia's Nevado del Ruiz volcano in 1985, for example, killed 22,000 people and left 10,000 more homeless. More than 600,000 people lost their homes in Dominica and the Dominican Republic because of Hurricane David in 1979. The Managua earthquake in 1972 left more than 300,000 homeless in Nicaragua, with damages equal to a year's GNP for that country.

Nearly all countries risk devastation by natural hazards. Truly, such hazards recognize no geopolitical boundaries. Yet losses from these events rise each year, despite progress in understanding natural hazards and how to mitigate their effects. Though economic losses are highest—in monetary value—in industrialized nations, the greatest burden from natural catastrophes falls on developing nations, where high death tolls and greater relative economic loss deal a double blow.

The magnitude of the problem worldwide might seem to defy solution. Yet hazard reduction successes clearly show that heavy losses at the hands of nature are not inevitable. It may not be possible to prevent the occurrence of natural hazards, but the disasters they generate can often be avoided. In general, hazard reduction refers to the process of lessening the impacts of a potential event on the social and built environments. In essence, this means reducing deaths, injuries, and property damage, and minimizing the destruction of a community's social and economic fabric.

Experience demonstrates that we have enough knowledge already, if properly applied, to reduce both human and property losses substantially. In fact, progress in scientific and technical understanding of natural hazards, as well as in techniques to mitigate their effects, has lead to the proposal for an International Decade for Natural Hazard Reduction (IDNHR). Such a concerted effort to develop, disseminate, and apply this knowledge could yield both immediate and long-term benefits worldwide.

The concept of a global program to reduce natural hazards, involving collaborative efforts among culturally and economically diverse nations, has received enthusiastic support from the scientific and technological community at large.

International organizations including the International Council of Scientific Unions (ICSU), the International Union of Geodesy and Geophysics (IUGG), the International Union of Geological Sciences (IUGS), the International Association of Engineering Geology (IAEG), the Inter-Union Commission on the Lithosphere (ICL), the International Association for Earthquake Engineering (IAEE), and the International Association for Wind Engineering (IAWE) have expressed support for the Decade. At least 17 national professional groups, including the Science Council of Japan, the Royal Society of Canada, the Asociacion de Ingenieros Estructurales (Argentina), the Earthquake Engineering Research Institute (United States), the Mexican Academy of Engineering, and the Engineering Institute of Thailand have also responded with strong interest and encouragement.

In view of this growing support for the IDNHR, the time is ripe to bring the matter to the attention of governments and harness the energies of scientists, engineers, practitioners, and others who are willing to devote their talents to creating a more hazard-resilient world.

The present report suggests a broad framework for the conduct of the IDNHR. It should not be seen as a detailed planning document: such a blueprint must be the product of future discussions among prospective participants. Thus, the report suggests many actions, but proscribes none. It is a call to action to a diverse, global audience and seeks a unity of vision without prejudging possible IDNHR activities.

HAZARD REDUCTION

It is generally recognized that the impacts of natural hazards are increasing and will continue to do so unless the world community takes concerted action. The reasons are clear: population growth and concentration in urban areas; increasing capital investment coupled with new, sometimes vulnerable technologies; the large numbers of unsafe buildings, vulnerable critical facilities, and fragile lifelines; and the increasing interdependence of people in local, national, and international communities. All these factors increase the world's vulnerability to natural hazards.

The scientific and technical applications useful in mitigating the effects of natural hazards include: building structures to withstand the actions of the hazards, preventing or changing the characteristics of the hazards, predicting and warning of hazards, and identifying and avoiding sites where hazards are likely to strike most strongly. In addition, social strategies can mitigate the effects of hazards: restricting land use; developing emergency preparedness measures; spreading economic losses over a large population through insurance, taxation, and monetary grants; and restructuring a community so that it is less vulnerable to hazards.

How are the effects of natural hazards on a community reduced? The first step is hazard and risk assessment: determining the types of hazards likely to occur, their characteristics and consequences, and the vulnerability of the community. Disaster preparedness is a second step. Essentially, it is the detailed planning for prompt and efficient response once a natural hazard strikes.

Disaster mitigation is a third crucial step—and a primary focus of IDNHR activity. It includes such actions as increasing the earthquake- and wind-resistance of structures, building dams and barriers to reduce the effects of floods and tsunamis, and drafting and enforcing grading codes to prevent landslides. Hazard prediction and warnings are also crucial to hazard reduction, with great potential for reducing loss of life.

Though many hazard mitigation measures are known, they are often not applied worldwide because experience in their application or critical data for their effective use in a particular region are not available. In addition, many promising mitigation approaches lack the ongoing research effort required to develop them and the funding to apply them. The IDNHR offers an opportunity to overcome these difficulties.

Along with increasing our understanding of the physics of various hazards, the IDNHR also provides an opportunity to address the socioeconomics of hazard mitigation: communicating the risk and the benefits of applying mitigation methods before a disaster strikes, encouraging response to hazard warnings, and maintaining a hazard-conscious attitude between events. For each natural hazard, projects are suggested in the body of this report. But they are only the beginning of activities possible during the International Decade for Natural Hazard Reduction.

ORGANIZATION AND ACTIVITIES OF THE IDNHR

The global scope of the IDNHR demands that it be launched and administered on an international basis. Historically, the International Council of Scientific Unions (ICSU) has served as the body to promote and execute multilateral scientific projects through its many affiliates. However, hazard reduction as pursued during the Decade will necessarily emphasize engineering capabilities and social strategies, in addition to scientific endeavors. Currently, no organization exists to link these activities on an international level. In the engineering area, the World Federation of Engineering Organizations (WFEO) was recently created and could contribute to the Decade in concert with ICSU. But combining these efforts with international governmental acceptance of the Decade's goals and means will require the participation of the United Nations, with its significant social and political resources.

The United Nations embraces a number of organizations, each with its own charge. Many of these, such as the World Meteorological Organization (WMO), the United Nations Development Programme (UNDP), the United Nations Disaster Relief Coordinator (UNDRO), and the United Nations Educational, Scientific, and Cultural Organization (UNESCO), will have a natural interest in the activities of the Decade. In view of the complexity of the U.N. system, it may be best for the United Nations itself to decide how best to promote the IDNHR in cooperation with major scientific and engineering organizations such as ICSU and WFEO.

At an appropriate stage, an international coordinating mechanism should be established to provide a focal point for implementing the Decade globally. An <u>international committee</u> jointly sponsored by the United Nations and appropriate international nongovernmental organizations might be considered. Interested member states could form <u>national committees</u> to participate in the Decade and, if possible, establish individual <u>National Decades for Natural Hazard Reduction</u>. A member of each national committee could be a member of the international committee.

The activities of the IDNHR would be carried out through both national and international cooperative efforts. For some natural hazards, there is already international cooperation on a limited scale. For example, in a number of earthquake-prone countries, strong-motion seismographs for recording destructive ground shaking provide data for design of earthquake-resistant structures. Similar efforts for other major natural hazards could be planned and coordinated on a worldwide basis. These could include research, instrument development, data processing and dissemination, development of engineering standards, and promotion of educational programs.

A U.S. DECADE FOR NATURAL HAZARD REDUCTION

U.S. participation in the IDNHR would be organized around a strong U.S. Decade for Natural Hazard Reduction (USDNHR). The USDNHR would provide knowledge and mitigation practices that can cut impacts of natural hazards at least 50 percent by the year 2000. Achieving this national goal requires a major program of research, technological development, project applications, and public information activities: a nationwide assessment of natural hazards and their risks; collection, analysis, and dissemination of information on hazards; an assessment of current knowledge and practices and identification of gaps in knowledge; a research program to fill those gaps; effective educational programs; and cooperative research activities in and among all relevant disciplines and professions.*

* A National Research Council report proposing the detailed conduct of the USDNHR will appear under separate cover.

RECOMMENDATIONS OF THE ADVISORY COMMITTEE

The Decade, encompassing both the IDNHR and individual National Decades for Natural Hazard Reduction, would be one of intense activity, beginning with the effort to pool and implement existing capabilities for immediate use. The interrelated strategies presented in the recommendations that follow are intended to achieve life-saving and economic advantages during the Decade and beyond. In so doing, they would lay the foundation for continuing achievements in the next century that will yield a world less at risk from the violent forces of nature.

The Advisory Committee on the International Decade for Natural Hazard Reduction recommends the following:

1. An International Decade for Natural Hazard Reduction (IDNHR) should be established for the period 1990-2000.

The IDNHR's objective is to reduce catastrophic life loss, property damage, and social and economic disruption from natural hazards. The IDNHR should initially focus on earthquakes, windstorms (cyclones, hurricanes, tornadoes), floods, tsunamis, landslides, volcanic eruptions, and wildfires. Its objective should be pursued by:

o collecting existing hazard mitigation experience and practices and identifying gaps in current knowledge,

o accelerating application of known mitigation and preparedness approaches, and

o developing scientific and engineering knowledge that offers substantial potential for improving hazard mitigation practices.

This objective would be accomplished through:

o cooperative research,

o demonstration projects,

o information dissemination,

o technical assistance,

o technology transfer, and

o education and training.

These activities should be tailored to specific hazards and locations, allowing for cultural and economic diversity.

2. The United States should establish a U.S. National Decade for Natural Hazard Reduction (USDNHR) to provide a focus for U.S. activities. The National Research Council, with the concurrence of the U.S. government, should establish

a national committee for the Decade to provide leadership for U.S. national efforts; seek national support from federal and state governments, foundations, and professional, scientific, and other organizations; and coordinate U.S. activities with the IDNHR program. Appointments to the national committee should include professional organizations, federal agencies, and others; it should be operational by October 1, 1987.

3. All nations should be encouraged to participate in the IDNHR, including those that suffer from natural disasters as well as those that can contribute to reducing the effects of natural hazards.

4. The United Nations should promote and facilitate the IDNHR, with full participation of the concerned nations and of the relevant international engineering, scientific, and social science communities. The United Nations should convene an international planning meeting as early as possible in 1988 to define objectives for the International Decade and to formulate an institutional framework for the technical conduct of the program.

Selected* Natural Disasters of This Century

Year	Event	Location	Approximate Death Toll
1900	Hurricane	USA	6,000
1902	Volcanic Eruption	Martinique	29,000
1902	Volcanic Eruption	Guatemala	6,000
1906	Typhoon	Hong Kong	10,000
1906	Earthquake	Taiwan	6,000
1906	Earthquake/Fire	USA	1,500
1908	Earthquake	Italy	75,000
1911	Volcanic Eruption	Philippines	1,300
1915	Earthquake	Italy	30,000
1916	Landslide	Italy, Austria	10,000
1919	Volcanic Eruption	Indonesia	5,200
1920	Earthquake/Landslide	China	200,000
1923	Earthquake/Fire	Japan	143,000
1928	Hurricane/Flood	USA	2,000
1930	Volcanic Eruption	Indonesia	1,400
1932	Earthquake	China	70,000
1933	Tsunami	Japan	3,000
1935	Earthquake	India	60,000
1938	Hurricane	USA	600
1939	Earthquake/Tsunami	Chile	30,000
1945	Floods/Landslides	Japan	1,200
1946	Tsunami	Japan	1,400
1948	Earthquake	USSR	100,000
1949	Floods	China	57,000
1949	Earthquake/Landslide	USSR	12,000-20,000
1951	Volcanic Eruption	Pupua New Guinea	2,900
1953	Floods	North Sea coast (Europe)	1,800
1954	Landslide	Austria	200
1954	Floods	China	40,000
1959	Typhoon	Japan	4,600
1960	Earthquake	Morocco	12,000

* Disasters selected to represent global vulnerability to rapid-onset natural disasters.

SOURCE: Compiled from (a) Office of U.S. Foreign Disaster Assistance (1987); (b) National Geographic Society (1986); (c) K. Toki, Disaster Prevention Research Institute (Japan), personal communication (1987); (d) R.L. Schuster, U.S. Geological Survey, personal communication (1987); (e) C. Newhall, U.S. Geological Survey, personal communication (1987).

Selected Natural Disasters of This Century (Continued)

Year	Event	Location	Approximate Death Toll
1961	Typhoon	Hong Kong	400
1962	Landslide	Peru	4,000-5,000
1962	Earthquake	Iran	12,000
1963	Tropical Cyclone	Bangladesh	22,000
1963	Volcanic Eruption	Indonesia	1,200
1963	Landslide	Italy	2,000
1965	Tropical Cyclone	Bangladesh	17,000
1965	Tropical Cyclone	Bangladesh	30,000
1965	Tropical Cyclone	Bangladesh	10,000
1968	Earthquake	Iran	12,000
1970	Earthquake/Landslide	Peru	70,000
1970	Tropical Cyclone	Bangladesh	300,000-500,000
1971	Tropical Cyclone	India	10,000-25,000
1976	Earthquake	China	250,000
1976	Earthquake	Guatemala	24,000
1976	Earthquake	Italy	900
1977	Tropical Cyclone	India	20,000
1978	Earthquake	Iran	25,000
1982	Volcanic Eruption	Mexico	1,700
1985	Tropical Cyclone	Bangladesh	10,000
1985	Earthquake	Mexico	10,000
1985	Volcanic Eruption	Colombia	22,000
1987	Wildfire	China	200

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REDUCING THE IMPACTS OF NATURAL HAZARDS

RAPID-ONSET AND LONG-TERM HAZARDS

The natural hazards emphasized in this report--floods, landslides, earthquakes, tsunamis, hurricanes, tornadoes, volcanic eruptions, and wildfires--share many characteristics. All are relatively sudden and are of short duration. Their occurrence is easily identified geographically. They occur frequently enough, globally, that we now have a large body of data on them and considerable experience in alleviating their effects. And we can reduce their impacts with a common set of skills, including immediate warnings, construction techniques, land use planning, and emergency relief. In many countries, knowledgeable scientists, engineers, and others are prepared to help in this mitigation effort.

The effects of many long-term natural hazards--drought, insect plagues, and desertification, for example--can also be mitigated. These hazards can be just as devastating as rapid-onset hazards, but dealing with them calls for a somewhat different set of skills. Generally, mitigating these hazards requires a greater ecological or social emphasis, and civil engineering approaches are less critical than for short-duration hazards. Further, the accumulation of knowledge, trained professionals, and public awareness already concentrated on rapid-onset hazards means that continued work on them during the Decade will yield the most tangible and immediate benefits, given the limited resources available. Thus, while not excluding long-term hazards, the initial focus of the IDNHR should be the eight hazards listed above.

Of course, many of the activities designed to cope with rapid-onset hazards will also lessen the risks of long-term hazards. For instance, a better understanding of meteorological processes involved in storm hazards may benefit our understanding of drought as well. In addition, other efforts, such as the proposed International Geophysical Year (IGY) and the International Biosphere-Geosphere Program (IGBP), should measurably improve our understanding of the ecological basis of many long-term hazards.

Technological hazards, although of great importance, are not considered in this report. They are characterized by opportunities for human control--both political and technological--that are not available for natural hazards.

A WORLD AT RISK

Virtually all parts of the world are at risk from the inevitable occurrence of one or more types of natural hazards. Each year, hundreds of potentially damaging earthquakes (magnitude 6 or greater) occur. Those that are located sufficiently near a city precipitate disasters. Most earthquakes occur at the margins of major tectonic plates. The highest percentage of the total seismic energy released in earthquakes is distributed along the "ring of fire," which marks the boundary of the Pacific plate. It is also the zone at greatest risk from tsunamis and volcanic eruptions. Although these three natural hazards can cause severe economic and social disruptions, they occur relatively infrequently. In contrast, floods, landslides, and severe windstorms (cyclones, hurricanes, and tornadoes) are more frequent. Floods occur annually in almost all nations. They are also a consequence of the storms associated with hurricanes and cyclones. Landslides occur almost universally, usually as a function of the slope of the terrain and natural and human actions that reduce the capacity of a slope to support rock and soil. Wildfires occur seasonally in many parts of the world in wooded or brush areas during hot, dry weather; uncontrolled fires also occur in cities in conjunction with earthquakes and other hazards. Hurricanes and cyclones are annual seasonal storms in tropical ocean areas, and tornadoes, also seasonal, are spawned inland.

Natural hazards can occur individually or in combination with other hazards. For example, earthquakes, landslides, floods, and wildfires were part of the May 1980 eruption of Mount St. Helens. Hurricanes typically combine with flooding, as in June 1972 during Hurricane Agnes. Earthquakes, landslides, and tsunamis can occur together, as they did in the Prince William, Alaska, earthquake in March 1964. Earthquakes and fires occurred together in San Francisco in 1906 and in Tokyo in 1923.

Four interrelated factors continue to place the world's population centers at risk from natural hazards—more so now than ever before:

- rapid population growth and its increasing concentration in urban areas,
- increasing capital outlays worldwide, coupled with new, sometimes vulnerable technologies,

o the existence of large numbers of unsafe buildings, vulnerable critical facilities, and fragile lifelines, and

o the interdependence of people in local, national, and global communities.

Worldwide population growth and its increasing concentration in urban areas—particularly areas of high risk, such as seismic regions, mountains and hillsides, coasts, and flood plains—accentuate the potential for natural disaster. As governments attempt to reconcile public safety interests with quality-of-life issues and short-term economic opportunities, new demands are placed on management of these hazards. Where are growing populations free to settle? How are people in risk-prone areas to be insured against loss? What increase in expenditures should be made for safer construction? What investment should be made in prediction and warning systems, and who will pay?

Hand in hand with population growth has come increased capital development. Globally, the number and value of structures have grown markedly. Along with the burgeoning complexity and price tag of the physical plant responsible for the world's economic output, capital development virtually ensures that each natural hazard will encounter and destroy an increasing amount of property if steps are not taken to improve the safety of cities.

Technological advances, though intended to reduce the constraints imposed by nature, often create new and unexpected impacts. The move off the farm and toward urbanization, new high-rise buildings, large dams, construction on man-made islands in coastal and harbor areas, the proliferation of nuclear reactors, reliance on mobile homes for low-cost housing, new modes of travel and more extensive transportation worldwide—each of these trends creates new vulnerabilities to natural hazards.

The large stock of hazardous buildings is also critical to increasing world risk. Many structures were built well before a particular hazard was understood, often without the benefit of modern design principles. In addition, hospitals, schools, fire and police stations, and other critical facilities are similarly at risk due to their location or construction. Lifelines—the vital links of transport, supply, and communication—are likewise vulnerable in many areas.

Finally, the interdependence of individuals, communities, and nations continues to grow: economies are linked by mutual need, cultures by an expanded ability to travel and communicate. Thus, more than ever before, natural disasters are shared events, affecting others far outside the immediate area. Disruption of local economies, for instance, may bring shortages in neighboring regions or a flood of refugees. Social and political turmoil sparked by a disaster in one country can have repercussions in adjacent nations. International relief efforts tax all nations' resources—resources that could be used to build rather than to rebuild.

THE BENEFITS OF MITIGATION: CASE STUDIES

Though natural hazards may be inevitable, the disasters they precipitate can be prevented or mitigated. Reliable prediction and warning, carefully planned emergency response, judicious land use policies, and hazard-resistant designs have all led to notable successes. The following case studies contrast situations in which actions were taken to anticipate a hazard with other situations in which no action was taken. They speak eloquently of the promise of a hazard-resilient world.

Bangladesh: Coping with Killer Cyclones

In 1970, a killer cyclone struck Bangladesh and precipitated the worst storm disaster of this century, killing 300,000-500,000 people and leaving 1.3 million homeless. Many victims were migratory laborers, squatters, and fishermen subsisting on the shifting islets known as chars. They were caught without warning. In response to this event and the continuing dangers posed by such storms, the U.S. and Bangladesh governments worked closely to install a satellite-based severe storm warning system. Using a full array of new tools to track and forecast storm strength, direction, and potential impact, this system allows residents of the low-lying coastal areas to be alerted to a storm's approach and to escape to higher ground.

In the early morning hours of May 25, 1985, the warning system proved its worth as another killer cyclone of equivalent strength struck Bangladesh. Winds exceeded 160 kilometers per hour, generating surf 3-8 meters above normal. The government had issued advance warnings—both nationally and locally—advising residents of the danger. Though some 10,000 died, the ultimate impact of the 1985 cyclone was many times less than that of the 1970 event. The ability to warn—to be understood in local dialects and to communicate accurately the probable threat to life and property with sufficient lead time for action--was the basis for this successful effort in the face of disaster.

Tangshan and Valparaiso: Modern Earthquake Engineering

In 1976, a magnitude 7.8 earthquake devastated Tangshan, China. Of the 1.5 million people living in the affected region, most lost their homes and more than 250,000 died. Nine years later, in 1985, a magnitude 7.8 earthquake occurred near Valparaiso, Chile, affecting some 1 million people. Though the quakes were of equal magnitude, only 150 died in Valparaiso and damage was moderate.

The difference in the extent of damage in the two cities was due to building design. Valparaiso incorporated modern seismic design to prevent collapse and minimize damage and Tangshan did not. The limited residential, commercial, and industrial damage in Valparaiso contrasts sharply with the almost total damage suffered in Tangshan and provides a measure of the potential of hazard-resistant design.

Haicheng and Tangshan, China: The Lessons of Prediction

Contrasting the Tangshan disaster with another Chinese earthquake shows the potential benefits of earthquake prediction. In February 1975, after studying various signs thought to indicate an impending earthquake, authorities in the northern province of Lianong ordered the evacuation of several cities. Some hours later, a large earthquake (magnitude 7.3) damaged 1,000 square kilometers (385 square miles) and demolished 90 percent of the city of Haicheng. Fortunately, the people were out in the streets and open spaces, and relatively few were killed or injured.

A little over a year later, the Tangshan quake (magnitude 7.8) occurred. With earthquake prediction in its infancy, no short-term prediction had been made, and the poorly built masonry buildings became death traps.

These experiences demonstrate the need to develop earthquake prediction from an unreliable art to an established science. In the United States, research on prediction is under way in Parkfield, on the San Andreas fault in California. Hundreds of instruments have been deployed there for continuous monitoring of minute physical changes in the earth.

Though earthquake prediction depends on scientific research, use of this information depends on effective decision-making processes by scientists and local officials. They must decide when the public should be warned and how to ensure that the warning reaches all those who are vulnerable. Once warned, a public prepared by education and training must then take action, as in Haicheng.

Mount St. Helens and Nevado del Ruiz: Warnings Heeded and Ignored

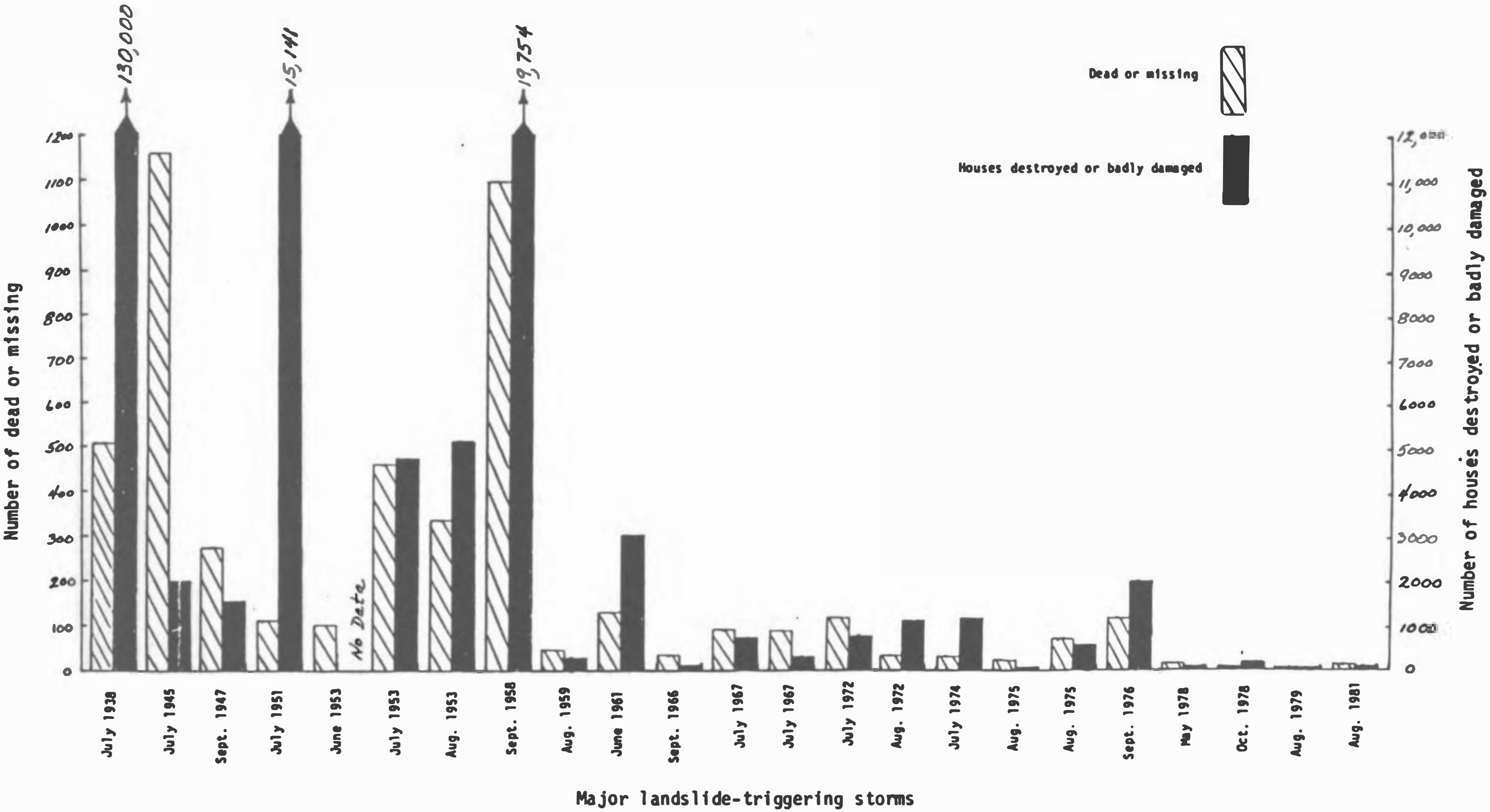
A large loss of life was averted on May 18, 1980, when Mount St. Helens volcano in Washington state erupted. The eruption devastated an area as far as 29 kilometers from the volcano—causing landslides, debris flows, and floods. Total economic losses are estimated at $860 million. Two years before the blast, scientists had identified the volcano's potential hazards. When it began to show signs of renewed activity beginning in late March 1980, apparently building toward a major eruption, the hazard zone was evacuated. Land use of the area had been so restricted that when the volcano finally erupted eight weeks later, only 57 lives were lost due to the blast and associated landslide and fire.

More than 22,000 Colombians were killed as a result of a relatively small volcanic eruption on November 13, 1985, when Nevado del Ruiz, the northernmost active volcano in the Andes, erupted. Hot volcanic ash scoured and melted part of the ice cap on the volcano's summit, triggering debris flows that swept down river valleys and overran villages in their path. The catastrophic loss of life, caused by a failure in emergency response, could have been averted. Colombian and international scientists, alerted by nearly a year of precursory activity, had warned that Ruiz might erupt and had prepared a hazard zoning map that accurately predicted the tragic effects of the eruption weeks earlier.

Japan and Los Angeles: Landslide Prevention

Probably the world's most comprehensive program of reducing landslide losses is in Japan. Its strong national program of landslide control has sharply reduced the risk of death or property loss from the high levels of 30 years ago. Beginning in 1958, the Japanese government enacted strong legislation to prevent landslides. It provided for land use planning and construction of check dams, drainage systems, and other physical controls to prevent slope failures. These measures have met with great success. In 1938, nearly 130,000 homes were destroyed and more than 500 lives lost in landslides. Yet in 1976--the worst year for landslides in Japan in the last two decades--only 2,000 homes were destroyed and fewer than 125 lives lost. Since then, the numbers have improved still further.

The city of Los Angeles also has an impressive program to reduce landslide damage. Until 1952, controls on hillside grading and development in Los Angeles were limited. Then, after severely damaging winter storms, the city adopted a grading code that instituted procedures for safe development of hillsides. The grading regulations were significantly improved in 1963. The benefits of these regulations are a clear drop in the risk of landslide damage on sites developed after 1963. For example, during the severe storms of 1978, for a comparable number of sites, the damages to sites developed before 1963 were more than 10 times greater than to those sites developed after 1963.



Losses due to major landslide disasters (mainly debris flows) in Japan from 1938-81. All of these landslides were caused by heavy rainfall, most commonly related to typhoons, and many were associated with catastrophic flooding. Source: Ministry of Construction (Japan). 1983.

Sanriku, Japan: Success against Tsunamis

In 1896, a tsunami generated by a nearby earthquake struck the Sanriku district of Japan, several hundred kilometers north of Tokyo. The maximum run-up (height of the wave) recorded in this region was approximately 30 meters, and thousands lost their lives. Nearly 40 years later, in 1933, another major tsunami from a local earthquake struck the region, killing about 3,000 and causing significant property damage. Again in 1960, the Sanriku district suffered a serious tsunami generated in Chile; about 200 people died and property valued at $50 million was lost.

These events led to construction of major protective structures, land use management, and a district warning system to protect coastal communities from serious inundation. One example is the seawall built by the town of Taro. About 8 meters high, it is shoreward of the fishing harbor, which itself is protected from storm waves by a breakwater. With an adequate warning system, the area can now be evacuated to the town in case of an approaching tsunami.

In 1960, the Chilean tsunami flooded the center of the city of Ofunato, also located in the Sanriku district, to a depth of several meters. Since then, a massive tsunami breakwater was built across the entrance to Ofunato Bay. It protected the city from at least one local tsunami in 1968. Several kilometers north of Ofunato, a similar structure was built at Kamaishi to protect the local steel industry and fishing fleet. Thus, Japan has effectively protected itself in selected regions from serious damage by combining large protective structures with effective land use management.

The city of Hilo, Hawaii, approached tsunami protection differently. After sustaining damage from the 1960 Chilean tsunami, Hilo conducted a study to define protection against similar events. The most economic solution was to create a buffer zone near the coast that encompassed the area inundated in 1960. Coupled with a tsunami warning system, this approach has also proved effective.

SUCCESSFUL INTERNATIONAL EFFORTS

Much valuable work on the reduction of losses from natural hazards has been carried out by engineers, physical and social scientists, architects, community planners, emergency managers, and others in many countries. Not surprisingly, some of these efforts are international in their scope and participation. It is the success of these cooperative projects that underlies the concept of an International Decade for Natural Hazard Reduction. Some of these programs are described below.

World Meteorological Organization (WMO)

The World Meteorological Organization stands as an example of the benefits of international cooperation for hazard reduction. Recognizing that the world has but one atmosphere and that successful weather forecasting requires measurements and modeling of the atmosphere, ocean, and land surfaces as a whole, nations began entering into a series of agreements in 1947. These agreements provide for real-time exchange of data and establishment of standards for data quality control and timeliness. They also foster the sharing of expertise in weather prediction and modification and the fundamental understanding of atmospheric processes. As a result, each nation is able to provide for the public safety and economic protection of its citizens by drawing on an international cooperative framework.

Worldwide Standardized Seismograph Network (WWSSN)

This network was created in the early 1960s to upgrade observational seismology. It has been successful in improving and unifying earthquake occurrence maps worldwide. The mapping has improved earthquake risk assessment and contributed essential support to modern theories of plate tectonics. Success stemmed from three aspects of the network: it is worldwide, providing global coverage of the temporal and spatial patterns of seismicity and earthquake focal mechanisms; it consists of a standardized set of instruments, providing uniform response at all stations; and it is coordinated, with cooperating countries having explicit mechanisms for collecting and distributing the WWSSN data.

Tsunami Warning System (TWS)

The Tsunami Warning System was established in the wake of the Aleutian tsunami of April 1, 1946, which devastated parts of the Hawaiian Islands. Afterwards, scientists pointed out that the tsunami could have been forecast on the basis of the seismic waves recorded in Hawaii and at other seismic observatories within minutes of the earthquake and hours before the tsunami struck. There are now 22 seismic observatories and 53 tide stations in the TWS covering the Pacific Basin.

The first test of the TWS came in connection with the September 1948 Tonga Islands earthquake. A travel time of 6 hours and 35 minutes was predicted for the wave to move from the epicenter to Honolulu, and military and civilian agencies were alerted. Because the wave turned out to be small, the alert was canceled. The first major tsunami in the Pacific for which advance warning saved lives was in connection with the November 1952 Kamchatka earthquake. Since the system's inception, warnings have been given in connection with great earthquakes—such as the May 1960 Chilean earthquake and the March 1964 Prince William Sound, Alaska, earthquake. TWS has substantially reduced social and economic dislocations from tsunamis.

The Strong Motion Array in Taiwan (SMART-1)

In 1978, an international workshop was held on capturing strong ground motion records near the faults generating earthquakes of magnitude 7 and above. Following the workshop, the region near Lotung, Taiwan, was made available for a cooperative experiment on a spatial scale not attempted before. An array of digital strong motion instruments consisting of a central installation and 36 stations located on three concentric rings of radii 200 meters, 1 kilometer, and 2 kilometers was installed. The array has recorded more than 40 earthquakes having significant ground motions.

These data constitute a large percentage of the worldwide strong ground motion array data base. They provide a technical base for resolving such practical engineering design problems as the variability of the earthquake ground motion over short distances comparable to the base dimensions of engineered structures and frequency-dependent seismic wave attenuation.

UNESCO Landslide Project

The UNESCO project Protection of the Lithosphere as a Component of the Environment is an example of an international effort to cope with landslide hazards. This project, which lasted from 1981 to 1984, was administered by the Soviet Union, with cooperation by landslide experts from China, France, Japan, the United Kingdom, the United States, and several developing nations. It resulted in significant multinational landslide research and mitigation. The project sponsored international workshops and seminars and published research and mitigation studies that have proven significant in landslide hazard reduction.

Morava River Project

From 1974 to 1976, engineers from the University of California at Los Angeles (UCLA) and the U.S. Corps of Engineers Hydrologic Engineering Center conducted a successful technology transfer of digital computer models from the United States to Yugoslavia. Funded by the United Nations Development Programme, the transfer involved training Yugoslav engineers at UCLA in the use of 22 hydrologic, hydraulic, and geomorphologic models. These models were installed on computers in Belgrade and tested on the Morava River, a tributary of the Danube, for their usefulness in predicting floods and anticipating sediment transport. Frequent flooding had long plagued communities along the Morava and siltation had threatened to fill local reservoirs. The models have significantly upgraded flood control planning along the Morava.

United States/Japan Cooperative Earthquake Engineering Program

The United States/Japan Cooperative Research Program on Earthquake Engineering Utilizing Large-Scale Test Facilities recently completed a closely coordinated study involving complex static and dynamic tests on a seven-story reinforced concrete building and a six-story steel building. New understanding gained here of the inelastic response of buildings to strong motions has led to several improvements for possible incorporation into building codes worldwide.

3

THE HAZARD REDUCTION PROCESS

A common theme in the Chapter 2 case studies is that disasters can be avoided or minimized through application of science and technology. Without it, disasters are likely to increase as the pressures of population and commerce encourage the use of more hazard-prone areas.

Science and technology applications that can be used to avoid disasters are of two types, physical adjustments and social adjustments. Physical adjustments for avoiding a hazard's impacts include:

- planning and building to withstand a hazard,
- identifying and avoiding the sites where a hazard is likely to occur,
- predicting the occurrence of a hazard, and
- preventing or altering a hazard's characteristics.

Social adjustments for avoiding a hazard's impacts consist of:

- restricting the uses of land and establishing minimum standards for avoiding hazardous sites and conditions,
- instituting public awareness campaigns in areas prone to hazards,
- initiating emergency preparedness programs to protect life and property once a warning is issued or an event occurs,

o spreading the economic loss among a larger population through insurance, taxation, and monetary grants, and

o reconstructing a community so that it is less vulnerable to the next hazard.

These avoidance strategies substantially alter the impacts of natural hazards. When several are pursued together, they can reduce a hazard's impact from a catastrophe to a moderate disruption. The best mix of actions depends on the hazards faced by a community, the availability of scientific knowledge, and the resources and goals of the community. What is effective in one situation or hazard may not work in another. For instance, tolerating physical damage from a hurricane might be appropriate for a large nation whose economy will likely decline only a few tenths of a percent from hurricane losses. But such a strategy is inappropriate for a tiny country like Dominica, where a single hurricane engulfed the island and affected every community in 1979. Likewise, a single earthquake affected virtually the entire industrial production of Nicaragua in 1972.

Whatever the strategy, avoiding disasters must include anticipation of the hazard's impacts. Yet most measures now in use to cope with natural hazards are reactive: firefighting, search and rescue, emergency medical care, debris clearance, provision of food and temporary shelter, and provisions for temporary water supply and waste disposal. These emergency response measures may be planned in advance but are not put into effect until after a disaster occurs. It is clear, however, that major reductions in losses of life and property can only come when the emphasis shifts from reaction to anticipation. Emergency response and postdisaster relief are important and will still be needed, but on a declining scale as disaster preparedness, hazard-conscious land use management, hazard-resistant construction, and other anticipatory measures reduce the world's vulnerability to natural hazards.

Strategies for avoiding the impacts of natural hazards and lines of applied research and technology that can dramatically reduce the frequency of catastrophes are reviewed in the following sections.

HAZARD AND RISK ASSESSMENT

How does a community begin to reduce the impacts of natural disasters? The first step is to determine the types of hazards likely to occur, their frequency, characteristics, and consequences. Experience is a good teacher, but changes in population patterns, physical characteristics of structures, and economic development over the past century suggest that relying on experience alone is inadequate for judging vulnerability.

Risk assessments of the nature, extent, and consequences of natural hazards lie at the core of adopting efficient and economic actions to lessen catastrophe potential. There is a natural competition for resources between investment in hazard reduction measures for the future and use of capital and labor that will yield current income or improve the quality of life immediately. Evaluating risks can help in estimating the likely level of hazard and in determining the economic and social costs associated with various levels of investment in hazard reduction. Assessment has three essential features:

- o Determination of the hazard. This is often described in terms of hazard or intensity maps of the maximum event likely to occur, frequency of the event (for example, demarcation of a 50- or 100-year flood area), and the numerical values of design parameters required to withstand the forces of a natural hazard (for example, the level of ground motion a structure must accommodate).
- o Determination of the vulnerability of the structures and facilities exposed. This includes individual structures and networks of interacting structures, such as water supply and distribution pipelines, and social institutions, such as fire and hospital services.
- o Determination of the significance of the impacts. This determinetion must: differentiate among saving lives, protecting property, and preserving essential community functions; compare the benefits of avoiding a disaster with those of investing in other economic and social functions; recognize the different roles of structures and institutions in emergency response and recovery activities; and recognize the different and possibly conflicting goals and values of individuals and institutions within a community.

Knowing that a major natural hazard <u>may</u> occur is not sufficient in itself to cause action. California, where nine major earthquakes occurred in the last 150 years (including four great earthquakes), did not begin a comprehensive earthquake safety program until the seismic threat was clearly understood economically and politically. This understanding came about when the office of the President of the United States determined the scale of the impact of a catastrophic earthquake on the local and national economy. The specter of a staggering $100 billion loss—with attendant loss of life and damage to industrial productivity—prompted local, state, and federal governments to begin a concerted effort to prepare for the occurrence of great earthquakes.

The kinds of information that nations require to develop and adopt a catastrophe avoidance plan do not vary much from country to country, but the strategies appropriate to different countries obviously do. Formulating goals and taking action depend almost entirely upon social organization and on the willingness of the public to accept the consequences of its actions. Some individuals and groups will choose not to act because of an incorrect understanding of what they are to do, a lack of education in how to do it, or a vested interest in doing something else. The economic, social, and institutional dimensions of a community may well determine what is appropriate as well as what is possible.

DISASTER PREPAREDNESS

Disaster preparedness is the detailed planning for prompt and efficient response once a hazard occurs; it is the first step in adopting an anticipatory approach to natural hazards. This comprehensive effort includes public education and awareness campaigns, provision for issuing warnings, development of evacuation plans, and preparations for providing evacuees with emergency food and shelter. Such efforts have been very successful in reducing deaths due to natural hazards in some industrialized nations. The challenge during the IDNHR is to extend this success to developing as well as other industrialized nations. It requires a sensitivity to different sociocultural settings, including an ability to learn from local ways of adjusting to natural hazards.

HAZARD MITIGATION

Disaster preparedness and evacuation can reduce death and injuries, but they do little to prevent property damage and the sometimes devastating economic impact associated with disasters. This is the province of hazard mitigation, whose benefits can be substantial. For instance, prohibiting basements in new coastal buildings and strengthening their wind resistance by 50 percent might reduce storm losses up to $1 billion per year (1978 dollars) in the United States alone. Adding siting and construction controls in U.S. cities that do not currently have them and elevating all new buildings in the 50-year flood plain four feet might lower flood losses nearly $500 million (1978 dollars).

Essentially, the physical impacts of hazard occurrences can be reduced by preventing or modifying the occurrence of the hazard, avoiding the hazard by siting structures and functions away from the hazard, and strengthening structures to reduce or eliminate damage when a hazard occurs.

In certain instances, prevention or modification of a hazard is possible. For example, building dams, channeling rivers, and building levees are methods widely used to reduce losses from flooding. These methods are reasonably well understood and usually entail construction of large-scale civil works. However, modification of most other hazards is still at the research stage. For instance, there are some indications that weather can be modified to lessen the likelihood of hail, increase rainfall, and possibly alter the course of large storms. Future earthquakes may even be modified so that a number of small earthquakes would occur rather than a single large one.

Avoiding the hazard through land use management is effective for some hazards. Use of land that is prone to flooding, landsliding, or liquefaction can be avoided or limited to those purposes that are least threatening. For example, flood plains can be used for parks and farming; steep slopes can be left undeveloped to avoid either natural or triggered landslides; tsunami inundation areas can be planted as parks, thus both avoiding the hazard and reducing the run-up of the tsunami by increasing the surface roughness; and critical facilities can be located outside the possible flood plain that would be created should a nearby dam fail.

It is not possible to avoid all potentially hazardous areas. Rivers must be crossed. Water, electricity, and fuel must be transported. Commerce must be maintained. The acts of regulating land use and siting facilities based on potential hazard or the consequences of their failure go right to the heart of how a community functions. Hazard considerations are but a part—often ignored—of the overall decision process. Much remains to be learned about effectively integrating land use strategies into economic development, but experience from many communities shows that even simple restrictions on the use of flood plains, as mentioned above, can reduce the consequences of flooding.

Controlling building practices offers one of the most effective approaches to limiting the effects of natural hazards. When a structure is designed, constructed, and maintained to resist a hazard, then the hazard has little or no impact. But the design of a structure to withstand a hazardous event is not a simple matter. What forces will the structure encounter? How will its different elements interact? How will the construction materials perform? These are questions the engineer must answer.

Many empirical rules have evolved to aid the engineer in constructing buildings that perform well during natural hazards. However, building practices throughout the world are developing rapidly, creating both new dangers and new opportunities. Some improved construction techniques have already proved their worth. For example, using cement mortar rather than lime/sand mortar, using reinforcing steel, and attaching diaphragms to walls can reduce the vulnerability of masonry buildings from almost certain collapse in an earthquake to one of modest or light damage. Similarly, attaching the roof to the walls and the walls to the foundation of a wood frame house can greatly reduce wind destruction during hurricanes, cyclones, and tornadoes.

But rapid change in construction practices also poses new dangers. Techniques are often applied far from where they were developed, without regard to their limitations. Further, their performance may be conjectural, not understood from actual experience. Only observations of actual performance in the field—combined with laboratory research—can validate new methods. Such investigations do not yield results easily or quickly.

Among the principal tools for safe construction are building codes and regulations. They too offer both benefits and problems for transferring experience from one community or country to another. The benefit is that a group of knowledgeable individuals has assessed experience and research results to develop the code. The problem is that a code responds to the conditions, building materials, and construction practices of the community that originated it; the code may not be entirely applicable outside this context. Nonetheless, builders in other nations, unaware of those limitations, may try to use the code without adapting it.

As mentioned earlier, a key limitation to mitigating damage from natural hazards is the large inventory of substandard, even hazardous structures. Most worldwide research and development of building practices focuses on new buildings, not on rehabilitating existing unsafe buildings. Because existing facilities represent the main hazard everywhere in the world, research and performance evaluations have much to offer this critical area.

HAZARD PREDICTION

Predicting a major natural hazard has enormous potential for reducing its disastrous consequences. Even short advance notice gives time to protect life and property; a long period provides an opportunity to relocate and reinforce property. The capability to predict varies with the type of hazard and has made considerable strides through research and technical understanding. Computer modeling of watersheds, when linked to a network of meteorological and hydrographic stations, has enabled accurate flood warnings to be developed. From tornado watch programs linked to weather radar systems, the path of a tornado can be estimated, giving both the community and its fire, rescue, and modical services a short time to prepare. The development of Doppler radar has greatly advanced the ability to predict weather-related hazards and has lengthened the time between warning and the onset of a hazard. In regions of tropical storms, the precision of warnings issued in advance improves as a storm approaches, hour by hour; ultimately, accuracy is dictated by mathematical models of a storm and the data feeding into them.

The Pacific Tsunami Warning Center and its network of member countries is an excellent illustration of the application of science in a cooperative, mutually beneficial way. For earthquakes and other hazards, short-term prediction is generally more problematic. The inability to repeat the successful prediction of the Haicheng, China, earthquake—where thousands of casualties were avoided—is a reminder of both the difficulty of prediction and the need to pursue further research.

All these forecasts rely on a mathematical model or an empirical understanding of the physical phenomena, the weather patterns, or the tectonic structure of the earth—knowledge that can be continuously updated with observations. These observations sometimes include the actual sighting of a phenomenon—as with tornadoes and hurricanes—and the model then tracks the storms's progress. As these models improve, so will accuracy of the prediction. The significance of improving the accuracy of predicting a hurricane's landfall from a 160-kilometer (100-mile) accuracy to an 80-kilometer (50-mile) accuracy can be measured in the millions of dollars if the storm is near a large city.

Many of the problems of forecasting are sociological; others relate to methods of communication. A community's willingness to respond to instructions dictates the type of information to be provided as well as when and how it should be disseminated. If the information is uncertain, then the failure of the forecast event to materialize can lead to skepticism, which damages subsequent attempts to warn the public.

EMERGENCY RESPONSE

The moment of impact of a hazard initiates the emergency response period, when saving lives and controlling property loss become matters of minutes. Typically, the first on-site responses are the spontaneous actions of local residents. Much of their effectiveness depends on training; the speed and efficiency with which communitywide response occurs is determined by planning and rehearsal. For saving lives, prompt and coordinated search and rescue operations are crucial. Fundamental problems in all emergency responses include: getting accurate information on the nature and scope of the impacts, allocating and managing local resources, marshaling and allocating external resources, and dealing with the convergence of people and materials on the impacted area.

Though projects undertaken as part of the IDNHR will not involve relief operations for specific disasters, they will include careful analysis of responses to disasters under various social and political circumstances. Emergency response generally entails much wasted effort, and there are often many urgent tasks that remain unaddressed, and much working at cross purposes. Contributing to this condition is the fact that police and other public servants must suddenly perform many tasks for which they are not routinely trained. Both technological and social solutions are required to improve this situation. For example, development and installation of backup power sources and advance planning for making use of amateur radio operators have improved emergency response in many disasters. Likewise, various strategies for public education and advance training for emergency response tasks have also been successful.

RECOVERY AND REDEVELOPMENT

As the emergency period wanes, a community enters the long recovery and redevelopment period during which it restores itself. It buries the dead, treats the injured, houses the dispossessed, restores the damaged economy, and makes plans to minimize the hazards of future disasters, among many other activities. If the emergency response period is typically one in which the spirit of unity and cooperation prevails, then the recovery period is typically one in which old divisions and conflicts resurface, exacerbated by the difficult decisions that must be made. Conflicts arise between a strong sentimental force to rebuild the community just as it was before—perhaps in the flood plain or in a seismically vulnerable style—and a movement to seize the opportunity to make radical changes. Conflicts can also develop over the use of short-term solutions that interfere with more satisfactory long-term solutions. An example is the introduction of temporary housing, which often becomes permanent. Still other conflicts arise over allocation of inadequate resources and evaluation of contradictory advice from supposed experts. These conflicts often lower community morale and undermine respect for political leadership and institutions, compounding the problems of restoring a community.

Planning for future hazardous events involves several dangers during this period. Communities often rely excessively on a single strategy: for example, rebuilding the levees but making them higher and stronger, thus reducing the hazard of mild flooding but increasing the community's size--and thus the extent of damage--in case of more extensive flooding. Planning is also impeded by a sense of immunity. Residents may feel either that "we have had our quake and there won't be another like it in our lifetime," or that "we weathered this hurricane so we can weather anything nature throws at us."

Errors made in the recovery stage can stay with a community for generations. Comparative studies of recovery in several communities have identified some characteristic errors as well as examples of more successful experiences. However, further study is needed of both the short- and long-term economic consequences of various recovery patterns and their effects on political stability and cultural development.

Distributing the economic loss among a larger unaffected community lessens the severe economic impacts of natural catastrophes, although this strategy does not directly reduce casualties or damage. Insurance is one common vehicle for redistribution of loss. However, because of the magnitude of the loss from many catastrophes, the capacity of insurance and financial institutions may be inadequate to cover it. Other forms of redistribution are economic assistance from charitable and private disaster organizations and from governments, through tax receipts and international grants.

INSTITUTIONAL ISSUES

Responsibilities for hazard reduction are so widely distributed among such a variety of organizations that coordination—even for sharing of information—is a paramount problem. Much of the essential activity in reducing the impacts of natural hazards is carried out as a sideline by organizations whose main purposes have little to do with hazard reduction. For example, public education for hazard reduction is carried out by the schools, the mass media, voluntary associations, and employers. Equipment for research and rescue is borrowed from building contractors, and its nature and locations are seldom known by those directing emergency response. To remedy this situation, government must take a more active coordinating role. Leadership of public officials is essential at all stages of hazard reduction and emergency response.

Because most disasters occur intermittently, creating organizations solely for hazard reduction is not feasible. Consequently, sustaining and directing work done as a sideline by organizations with other primary purposes is a problem. Case studies show that difficulties arise in the relations between professional and lay groups; among local, national, and international organizations; between general and special-purpose organizations; between ad hoc and permanent organizations; and among all these groups. Much remains to be learned about promoting communication among organizations and encouraging patterns of coordination that do not stifle the groups involved. A key to reducing the impacts of a hazard is understanding how organizations perform before and during an event. This will come only from systematic observation of many institutions as they plan for and respond to different hazards.

NEEDS AND OPPORTUNITIES

One clear conclusion of this analysis is that there are many more opportunities to develop disaster avoidance approaches than there are efforts to achieve them.

Two major observations on the status of disaster avoidance actions worldwide warrant careful consideration by political and scientific leaders of nations at risk:

- many known procedures cannot be applied worldwide because experience in their application or critical data for their effective use in a particular region are not available, and
- many promising approaches lack the ongoing research effort required to develop them for future application.

Research on catastrophic natural disasters is hampered by the fact that they are relatively rare occurrences in any given region. But globally they are not rare. Because advances in the science and engineering of hazard mitigation require repeated observation of individual hazards, progress requires an international approach.

Though there are some very successful bilateral and multinational research efforts, they are usually narrowly focused on country-specific objectives. For example, the United States/Japan testing program on seismic performance of concrete frames has functioned well, but it does not include the types of structures likely to be used in other countries. Nor does it incorporate the experience and data of New Zealand, Mexico, Chile, Italy, the Soviet Union, and other seismically knowledgeable countries. Similarly, the Tsunami Warning System has performed well, but its focus is solely on estimating arrival times in the Pacific Basin, not on minimizing tsunami damage by sound land use and building practices.

As stated earlier, technologies developed for application in one country are often applied in another without adaptation. The Applied Technology Council (ATC) developed recommended building practices for earthquake-resistant design for use in the United States. One of the first implementors—even before the United States—was Colombia. Building practices and materials in Colombia are somewhat different, and the tectonic nature of Colombian earthquakes is different from that of California earthquakes, for which the ATC recommendations were principally formulated. Fortunately, contacts between Colombian and U.S. engineers involved in the ATC effort are strong. Colombian engineers were able to adapt the guidelines—with advice from U.S. developers—to their circumstances. Many others who have applied these findings have not had this advantage.

From this discussion it can be seen that global efforts toward natural hazard reduction are piecemeal, and nations' research and information dissemination programs are fragmentary and narrowly focused. Further, these limited national efforts will not lead to the rapid development and application of new approaches to avoiding and managing catastrophes. Though comprehensive programs of research and application are rare in any country, the components of such an effort are often present within a group of countries and could yield real research progress if they were coordinated and needless duplication reduced—in other words, if an international campaign were undertaken.

Why should an international effort be mounted? First, natural disasters exact costs that are unacceptable by any social, economic, or political measure. Second, applied science and technology is the only means to reduce these impacts. Third, natural hazards and catastrophes do not respect national boundaries, and the techniques to limit their occurrence are not specific to any country. Experience from events in one place may be useful elsewhere before a similar event occurs. A coordinated international effort offers the opportunity to develop and apply avoidance approaches more quickly and at a lower cost than can separate national strategies alone. Indeed, a cooperative international effort may be the only way to develop effective avoidance methods for global application, notwithstanding the successes of some bilateral programs.

The International Decade for Natural Hazard Reduction offers its participants the opportunity to accomplish the following:

1. Enhance the flow of information and experience across geographic and national boundaries.

2. Make efficient use of multinational and experimental facilities and laboratories throughout the world.

3. Achieve the critical mass of knowledge, experience, and investigative capability required to truly develop disaster avoidance.

4. Allow researchers and professionals of many nations to gain access to areas and information that would not otherwise be available.

5. Obtain and share demonstrable results within a relatively short time that clearly advance engineering and scientific understanding and can be adapted for use within the participants' own countries.

4

MAJOR NATURAL HAZARDS

The nature of each major natural hazard is distinct, as are the challenges associated with reducing its impacts. This chapter traces the unique character of the major hazards and suggests IDNHR projects to address each one. These project lists are by no means exhaustive and are intended only to indicate the possible scope of IDNHR activities. The chapter also explores the socioeconomic aspects of hazard reduction and the special challenges of coping with multiple hazards.

EARTHQUAKES

An earthquake—a sudden motion of the earth caused by an abrupt release of slowly accumulating stress—is a potent natural hazard. Dangers associated with earthquakes include the phenomena of ground shaking, surface faulting, ground failures, and tsunamis. Although earthquakes cause less economic loss annually than some other natural hazards, they have the potential for causing great sudden disasters. Within one minute, an earthquake can destroy part or all of a city. Depending upon its location and magnitude, it can damage buildings and homes valued at billions of dollars, cause loss of life and injury to tens of thousands, and totally disrupt a community's social and economic functioning.

At least 35 countries face a high probability of loss from earthquakes. Moderate (magnitudes of 6-7) and large (magnitudes of 7-8) earthquakes pose the greatest threat because they are much more frequent than great earthquakes (magnitudes of 8 and above). For example, a moderate earthquake takes place about once a year in California, but a great earthquake happens only once every 100 years or so.

The extent of a disaster wrought by an earthquake depends upon the magnitude of the earthquake, its proximity to a city, and the city's preparation to resist an earthquake. In the past 25 years, the two most destructive U.S. earthquakes were in Prince William Sound, Alaska, in March 1964 (magnitude 8.4) and in San Fernando, California, in February 1971 (magnitude 6.5). Damage of about $500 million (1971 dollars) and scores of deaths and injuries resulted from each. Yet the United States has been relatively fortunate. The Tangshan, China, earthquake of July 1976 (magnitude 7.8) destroyed the entire city, leaving more than 250,000 dead. The Mexico earthquake of September 1985 (magnitude 7.8) caused 10,000-20,000 deaths and about $6 billion in damages. The moderate (magnitude 6) earthquake of 1960 near Agadir, Morocco, caused more than 10,000 deaths in a city of 30,000. The 1908 Messina, Italy (magnitude 7.8) earthquake killed about 80,000, and the 1923 Tokyo earthquake (magnitude 9) killed more than 140,000.

The main goal of an earthquake hazard reduction program is to preserve lives through the economical rehabilitation of existing structures and the construction of safe new structures. One further goal is to ensure that emergency response, recovery, and redevelopment plans are made to provide continuity of economic, social, and political activities in a community.

Achieving these goals requires that the extent of the earthquake risks and the exposure of citizens first be identified. This task can take the form of preparing earthquake risk maps, which plot the probability of experiencing a specific level of ground motion within a specific time. Determining the exposure of citizens relies on evaluating the safety of existing structures, water and sewer systems, gas and oil pipelines, and other lifelines. However, determining structure safety is often handicapped by an inability to assess materials and designs used in older construction.

Even with the best determination of building properties and conditions, the level of damage a specific ground motion may cause still cannot be predicted accurately. Nonetheless, a number of techniques can be used to strengthen existing structures, and many buildings have been retrofitted for increased seismic resistance. As research further develops these techniques and their cost falls, more buildings can be upgraded.

What needs to be done during the Decade? First, programs must be initiated that include avoidance, through zoning, of construction on vulnerable sites as well as evaluation and reconstruction after a hazard occurs. In addition, emergency response for buildings and lifelines must be planned and care taken to ensure that these plans are properly implemented.

Second, instrumentation networks must be established to determine ground motion influences caused by local site conditions. Such networks will also provide the means to determine the relationship between specific ground motions and the degree of damage to man-made structures--from initial damage to ultimate collapse.

Third, a testing program must be undertaken to explore this relationship between ground motions and the behavior of man-made structures up to the point of collapse, and to develop economical methods to improve the safety of existing buildings.

Further, efforts must be made to sustain a reasonable level of earthquake preparedness in the minds of citizens. This need includes a continued readiness to respond to earthquake warnings despite the long periods between destructive quakes and the uncertainties of most warnings.

Potential projects during the IDNHR include:

o establishment of a cooperative international program in strong motion measurement and data analysis,

o organization of a coordinated international earthquake information service,

o development of new earthquake prediction models,

o study of the timing and methods for effective delivery of earthquake warnings,

o assessment of technical considerations in strengthening brittle reinforced-concrete buildings and other hazardous structures,

o study of the international financial and insurance implications of catastrophic earthquakes,

o improvement of techniques to control nonstructural damage (for example, ceilings, partitions, windows, and other interior fixtures),

o analysis of various strategies for preparedness and response to earthquakes,

o study of failure modes of structures,

o study of the special concerns in designing, constructing, and rehabilitating critical facilities,

o improvement of guidelines for earthquake-resistant design,

o preparation of unified risk maps that include hazard potential, frequency of occurrence, expected ground motions, and site variations,

o study of microzonation in worldwide seismotectonic analogs,

o development of seismic-safety analyses for existing dams and nuclear power facilities, and

o continued studies of seismic gaps (faults with no recent activities) and their implications.

LANDSLIDES

Landslides occur in virtually every country in the world, and they have a variety of causes: heavy rains, melting snow or ice, earthquakes, volcanoes, and human activities. Landslides often extend beyond the bounds of a single state or country, burying homes and other structures and disrupting transport and the delivery of emergency services.

Notable landslides of the recent past include the Reventador, Ecuador, landslides of March 1987. A magnitude 6.9 earthquake following a month of heavy rains precipitated landslides scouring the slopes of Mt. Reventador. Early estimates show 1,000 dead and 4,000 missing. In addition, the event ruptured the trans-Ecuador oil pipeline—the nation's prime economic asset—causing an approximate $1.5 billion loss. In 1962 and 1970, disastrous slides plunged from the slopes of Mount Huascaran in

Peru. In the 1970 event, caused by a 7.8 magnitude earthquake, nearly 20,000 died as mudflows buried the nearby towns of Yungay and Ranrahirca. In the United States, the April 1983 thaw of a heavy snow pack precipitated a landslide near Thistle, Utah, which caused more than $200 million in direct losses, cutting two major highways and a transcontinental rail link and damming the Spanish Fork River.

Landsliding in the United States causes at least $1-2 billion in economic losses and 25-50 deaths each year. Despite a growing understanding of the geology of landslides and a rapidly developing engineering capability for landslide control, losses continue to increase. This rise is largely a consequence of residential and commercial development that continues to expand onto the steeply sloping or unstable terrain that is most prone to landslides.

There are methods for mitigating landslide losses. Land use management, building and grading codes, the use of well-designed engineering techniques for landslide control and stabilization, the timely issuance of emergency warnings, and the availability of landslide insurance can significantly reduce the catastrophic effects of landslides. Though some techniques for predicting landslides have been developed, research in this area is insufficient. For example, recurrence interval techniques and other temporal descriptions of risk are essentially unexplored. Some research has been carried out on the use of early warning systems to alert the public to individual local landslides, and there have been a few successful demonstrations. But there has never been extensive implementation of an early warning system in any country.

Successful and cost-effective landslide mitigation programs can be implemented, and such programs do exist (Japan, for example). Though there have been some impressive local demonstrations of landslide control in other countries, information about them has not been widely disseminated.

Nonetheless, much can be done to reduce landslide losses everywhere. There are obvious needs for geologic and engineering research, development of new mapping techniques, widespread adoption and enforcement of appropriate building and grading codes, more effective land use planning and management, wide dissemination of information about landslide risk and loss reduction, and serious examination of the feasibility of landslide insurance.

An effective program to reduce landslide losses worldwide can begin today. Existing knowledge about landslide processes and loss reduction practices can provide a basis for widespread and effective implementation of the loss reduction techniques now available. At the same time, research should be undertaken to improve the technical base for formulating design, building, and grading codes and developing new techniques to prevent loss.

Potential projects during the IDNHR include:

o study of landslide processes, including landslide initiation and the mechanics of landslide transport and deposition,

o development and demonstration of improved landslide mapping methods on a broad range of map scales,

o organization of an international landslide information service to provide data and technical assistance to groups interested in setting up a landslide mapping program, o study of the economic, political, and social processes that encourage or impede landslide mitigation programs,

o development and application of land use practices and regulations that reduce vulnerability to landslides,

o development and use of landslide control measures, such as soil drainage,

o analyses of regional and temporal landslide distributions to develop recurrence models, predictive criteria, and risk assessments,

o instrumentation of landslide-prone areas for hazard assessment, prediction, and warning,

o assessment of interrelationships between landslides and other natural hazards, including intense storms, earthquakes, volcanoes, floods, and wildfires,

o development of design criteria relating ground deformation and damage to structures,

o improvement of response strategies for landslide disasters, and

o application of new techniques in satellite remote sensing, geophysics, and geotechnical engineering for delineation of areas of landslide hazard.

TSUNAMIS

Tsunamis are large ocean waves generated by impulses from geophysical events occurring on the ocean bottom or along the coastline, such as earthquakes, landslides, and volcanic eruptions. These waves usually have relatively small heights in the desp ocean, but they can become destructively large as they approach shallow water and run up on the shore. Tsunami damage is a direct result of three factors: inundation, wave impact on structures, and coastal erosion.

Tsunamis cause significant damage and loss of life in many regions of the world. About 6,000 people have been killed by these destructive waves in the past decade alone. In the United States, for example, the tsunamis generated by the Prince William Sound, Alaska, earthquake of March 1964 killed more than 120 people and caused damage estimated at greater than $100 million (1964 dollars), including extensive damage to the town of Crescent City, California.

Many other countries have been seriously affected by both distant and locally generated tsunamis. For example, the 1960 earthquake (magnitude 8.6) near Concepcion, Chile, generated a tsunami that traveled across the Pacific Ocean at about 800 kilometers an hour (500 miles per hour) and caused significant property damage and loss of life. The Japan Sea tsunami of May 1983 caused approximately 100 deaths and extensive property damage and flooding along the northwest coast of Japan. This tsunami was particularly well-documented, and the rich data set compiled from it will improve our understanding of tsunami action.

The occurrence of disastrous tsunamis is a major threat to 22 countries along the rim of the Pacific, although disastrous tsunamis have also been felt in Portugal, the Mediterranean, and other parts of the world. Current technology, if applied, can mitigate the destructive impacts of tsunamis on lives and property. Protection against tsunami run-up can be achieved by constructing barrier walls and other diversions, as has been done in Japan. But the cost of such projects and their degradation of natural seascapes restrict their use. Land use zoning of coastal areas may be a less costly way to reduce economic losses from tsunamis.

Saving lives through effective early warning of tsunamis propagated in the open ocean is certainly possible today. However, among the 22 countries in the circum-Pacific region, only a few have standard operating procedures for immediate evacuation or reliable, rapid communication systems capable of receiving real-time warnings from the Pacific Tsunami Warning Center. In recent years, Chile, with technical assistance from the United States, has significantly upgraded its disaster preparedness and evacuation planning efforts. The United States installed a prototype nearshore tsunami warning system that is used to trigger evacuations along the Chilean coast within minutes of major offshore earthquake events. The Chilean Standard Operations Procedure Manual for tsunami warning and evacuation is a model for other threatened nations.

A program to reduce tsunami losses would, certainly, include development of global forecasting of tsunami dangers and the evaluation and mitigation of coastal tsunami hazards. During the IDNHR, a significant effort should be made to gather field data related to the generation and propagation of a tsunami. For example, instruments could be deployed in a region off the Alaska Peninsula, where the probability of a tsunami-causing earthquake is high. Instruments could also be deployed in distant nearshore regions. Such a program would help refine predictive capabilities with regard to timing and the destructive potential of a wave.

For evaluation of coastal tsunami hazards, the probability of occurrence, the maximum limits of inundation, and maximum forces that can be exerted on stationary and moveable objects must be determined. Such information can provide land use guidelines and engineering design criteria for potentially threatened areas and could become the baseline for reducing life and property loss.

Potential projects during the IDNHR include:

- o open ocean measurement of tsunamis coupled with earthquake measurements to obtain field data on tsunami generation and propagation,
- o a program for nearshore measurement of tsunamis and their run-up, with instrumentation of selected sites around the Pacific that historically have been affected by tsunamis,
- o development and implementation of numerical models to be incorporated in warning systems to provide real-time tsunami inundation estimates,
- o confirmation of numerical models with large-scale hydraulic models, and
- o structuring of international teams for rapid response to investigate tsunami events quickly before evidence of run-up and damage is obliterated.

WINDSTORMS

Windstorm-related events worldwide cause an average of 30,000 deaths and $2.3 billion in damage each year. Severe tropical storms (called hurricanes in the Atlantic, Caribbean, and eastern Pacific, typhoons in the western Pacific, and cyclones in the Indian Ocean), tornadoes, blizzards, and other storms affect the built environment and agriculture in every country of the world.

Disasters associated with severe tropical cyclones can cover hundreds of square kilometers, lead to hundreds of thousands of casualties, and cause billions of dollars in economic loss. Winds approaching 350 kilometers per hour (200 miles per hour), rains exceeding 80 centimeters (30 inches) in a few days, and storm surges of 8 meters (25 feet) characterize the more intense storms of this type. About 15 percent of the world's population is at risk from tropical storms--in the southeastern United States, Japan, the Philippines, southern China, and South Asia. Particularly vulnerable to deadly storm surges are the river deltas of Asia, where death tolls of 300,000 or more have been recorded in a single event. In the United States, hurricanes are more often associated with widespread property damage, as in 1972, when Hurricane Agnes caused nearly $2 billion in damage--one of the costliest natural disasters in U.S. history.

The United States leads in the occurrence of tornadoes, but they have also been reported in Canada, Argentina, Australia, Bangladesh, India, and Europe. The most extensive tornado-related disasters have occurred in the United States. In 1974, 149 tornadoes struck from Canada to the Gulf of Mexico in 36 hours, killing more than 200 and causing damage exceeding $1 billion. Wind speeds approaching 500 kilometers per hour (300 miles per hour) are possible in a tornado, and windborne debris is a significant hazard. Individual storms are small in extent (fractions of a kilometer), but outbreaks of many storms affecting large areas (hundreds of square kilometers) are common in the United States. A tornado striking the center of a large city would certainly be a major disaster.

Though it is incommunicable to design for the most intense tornado winds, the less intense winds can be effectively resisted with use of appropriate construction techniques. Improved tornado warning times and instructions to the public that place people in optimum locations within buildings are credited with greatly reducing deaths and injuries from tornadoes in the United States.

Extratropical cyclones, fronts, thunderstorms, and downslope winds also threaten people and property. Damaging winds, lightning, hail, and ice that accompany these events kill thousands and cause billions of dollars in damage each year. These wind-related events can be dealt with more easily than severe tropical cyclones and tornadoes, but the extent of their occurrence is wider. Virtually no community in the world is immune.

Prediction of catastrophic winds—whether associated with extratropical cyclones, hurricanes, downslope windstorms, tornadoes, or thunderstorm gust fronts—involves forecasting on all time scales: long range (more than 10 days), intermediate range (3-10 days), short range (1-3 days), very short range (a few hours), and "nowcasts" (events in progress). Key to the utility of wind forecasts are timeliness, accuracy of location, and overall reliability. Key to their credibility are observations of current conditions that are accurate, quality controlled, and of high resolution in both space and time, and good models of weather processes on the scales observed.

In the near future, many nations need to invest substantially in modernizing their weather observation networks. This effort involves deploying new satellites, Doppler radars, automated surface networks, and other technologies. It also requires new information management systems to integrate the data.

Long-term prediction of the magnitude of extreme weather events permits evaluation of maximum structural loads and subsequent analysis of the economic viability of designing structures to accommodate those loads. For design purposes, the use of wind speeds predicted to occur once or twice a century should permit most structures, including individual houses, to withstand with only minor damage the maximum winds generated by more than half of all hurricanes and tornadoes.

As with other natural hazards, the two basic strategies in common use to decrease the impact of weather-related disasters are avoidance and mitigation. For example, a long-term avoidance strategy for hurricanes is land use planning in which construction on barrier islands and low coastal areas is restricted. On another level, a short-term avoidance strategy for hurricanes is a 12- to 24-hour evacuation notice aimed primarily at protecting lives.

Short-term mitigation measures for use after hurricane watches or warnings are posted include boarding up windows, installing aircraft tie-downs, and other quickly performed activities. Longer-term measures include modification of building practices based on 50- or 100-year predictions of the magnitude of extreme events. Improved construction and inspection requirements have dramatically decreased wind damage in both hurricanes and moderate-level tornadoes at a low cost during construction and have reduced loss of life and damage in severe tornadoes.

Potential projects during an IDNHR include:

o improvement of global weather networks using satellite and surface observations to forecast and track severe storm systems,

o coordinated international programs to study severe tropical storms, tornadoes, and other severe weather phenomena responsible for flash floods, blizzards, hail, and high winds,

- o enhancement of wind tunnel research on wind/structure interactions,
- o improvement of techniques for poststorm damage evaluation to assess the adequacy of current building practices,
- o mapping of hurricane wind fields after landfall,
- o standardization and assessment of extreme wind speeds and wind loads to improve building design practices,
- o improvement in construction practices to resist wind, with emphasis on low-cost housing,
- o investigation of the role of insurance in lessening the economic impacts of windstorm damage,
- o development of improved techniques for predicting storm surge vulnerability and risk,
- o design of storm shelters and refuges to save lives while minimizing the need for massive evacuation, and
- o enhancement of programs to aid local officials and emergency managers in deciding when and how to evacuate during severe storms.

FLOODS

Flooding is any abnormally high water flow that overtops the natural or artificial confining boundaries of a waterway. Each year, floods take an increasing number of lives and property. Single events can result in heavy tolls of death and property damage, as in the Sichuan, China, flood of 1983, when more than 1,300 died, 1.5 million were left homeless, and damages totaled $1.1 billion.

In the United States alone, rainstorms and their resulting flooding (including mud and debris flows) accounted for more than 63 percent (337 out of 531) of the federally declared disasters from 1965 to 1985. These floods caused 1,767 deaths.

Internationally, floods take an even greater proportional toll. From October 1, 1985, to September 30, 1986, a year when no exceptional flood disaster occurred, floods took 626 lives and affected more than 1.6 million others in six countries. The number of deaths is significantly higher in developing countries than in industrialized countries because communications are often poor and warning systems and evacuation plans inadequate. Further, the number of flood deaths is expected to increase as population pressures force people into vulnerable areas such as low-lying agricultural areas or overcrowded urban slums on flood plains.

Floods are caused not only by rain but also by man-made changes to the earth's surface: farming, deforestation, and urbanization, for example. These actions increase runoff from rains, and storms that previously would have caused no flooding inundate vast areas today. In addition to the human contribution to the causes of floods, disaster conditions are created by reckless building in vulnerable areas, poor watershed management, and failure to control flooding.

Flash floods are local floods of great volume and short duration. A flash flood generally results from a torrential rain or cloudburst on relatively small and widely dispersed streams. Runoff from the intense rainfall results in high flood waves. Discharges quickly reach a maximum and diminish almost as rapidly. Flood flows frequently contain high concentrations of sediment and debris. Flash floods also result from failure of a dam or the sudden breakup of an ice jam. Flash floods are particularly common in mountainous areas and desert regions, but they are a potential threat wherever the terrain is steep and when surface runoff rates are high, streams flow in narrow canyons, and severe thunderstorms occur.

Riverine floods are caused by precipitation over large areas, the spring snow melt, or both. They differ from flash floods in extent and duration. Whereas flash floods are of short duration in small streams, riverine floods take place in river systems whose tributaries may drain large geographic areas and encompass many independent river basins. Floods on large river systems may continue for periods ranging from a few hours to many days. Flood flows in large river systems are influenced primarily by variations in the intensity, amount, and distribution of precipitation. The condition of the ground (amount of soil moisture, seasonal variations in vegetation, depth of snow cover, imperviousness to water due to urbanization) directly affects runoff.

Floods damage human settlements, force evacuation, damage crops and food stocks, strip farmland, wash away irrigation systems, erode large areas of land or make them otherwise unusable, and change the course of streams and rivers. Alleviating the harmful effects of floods globally requires action on three fronts: reducing the vulnerability of human settlements and residences, reducing the vulnerability of local and national economies, and strengthening the social structure of communities so that they can absorb the impacts of a disaster and recover rapidly.

The first step in vulnerability reduction is to identify the high-risk areas through risk maps showing flood probabilities. Once these maps are complete, specific mitigation measures can commence. These include:

o development of extensive public awareness programs to inform the public about flood hazards and illustrate what can be done to prevent a disaster, o land use zoning to control development,

o construction of dams, reservoirs, channel by-passes, levees, and other protective works,

o restrictive development regulations to ensure that any development meets certain standards that take into consideration the threat to a site,

o land exchange, which might provide alternatives to development of vulnerable sites,

o establishment of incentives to encourage development on safer sites and safer methods of construction (for example, favorable taxation, loans, and subsidies to those qualifying in terms of building methods or sites),

o diversification of agricultural production, that is, identification and planting of flood-resistant crops and adjustment of planting season, if possible, to work around the flood season,

o establishment of cash and food reserves,

o reforestation, range management, and animal grazing controls to increase absorption and reduce rapid runoff, and

o construction of raised areas or buildings specified as refuges when evacuation is impossible.

Potential projects during the IDNHR include:

o development of cost-effective, real-time flood warning systems readily adaptable for developing countries,

o international technology transfer of computer models specifically designed for flood analysis, including models for the peak flood routing of riverine and flash floods down river channels, and models that delineate water surface profiles throughout the flood plain, o research on the maximum probable rainfall and runoff in flood-prone areas,

o international technology transfer of techniques and methods for the planning, design, and implementation of structural and nonstructural flood control works, and

o establishment of international regional flood centers on the world's major rivers.

VOLCANOES

Volcanic eruptions have claimed more than 266,000 lives in the past 400 years. Fatalities occurred in about 5 percent of all eruptions; one out of six of the earth's active volcanoes has caused death. Because of the increasing population density on the planet, volcanic hazards are of growing concern. They are likely to take a greater toll in the future unless volcano hazard assessment and monitoring efforts and techniques improve. Volcanic activity is confined to well-defined geologic zones that are related to the unstable margins of crustal plates. Eruptions have immediate catastrophic effects through ash falls, surges of lethal gas, blasts, mudflows or lahars, and lava flows. The largest and most dangerous eruptions occur from volcanoes that lie dormant for hundreds of years between periods of activity. Consequently, their potential hazard is often ignored during planning and development of the surrounding region. Vesuvius, the volcano near Naples, Italy, and the Rabaul Caldera in Papua, New Guinea, are prime examples. In both instances, large populations have settled in the hazard zones.

Among the hazards of volcanic activity are the deposition of ashes—such as buried the city of Pompeii—lava flows, landslides, mudflows, and rock falls. Pyroclastic flows and surges, which claimed 29,000 lives in the eruption of Mount Pele in Martinique in 1902 and 2,000 lives around El Chichon in Mexico in 1982, are particularly lethal. These density currents of extremely hot gases and particles flow down the slopes of a volcano at tens to hundreds of meters per second and cover hundreds of square kilometers. Because of their suddenness and speed, pyroclastic flows and surges are difficult to escape; within minutes of their initiation, they can engulf towns and villages.

Mudflows account for at least 10 percent of all volcano-related deaths. They are flowing masses of volcanic debris mixed with water. The water may be derived from a volcano's icecap: a relatively minor eruption of snow-clad Nevado del Ruiz in 1985 triggered lahars that killed more than 22,000 in Colombia.

Very large eruptions may also have long-term effects, including climate change and agricultural disruption. The large explosive eruption of Tambora in Indonesia in 1815 caused a major cooling of the Northern Hemisphere and brought on the "year without summer." The ash fall from the eruption so curtailed local food production that a famine occurred, claiming 80,000 lives on Sumbawa and Lombok Islands. An indirect effect of volcanic activity is the accumulation of volcanic gases in deep crater lakes. Sudden release of these gases can be catastrophic: gas releases from Lake Monoun and Lake Nyos in Cameroon in 1984 and 1986, respectively, claimed 1,800 lives.

Advances in understanding volcanoes and their hazards permit the identification of potentially hazardous areas near volcanoes and prediction of certain types of volcanic activity. Potential hazards can be assessed through geologic study and historical review of a volcano's activity. The assessments are useful primarily in forecasting the kinds, scales, and likelihood of activity, but are of little value in predicting the timing of future eruptions. The prediction of volcanic eruptions can be achieved on the basis of geophysical and geochemical volcano monitoring. Such prediction relies on detecting precursory events and using the rate of change in precursory phenomena such as minor tremors near the volcano. Hazard assessment studies have been carried out for only a small fraction of the earth's active volcanoes. Because of the costs, only a dozen volcanoes are well-monitored today, so that predicting eruptions is feasible for only these few.

Loss of life and property due to volcanic activity can be significantly reduced through coordinated national and international efforts at volcanic hazard assessment, monitoring, and warning. Once volcanic risk areas are identified, zoning to restrict land use and development is the single most effective mitigation measure.

Potential projects during the IDNHR include:

o identification and global mapping of active and potentially active volcanoes,

o assessment of the potential hazards of these volcanoes through study of their deposits and history of past eruptions,

o quantitative assessment of the intensity (mass eruption rate) and magnitude (total eruptive mass) of all historic eruptions as a step toward establishment of a global view of volcanic energy release, o baseline geophysical and geochemical monitoring of volcanoes, particularly in densely populated areas, to provide early warning of eruptions and to signal when activity has ceased,

o training and education programs for specialists in all volcanically active countries,

o formation of expert international volcano crisis assistance teams to respond to developing volcano emergencies,

o development of coordinated emergency warning, evacuation, and response methods and techniques, and

o study of the environmental impacts of volcanic eruptions on the earth's atmosphere and on world climate.

WILDFIRES

Wildfires are uncontrolled conflagrations that spread freely through the environment. They may be initiated by natural causes or human acts. Lightning causes many wildfires; others are caused by sparks from campfires, arson, and even earthquakes and volcanic eruptions. Some wildfires rage in wooded areas, some in brush, and some sweep through cities.

In wild areas, timber and forage may be destroyed, animal habitat disrupted, soil nutrients depleted, and scenic value diminished in the wake of wildfire. Rapid runoff from a burned-over area can also contribute to flooding, while erosion of exposed soil can trigger landslides. As human populations continue to encroach on areas of abundant natural fuels, wildfires increasingly include significant human tolls. Fires at the wildland/urban interface can quickly decimate suburban, resort, and farming communities, leading to great loss of life and destruction of a community's economic base.

Several recent examples demonstrate the destructive potential of wildfire. In May 1987, one of the largest wildfires on record occurred in China. This fire burned 10,000 square kilometers, killed 191 people, destroyed 12,000 homes, and forced 56,000 people to flee. In February 1967, the "Black Tuesday" fire in Tasmania, Australia, burned more than 260 square kilometers (100 square miles), destroying more than 2,000 structures, killing 50,000 sheep, and consuming more than 5 percent of the pasture land in the state.

Earlier, a series of brush fires in Ghana in 1983 destroyed 35 percent—154,000 metric tons—of the country's standing crops and stored cereal. Earthquake-induced fires are typified by the San Francisco fire in 1906 and the Tokyo fire in 1923. Both fires consumed substantial portions of the cities.

Much can be done to prevent, control, and mitigate wildfire and its effects. Prevention, of course, is the first line of attack. It is sometimes feasible to modify vegetative fuels and reduce the severity of fire hazard. Controlled burning, thinning vegetation or replacing it with more fire-resistent species, and creating voids or breaks in large expanses of natural fuels are all ways to deprive fires of fuel.

Prevention has its human side as well. Public education activities, such as those that familiarized the U.S. population with Smokey the Bear's popular message, "Remember, only you can prevent forest fires," are effective in creating an awareness of the need to be careful with fire. The message is significant, considering that people cause a substantial number of wildfires.

Improvement in both firefighter training and equipment also yields rich dividends. In some countries, such as the United States, much has been done to prepare firefighters and their organizations to respond quickly and effectively. Elsewhere, the application of existing basic fire suppression technology could greatly reduce the destruction of wildfires. In all countries, there is considerable room for improving firefighting capability in wildland/urban interface situations. For example, most U.S. firefighters are trained and equipped to fight either wildland or structural fires--not both.

The construction, design, and composition of a structure influence the probability of its surviving a wildfire threat. Wood shingle roofs become highly flammable; fiberglass skylights and attic vents melt, permitting embers to enter a building; open-furred roofing (as with Spanish tile) also lets embers in; and unshuttered glass windows blow out from heat stress. All these hazardous conditions can be addressed with low-technology solutions.

Actions taken after a fire can also mitigate the severity of both the short- and long-term impacts. On large burns, planting grass seed or other ground cover reduces soil erosion. Erosion can also be controlled with structural and earthen barriers to retard surface runoff.

Many advances have been made in understanding the physical and biological relationships of wildfire control and prevention. But the social aspects of wildland/urban interface areas still present many difficulties. Solutions require a better understanding of how to change behavior in the face of increasing fire risk or how to adapt fire protection to behavior patterns.

Many measures for mitigating other natural hazards can be applied to the wildland fires, including retrofitting, disaster relief, modification of existing uses, and postdisaster planning.

Potential projects during the IDNHR include:

o determination of the distribution of the wildland/urban interface and monitoring of its fire-related trends, such as housing design, materials, and placement,

o refinement of the understanding of fire physics and the expected behavior of large fires, particularly as they relate to the wildland/urban interface,

o development of models for evaluating the risks of individual community designs and structures,

o initiation of an international program to exchange knowledge of fire suppression techniques and fire effects and identification of knowledge gaps unique to individual regions,

o improvement of fire-resistant construction materials, systems, and standards,

o study of how to manage wildfire smoke to eliminate health hazards and the negative effects on air corridors and transportation networks,

o research on the relationship of fire to desertification, climate change, and biodiversity,

- development of long-range weather forecasting procedures keyed to predictions of fire severity,
- improvement of the ability to communicate the economic consequences of fire hazard mitigation activities and to assess the economic tradeoffs among the hazard reduction strategies,
- characterization of homeowners, builders, firefighters, and local governments as to their understanding and perceptions of risks and the factors that motivate them in relation to wildfire,
- integration of existing social, economic, fire behavior, and environmental models to develop programs for influencing behavior toward fire hazards, and
- assessment of the hazard and the vulnerability for cities at risk from large, uncontrolled fires, (especially earthquake-ignited fires), and development of plans for fire control in the event of street blockage by collapsed buildings, damage to water supply and distribution, and damage to fire stations and communications systems.

SOCIOECONOMIC ASPECTS OF HAZARD REDUCTION

To be successful, methods for reducing natural hazards must be carefully adjusted to the communities they serve. Science and technology can help avert natural disasters, but only when applied with a community's social, cultural, political, and economic context in mind. An area's economic and other resources—and the competing demands for them—affect the level of risk it will tolerate and determine the approaches it takes to hazard reduction. An area with abundant resources and relatively few unsafe structures may, for example, choose seismic reinforcement of its buildings to minimize risks. Another community where resources are scarce and the number of unsafe structures is large may choose to live with moderate risk, relying on short-term earthquake prediction and careful emergency planning.

Hazard reduction measures have unforeseen economic consequences. For example, how would the prediction of an earthquake within five years affect the economy of a mid-sized community? In some areas, well-intentioned international relief efforts following a major disaster have bankrupted local businesses by eliminating their markets. In other instances, unforeseen economic benefits from particular measures could have justified greater investment in hazard reduction than seemed reasonable at the time.

Hazard reduction measures often benefit some segments of a community at the expense of others. For example, removing vulnerable flood plain homes or requiring costly seismic reinforcement of old buildings can reduce the supply of low-cost housing for the poor. And tax exemptions for the costs of upgrading the safety of privately owned buildings are of little use to many retirees and others with a small or no taxable income.

Specific approaches to hazard reduction can sometimes violate widely shared community values. Some historic buildings that are unsafe have been insensitively destroyed or defaced. Or the natural beauty of streams and waterfronts has been marred by concrete channels and seawalls. In some instances, the acceptance of risk, combined with an emphasis on emergency evacuation planning, may be preferable to environmental desecration or the profanation of sacred sites.

Why does available scientific and technological knowledge exceed our use of it to reduce hazards? A number of obstacles can stand in the way of adopting of mitigation techniques. For instance, some measures are resisted because they appear to threaten the economic or political interests of important groups in a community. Understanding these interests and local political processes is essential.

Traditional practices and cultural meanings are also a source of resistance. People may refuse to move from especially vulnerable locations solely for sentimental reasons. And traditional practices that contribute to vulnerability--like development of seashore property in hurricane areas--may continue even when a danger is realized. Understanding local tradition and leadership often helps negotiations in these instances.

Difficulties also arise in communicating warnings and other disaster information to various populations in a community. Warnings are sometimes delayed or information on hazardous conditions withheld because of an uncertain public response. A warning given too early or a false alarm may cause people to doubt subsequent warnings; yet mass panic--though relatively rare--could ensue from a last-minute warning. Much remains to be learned about how to ensure that disaster information is understood and responded to constructively.

Mitigation measures are designed with the future in mind and frequently show no immediate benefits. This gives rise to the problem of discovering and cultivating incentives for organizations and individuals to undertake hazard reduction programs. Even after initial steps are taken, sustaining interest and preparedness during extended periods between disasters requires careful study.

Further, responsibilities for hazard reduction and emergency response are distributed among many organizations and government agencies. This disparateness impedes coordination of efforts and often impedes effective hazard mitigation. Though a good deal of research has been devoted to finding ways to facilitate coordination, much remains to be learned.

Potential projects during the IDNHR include:

- development of guidelines for establishing acceptable risk and selecting hazard reduction strategies under varied economic and sociocultural conditions,
- a wide-ranging comparative study of the economic effects of various hazard reduction measures,
- development of guidelines for ensuring that the effects of hazard reduction programs on the community are shared equitably,
- a comparative study of the relationship between hazard reduction measures and major community values in diverse cultural settings,
- a comparative study of the political processes affecting the success of hazard reduction programs and development of suggestions for effectively dealing with these processes,
- selective study of situations in which traditional practices and cultural meanings impede potentially beneficial hazard reduction programs,
- development and dissemination of guidelines for disaster information programs and for release of hazard warnings based on study of conditions leading to public misunderstanding, mass panic, false-alarm disillusionment, and other counterproductive responses,
- development of guidelines for promoting community involvement, motivating organizational and individual participation, and sustaining interest and activity in hazard reduction programs, and

o development of manuals for achieving effective coordination among organizations involved in hazard reduction and disaster response.

INTERACTION OF MULTIPLE HAZARDS

Natural hazards often take place as multiple processes in which an initial hazard triggers secondary events. For example, an earthquake may trigger a submarine landslide, which in turn may cause a tsunami, with devastating effects. Or two or more hazards, although not directly related to each other, may occur at the same time in the same or adjacent localities, triggered by a common cause. For example, heavy precipitation may induce debris flows or mudflows along hillslopes at the same time that flooding occurs in adjacent river valleys. As mentioned earlier, several examples of such interrelated multiple hazard events stand out: the 1964 Prince William Sound, Alaska, earthquake (magnitude 8.4), which triggered tsunamis, local flooding, and many landslides; the killer cyclones in Bangladesh in 1970 and 1985, when wind and flood hazards combined to kill at least 300,000 and leave 1.3 million homeless; the 1980 eruption of Mount St. Helens in Washington, which occurred in association with earthquake activity, wildfire that consumed large tracts of timber, and rock-slide failure of the northern side of the volcano's cone, which in turn precipitated debris flows and floods up to 100 kilometers downstream; the 1986 Ecuadoran earthquake, which caused landslides and flooding due to the formation and breaching of natural dams; and the 1923 Tokyo earthquake, which caused a disastrous fire, killing 40,000.

Typically, natural hazard mitigation is undertaken on the basis of individual hazards. There are earthquake damage reduction programs, flood control programs, landslide stabilization programs, and other such programs. Though they possess many common features, they also have unique elements that may not be applicable to more than one kind of hazard. In addition, the same mitigative or response action may be generally applicable to different types of hazards, but may not be identical for each hazard. For instance, an evacuation plan may be appropriate for a number of different hazards, but routes may have to be modified to avoid low elevations during floods and hillsides during landslides. Building code requirements may deal with floods, earthquakes, landslides, and tornadoes, but the ideal requirement for structural walls may be different for each hazard. For example, a building elevated to avoid floods may be at greater risk from earthquake hazards.

Multiple-hazard mitigation can and should be viewed as a logical and necessary mechanism for overcoming the limitations of existing single-hazard mitigation programs. Hazard-interaction problems require a shift of perspective from the incrementalism of separate hazards to a broader systems framework. Increasingly, scientists, engineers, land use planners, and public officials are recognizing the existence of interactive hazards that may occur simultaneously or in sequence and may produce synergistic, cumulative impacts that are different from those of their separately acting component hazards.

LONG-TERM NATURAL HAZARDS

A group of important natural hazards can be distinguished from those described above because they are not typified by a rapid onset. Instead, these hazards are relatively slow in their onset but prolonged in their impact. Droughts, famines, epidemics, and desertification are well-known long-term disasters.

Drought may be defined as any unusual prolonged dry period. Though generally associated with semiarid or desert climates, they also occur in areas that normally enjoy adequate rainfall. Droughts are usually accompanied by dry, hot winds, and they may be terminated by violent storms.

The basic causes of drought are still not clear. It is generally believed that droughts are a consequence of changing global weather patterns triggered by such ecological events as solar radiation, excessive buildup of heat on the earth's surface, and increased particulate matter in the earth's atmosphere. Droughts are accompanied by reduced cloud cover, thus increasing exposure of the land to solar radiation. The result--increased transpiration and evaporation rates--tends to perpetuate the drought. Once established, these conditions are difficult to reverse.

Human activities also contribute to development of drought conditions. Overgrazing, poor cropping methods, deforestation, and improper soil conservation techniques often help to create a drought.

Desertification is a secondary effect of drought. Technically, desertification occurs when the soil reaches a given level of dryness. Simply stated, desertification occurs when land takes on the characteristics of a desert. It can mean the encroachment of sand dunes and the loss of most vegetation or replacement of normal vegetation with desert scrub bushes and other plants especially adapted to the desert environment. In either case, the land is rendered useless without large-scale and costly reclamation measures.

Fighting desertification is both costly and frustrating. Few developing countries have the resources necessary to stop this process once it takes hold, and reclamation successes have been rather limited. The best way to stop desertification is to prevent its initiation, and the best way to accomplish this is through comprehensive measures that address widespread economic and agricultural development.

Reducing the hazards of drought and desertification requires a balanced program that develops good water resources, addresses the problems of soil erosion, and adopts realistic limits on the expansion of animal herds, or accompanies the expansion of herds with comprehensive range management. Agricultural improvements to prevent these hazards include modifying cropping patterns and introducing drought-resistant crop varieties; rangeland management includes improvement of grazing lands and grazing patterns, introduction of feedlots, and protection of shrubs and trees.

Expansive soils—soils that exhibit large potential for shrinking and swelling with changes in moisture content—are another long-term hazard. Construction on these soils is extremely vulnerable to damage--even total destruction—as the ground surface elevation changes in response to seasonal fluctuations and rainfall. The problem is particularly acute in arid and semiarid regions. Shrinking and swelling soils are found in industrialized and developing nations alike. The total cost of damage associated with expansive soils is estimated at a minimum of $6 billion per year in the United States alone; it is the nation's most costly natural hazard. Extremely high costs are likely to be typical for many other nations as well. Though mitigation measures involving land use and building design are well known, they are often not applied due to ignorance, cost, and lack of enforcement.

5

ACTIVITIES FOR AN INTERNATIONAL DECADE

An activity of the scope of the IDNHR requires careful planning in the best spirit of international cooperation. The detailed planning and organization of the Decade is not the province of this report. However, this chapter explores activities of general importance to the conduct of the Decade, whatever its configuration. Topics include the nature of cooperative projects, facilitating communication at both the scientific and lay levels, and some suggestions for regional hazard facilities.

COOPERATIVE PROJECTS: ESSENCE OF THE IDNHR

Types of Cooperative Projects

A primary focus of the IDNHR is initiation of a wide range of cooperative projects designed to put into practice the knowledge that exists and to stimulate further cooperation and research. Cooperative activities between scientists and practitioners—those responsible for implementing hazard reduction measures—can be both domestic and international in scope. Possible cooperative projects generally fall into three categories:

- o the collection, dissemination, or application of existing knowledge and identification of gaps in knowledge,

- applied research that is problem-focused and aimed at filling gaps that have been identified, and

- new research that can yield additional knowledge for general application.

Projects That Apply Existing Knowledge

Research since World War II provides the technical capability to greatly reduce the number of deaths caused by natural hazards. For earthquakes, cyclones, and other rapid-onset events, most deaths occur in the Third World. Most of them result from the failure of improperly designed and constructed buildings. By simply distilling existing information and translating it into practical guidelines for improved construction, we can significantly improve the performance of even the most basic buildings. In a sense, the buildings that are least challenging have been ignored. Instead, attention is focused on the more complex and scientifically interesting structures. For example, high-rise, high-cost, and high-occupancy buildings have commanded the attention of the research community, and nonengineered buildings have received relatively little attention. During the International Decade for Natural Hazard Reduction, all sectors will receive more attention, increasing the application of knowledge to areas where results can be immediately attained and stimulating further work in the more complex building systems.

The safety of facilities whose failure would affect large populations—dams, nuclear power plants, pipelines, refineries, chemical processing plants, and others—will be improved by coordinating and codifying procedures for hazard assessment, risk analysis, and engineering design. This could be achieved through cooperative projects. Further, knowledge about disaster preparedness gained from individual disasters can be disseminated and applied worldwide through cooperative ventures. In addition, disaster data that now exist in individual countries and in different data files in a single country can be collected, processed, and disseminated through cooperative effort. This effort would benefit all concerned nations and help identify significant gaps in knowledge.

Problem-Focused Applied Research

Many problems attendant to natural hazards can be addressed through cooperative hazard mitigation projects that unite scientists and practitioners in activities that focus on common problems. For example, after identifying a particular problem area—such as using meteorological data to better prepare for an approaching hurricane—scientists and practitioners could then form a team to address the situation. The scientists would provide on-the-spot research to complement the ongoing implementation efforts of the disaster planning officials. In this way, the research/implementation/feedback process could be accelerated, and the projects could demonstrate positive results achieved within a reasonable time. This type of problem-focused project could be a key activity of the IDNHR.

Another example of problem-focused research relates to the earthquake safety of existing concrete dams. A safety analysis of an arch dam, for instance, requires data on seismic motions at the points of contact between the dam and the canyon floor and walls. These motions have never been recorded. A single country instrumenting some of its dams might have to wait a long time before recording the desired information. An international approach, with dams in various seismically active areas being instrumented, could provide the information much sooner.

New Research

The IDNHR will also stimulate major new research. Whether they are geophysical studies of tsunami generation or the development of a cooperative international program in strong earthquake motion measurement, the possible cooperative projects under the aegis of the Decade are numerous. Further, once attention focuses on the activities of the Decade, new topics will emerge. Be they scientific, technical, social, or administrative, many will require new research efforts and fresh approaches. By bringing researchers and practitioners together in a variety of forums, the IDNHR can generate new ideas and greatly enhance the state-of-the-art in all areas. International workshops organized around specific disasters or specific mitigation approaches will provide a structure for in-depth discussions to formulate new programs of crucial research.

The Scope of International Projects

The nature and scope of cooperative international projects will vary depending on the topic. For example, some geophysical projects require a regional approach and will involve scientists from several—often many—countries. The study funded by the United Nations on earthquake risk in the Balkan region in the 1970s involved hundreds of earth scientists from the region and from other participating countries. Possible regional projects include:

- o risk and hazard mapping,
- o geophysical studies,
- o climatic studies,
- o networks of data recording instruments, and
- o regional early warning networks.

On the other hand, projects designed to improve building performance must often be undertaken on a country-by-country approach. Sometimes they must be broken down even further within a country to interprovincial levels. However, even in these activities, building types tend to repeat—albeit with variations. The IDHNR will bring engineers, architects, and planners with practical experience in one country into contact with their colleagues in other countries to share their experiences. Possible projects include:

- o reducing the vulnerability of residential housing,
- o planning for disaster preparedness,
- o developing repair procedures for postdisaster reconstruction, and
- o formulating consistent building regulations, standards, and practices.

Experience from other internationally recognized decades (for example, the International Hydrological Decade and the Decade of Child Survival) shows that simply identifying a topic and designating it as a matter of international concern generates an unprecedented awareness of the subject and commitment to the issues by virtually every nation. For example, the United Nations estimates that, in the International Year of Shelter for the Homeless alone, over $1 billion in new projects has been committed worldwide. In a decade of expanded hazard reduction activities, with virtually every disaster-prone country carrying out new initiatives, the opportunities for cooperative activities, joint projects, technical exchanges, and new research are unbounded.

COMMUNICATION OF RISK

Improving Warning Systems

During the IDNHR, a major effort should be made to improve reliability of the warning system used for each natural hazard. Warning systems—some more reliable than others—exist for several hazards. The warning time available varies for each hazard, and different actions are possible according to the length of the warning. When the warning is up to a few minutes, as with some tornadoes, the appropriate actions are to seek shelter, avoiding areas where falling objects or debris may strike. When the warning is a few hours, as with predicted flood crests along a river, a community can activate emergency plans, reinforce protective works, and halt hazardous industrial processes. Still other circumstances may offer several days, weeks, or months of warning, as in the case of some volcanic eruptions. Further complicating the warning process is the fact that a hazard may affect only a few in the community, as with a riverine flood, or everyone, as with a hurricane. Obviously, each warning period and kind of community impact may require a different warning system to inform the community.

The tsunami warning system is an example of the need for improved reliability. The present warning system for the Pacific region is based on detecting a major earthquake, evaluating its tsunami-causing character in terms of the epicenter and magnitude of the earthquake, determining whether a tsunami has been generated, and evaluating the potential for damage at a particular site. The inaccuracies associated with this process result in a warning system of only limited reliability. For example, the Aleutian earthquake in the spring of 1986 resulted in a warning issued in Honolulu, Hawaii, that caused a chaotic evacuation for a tsunami of negligible amplitude. In its overall effect, this warning was worse than no warning at all. If the tsunami-causing character of the earthquake could have been evaluated more accurately, the warning would have been more appropriate to the real hazard posed.

Most often, physical models of the phenomena need improvement to provide timely warning for evacuation and other emergency responses. This need may mean that development of numerical models to predict, for example, inundation regions on a real-time basis is required. It may also mean that new measurement techniques need to be developed to provide basic data for these models.

Educational Programs

Education is at the core of any disaster mitigation program. Achievement of the IDNHR goals requires varied educational programs suited to a broad range of audiences. From initiating specialized graduate research programs to stimulating public awareness in remote regions subject to natural disasters, the transfer of knowledge is key to major success in hazard reduction.

At an early stage of the IDNHR, the full range of educational programs must be defined and resources assigned. Many of these programs will be unprecedented in scope and will require innovative design. Complex issues of social, economic, and language differences among participating countries present additional challenges.

Because public support for hazard mitigation is vital in all countries, a key activity of the Decade should be expanding public awareness of hazard reduction possibilities. However, achieving public support is not simply a matter of spreading the word. Ill-conceived public awareness campaigns can be ineffectual or even counterproductive. Obstacles to enlisting public support include ignorance of cultural and political factors, failure to understand the probable economic consequences of various mitigation measures, and the difficulty of achieving cooperation among organizations involved in hazard mitigation. Nonetheless, many countries have developed public awareness programs, and international exchange of communication techniques is a field in need of further development of ideas and methods. Possible cooperative projects include:

- public awareness and involvement activities,
- monitoring the economics of mitigation efforts,
- exploring culturally based reactions to disasters,
- improving cooperation among organizations, and
- providing information to planners and financiers of major construction projects.

To provide technical and scientific support for hazard reduction activities in future decades, new generations of engineers and scientists will need to be trained and motivated. Participating countries can benefit from organized exchange programs to bring students to areas where special mitigation expertise exists. To acquaint students with the professional opportunities and encourage their entry into this field, the Decade should stimulate a wide range of student activities. An example is the international engineering and planning competitions held as a prelude to the 1976 United Nations Habitat Conference in Vancouver, British Columbia. Students were encouraged to select a community that met given criteria and to develop model plans for upgrading the environment and living conditions. In the IDNHR, similar activities could be encouraged in order to involve students in developing workable solutions for specific communities or conditions—possibly in their own countries or in selected well-known hazardous situations.

Other types of educational programs to be considered as part of the IDNHR are:

- programs in hazard-prone countries, including local programs on implementing natural hazard reduction, development of materials in native languages, and workshops and seminars given by experienced mitigation practitioners,
- specific university curricula focused on natural hazard reduction, and seminars and workshops focused on actual practice of mitigation measures,
- personnel training and exchanges, involving practitioner exchange, student intern programs, and international student fellowship programs, and
- educational communication, including global satellite transmission of educational video programs and establishment of an international education exchange network using personal computers.

Information Exchange

Each natural hazard—whether it is an earthquake, flood, windstorm, landslide, wildfire, or volcano—has a unique set of data that identifies it. These data provide the basis for our understanding of the nature of hazards, the human response to them, and the effectiveness of previous mitigation measures. The more complete these data, the sounder the basis for future mitigation efforts. The data for each hazard falls into three broad categories:

o data describing the natural hazard event (for example, wind velocity measurements and strong motion earthquake recordings),

o data describing the damage impact of the hazard event (for example, number of buildings damaged or number of deaths), and

o data and information describing the institutional response to a hazard event (for example, emergency service and lifeline performance).

Ideally, all these data would be immediately available for each of the major natural hazards. For example, the ideal data set in these three categories for floods includes:

o the temporal and spacial distribution of the rainfall that caused the flood, o the temporal and spacial distribution of the flood, including the inundated area,

o the total property damage costs and the number of lives lost, and

o the performance of the flood warning system, the lifeline system, and the disaster relief organizations.

Building the capability for such data gathering and exchange is an appropriate activity for the Decade. To implement a complete information gathering system for each natural hazard requires networks of real-time data gathering instruments. They could be linked by satellite to a regional hazard reduction facility for rapid dissemination to all interested groups.

Complementing this emphasis on data gathering must be an equal emphasis on data handling and information flow. The great volume of data that already exists on natural hazards throughout the world has not been brought together into a usable, coherent system. Poor data quality, lack of standardization, outmoded data storage equipment, and the use of unvalidated analytical methods are all contributing factors. Yet the volume of new data expected during the Decade is enormous. If the activities of the Decade are to be a success--with information accessible to all--much attention must be given to handling and organizing these data into a useful information system. This system, together with tested analytical techniques, simulations, and risk/benefit methods, will provide the information base necessary for timely and appropriate actions.

Communicating this information also requires attention. A primary focus of the IDNHR will be to improve communication between researchers and those responsible for applying the knowledge gained from research.

New routes—such as clearinghouses—for disseminating data should be tested, and special education programs for planners, builders, emergency managers, and other professionals should be developed.

CONFERENCES AND COMMITTEES

Conduct of the international decade should include an organized series of meetings for planning and evaluating progress. Some will be large, with representation from many countries; others may be relatively small, involving representatives from only a few countries or a single country. Careful planning is required to ensure that the meetings are productive. Planning is particularly important in the initial phases of the IDNHR, when the overall scope of the program is formulated and directions established for individual hazards.

Each cooperating country should establish a national Decade for Natural Hazard Reduction committee for planning and coordinating national efforts. It is advisable that the national committee appoint a subcommittee for each natural hazard of concern, with each subcommittee represented on the national committee. The national committee should also have representation from national organizations, government agencies, the disaster preparedness community, and other concerned groups.

An international committee must be established, with representation from the national committees, to plan and guide international activities. An international planning meeting should be held as soon as possible to discuss the International Decade for Natural Hazard Reduction, to draw up guidelines, and to make recommendations.

APPENDIX

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