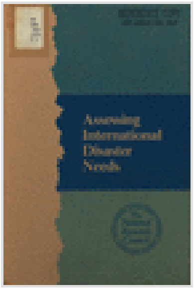

# Assessing International Disaster Needs (1979)

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# Assessing International Disaster Needs

Committee on International
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Commission on Sociotechnical Systems
National Research Council



NATIONAL ACADEMY OF SCIENCES Washington, D.C. 1979

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 to appropriate balance.

The 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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# Preface

The Committee on International Disaster Assistance of the Commission on Sociotechnical Systems, National Research Council, was organized in September 1976 under the sponsorship and with financial support of the Agency for International Development's Office of U.S. Foreign Disaster Assistance (AID/OUSFDA). The results of its first year's work were summarized in a report called *The U.S. Government Foreign Disaster Assistance Program*.

A central theme in that report was the need for substantial improvement in the information on which international predisaster and postdisaster decisions and actions are based. The Committee identified four particular areas in which improved information is needed: (1) hazard analysis, (2) vulnerability analysis, (3) disaster-relevant resource analysis, and (4) assessment of agent impact and victim needs.

As a result of discussions between the Committee and the AID/OUSFDA about a second-year contract, the Committee was asked to concentrate on the problems of predisaster hazard monitoring and postdisaster damage and needs assessment. This request was based on mutual recognition that future improvements in the administration of international disaster preparedness and assistance programs depend in large measure on improving such monitoring and assessment methods. Consequently, in September 1977, the AID/OUSFDA asked the Committee to review the current state of the art in ground surveys, aerial assessment, and remote sensing technologies for predisaster hazard monitoring and postdisaster assessment of damage and needs, with particular reference to natural disasters occurring in the developing nations of the world. Concurrently, the Committee was asked to review the international coordination problems related to these topics. This report deals with the work of the Committee in those areas. It should be noted, however, that the views expressed in the report are not necessarily shared by AID/OUSFDA.

The Committee clearly recognized the complexity of the problems and the impossibility of dealing with all of them comprehensively in a 1-year study. Thus the Committee chose to emphasize primarily the technologies and methods for improving assessment of damage and needs, rather than hazard monitoring, because the latter subject would have required much more comprehensive investigation. Similarly, the Committee chose to concentrate on problems of assessing damage and needs relating to health and human settlements rather than trying to cover the entire range of topics that should be included in systematic postdisaster assessments. That choice was influenced by the types of expertise available in the Committee membership and by the belief that it would be better to deal comprehensively with two subject areas rather than superficially with all types of damage and needs. The Committee believes, however, that its work in these two areas will demonstrate the usefulness of damage and needs assessment techniques in other areas.

Another limitation of this report relates to the scientific and scholarly standards that the Committee established for this investigation. It chose to give primary weight to well-documented, systematic research studies and to carefully prepared case studies. Although the Committee tried to identify and use such documentary evidence wherever possible, much of the experience with damage and needs assessment technologies and methods remains undocumented--as do the plans for their use by U.S., foreign, and international disaster assistance agencies. In the absence of adequate documentation, the Committee was forced to rely on its own collective experience, which is extensive, as the primary base for evaluating the current state of the art.

Finally, the Committee recognizes that analysis of the state of the art of damage and needs assessment techniques will not automatically lead to improvement in future disaster preparedness and assistance plans and operations. The developing nations differ greatly in their capacity to use these technologies and methods. Major efforts are needed to develop the necessary facilities, organizations, and trained personnel to apply the improved techniques detailed in this report. Those efforts will not be easy. They will require significant amounts of time, money, and other resources. The Committee believes, however, that cooperative arrangements among the developing nations themselves and between those nations and the numerous agencies involved in international disaster assistance can produce steady improvement in the capability for disaster damage and needs assessment throughout the world. If this report advances this process of cooperative collaboration, it will have achieved its essential purpose.

As Chairman, I thank the Committee members, individually and collectively, for the many months of hard work and creative energies that made this study possible. On behalf of the Committee, I also wish to acknowledge the invaluable assistance rendered by the Committee's staff: Charles E. Fritz, Executive Secretary, was largely responsible for launching the Committee's efforts; during the course of the present project, he continued to give valuable guidance based on his many years of experience in disaster research and his knowledge of National Academy of Sciences-National Research Council procedures. Alcira G. Kreimer, staff officer, was responsible for support of the daily work of the Committee and made many valuable contributions both to the analytical work and to the preparation of the final report. Helen D. Johnson, administrative secretary, and Sharon D. Carpenter, secretary, handled the many administrative tasks connected with this study with aplomb, cheerfulness, and efficiency.

RUSSELL R. DYNES, *Chairman*
Committee on International Disaster Assistance

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# Summary

When a natural disaster strikes a developing country, one of the difficulties international relief agencies and would-be donor governments have is knowing what kind of aid to supply. Disaster information gathering is therefore essential, and it involves more than a swift inventory of emergency needs in the days immediately following a catastrophe. For one thing, not all disasters are sudden, like earthquakes, floods, typhoons, or tsunamis; some are gradual, "creeping" disasters, such as drought and famine.

Whether the disaster is sudden or gradual, decision makers and planners need to find out what conditions in the stricken area were *before* the disaster, what local and national resources can be brought to bear without outside help, how the area's long-term development plans should affect rehabilitation and reconstruction in the disaster's aftermath, and what measures are needed to guard against further threats. Moreover, this information needs to go to the appropriate officials at local and national levels as well as the international level. Authorities at all levels in both public and private relief agencies need to coordinate their efforts based on whatever information they can amass.

## Purpose of Report

In pursuance of its previous work on the subject, the Committee on International Disaster Assistance was asked by the Agency for International Development's Office of U.S. Foreign Disaster Assistance (AID/OUSFDA) to evaluate various ways of collecting information about disasters and to examine problems of coordinating information gathering and distribution among the numerous international groups involved in disaster work. This report was specifically prepared for the AID/OUSFDA, but it is also intended for review by all appropriate international agencies and by officials in disaster-prone countries.

The Committee based its work on two assumptions: (1) that the purpose of international aid is to complement, not supplant, what the stricken country can do for itself, and (2) that such aid should help fulfill the individual country's overall societal goals rather than be aimed simply at helping individual victims.

The picture that has emerged from research is one of constraints on development of disaster preparedness programs, of great resourcefulness and adaptability of disaster-stricken communities, and of uncertain long-term effects stemming from disasters. The first-year report of the Committee, in fact, emphasized that the assumption that outside foreign assistance can be given quickly in most disasters should be seriously questioned. Foreign disaster assistance usually does not arrive in time to help during the immediate emergency, may not be relevant or usable when it does arrive, and its very presence may create further problems. Improved assessment of damage and needs can help minimize these problems and generate a more realistic and effective response.

## Information Needs and Problems

*Before* disaster strikes, information is needed for the following purposes: (1) identifying potential hazards and their characteristics, (2) hazard analysis and forecasting/warning systems, (3) vulnerability analysis of what and who is endangered, (4) preparedness planning, and (5) establishment of a baseline against which to compare conditions after a disaster has occurred.

*After* disaster has struck, the following information is needed: (1) type and size of disaster; (2) assessment of damage and needs, collected through existing channels, field surveys, or remote sensing; depending on the time elapsed since the disaster, this assessment should include data on such items as injuries, shortages, and losses of essential supplies and services, resources available within the country and region, further risks to survivors, and relief efforts already under way; and (3) monitoring and evaluation of reconstruction.

The Committee found a variety of problems pertaining to collecting data on disasters before and after they occur:

- Too often international relief aid has been geared for *total* needs in the stricken area, not taking into account resources that may already be on hand in the affected area and surrounding region. It is important to distinguish between total predisaster needs and the additional needs brought on by the emergency. In health, for instance, the first concern should be to find out what additional resources--health delivery personnel, medical supplies--are needed to meet the problems wrought by disaster. Requests for donations made on the basis of presumed or assessed total needs usually result in duplication and waste.
- It is a mistake to try to apply conventional management principles to data collection or relief work immediately following a sudden disaster because conditions are too chaotic. This confusion should be accepted as given when planning for the immediate aftermath of a disaster.
- Experts from industrialized countries have difficulty distinguishing disaster-related needs from chronic problems characteristic of developing countries. They may overstate emergency requirements because they falsely attribute to the disaster deficiencies in basic services and infrastructure, such as sanitation and water supplies, that were there long before. They also may impose standards wholly inappropriate for a developing area. (For example, following the Nicaragua earthquake, quakeproofing construction standards from California were adopted, but they proved too expensive for Nicaraguans to follow.)
- International relief agencies need better reports on what is already being done at the local level after a disaster occurs. Local response--in the disaster area itself--is generally better than commonly thought. Indeed, perhaps the most noteworthy but frequently overlooked characteristic of disaster-stricken communities is the emergence of considerable spontaneously organized social response on the part of many discrete groups, some previously existing and some entirely new. For example in Nicaragua after the earthquake the extended family proved to be one of the most important institutions in organizing networks of material and effective relief. In many cases it provided the aid that the government and official institutions were not able to provide at the emergency stage.[1]

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[1]See R. Kates *et al.*, "Human Impact of the Managua Earthquake," *Science*, Vol. 182 (1973), pp. 981-990; and A. Kreimer, "Post-Disaster Reconstruction Planning: The Cases of Nicaragua and Guatemala," *Mass Emergencies*, Vol. 3, No. 1 (March 1978), pp. 23-40.

With better information, international agencies can adjust their aid to handle only those needs that local resources are inadequate to take care of.

- Reports in the news media, which can influence the kind of attention both disaster agencies and the general public pay to a specific disaster, are sometimes inaccurate. Early but misleading reports can result in inappropriate and costly relief efforts. Disaster agencies need to help news media correspondents understand the dynamics of disasters and report events accurately. It is important, therefore, to know how news correspondents obtain their information under disaster conditions so as to suggest ways of improving their procedures.
- Despite recent efforts aimed at improvement, poor coordination among relief groups still causes duplication of effort in information gathering. Requests for particular supplies or services often arrive at the wrong agency at the wrong time.
- Too few persons from disaster-prone countries are now participating in information-gathering work. International disaster workers need the knowledge of citizens familiar with the area.
- Information-gathering technology must be appropriate to the technical level of the country being surveyed. Data requiring computer analysis, for instance, is useless if a computer is not available in time.
- Monitoring of the indicators of creeping disasters--water table levels, nutrition levels, desertification--has been inadequate.
- It has been demonstrated that food marketing and distribution problems can cause a famine as easily as does food shortage. Therefore more careful assessment of marketing patterns in endangered areas is needed.

## Methods for Collecting Data

In addition to existing channels for transmitting information on disasters, two other methods of gaining information offer promise.

*Field surveys* can be used profitably at every stage before and after a disaster. Such surveys have not been performed extensively, partly for lack of qualified personnel. At least four areas of investigation are suitable for field surveys: (1) ground surveys for food shortages, (2) epidemiological surveillance, (3) structural damage assessments, and (4) inventories of damage to "lifelines"--water supply, transportation links, and energy and communications systems.

*Remote sensing* can offer a panoramic view of the affected area, provide information on inaccessible sections, and serve as a convenient way to monitor changes over a large area. It is especially useful when conducted in conjunction with ground surveys. There are two ways of acquiring the information:

- *By aircraft*. Low-, medium-, or high-altitude airplanes can conduct aerial surveys with cameras or radar equipment. High-altitude planes, however, require special support not available in developing countries.
- *By spacecraft*. LANDSAT's and meteorological satellites can supply wide-coverage images. LANDSAT is excellent for monitoring gradual agricultural changes; the meteorological satellites can supply timely windstorm warnings. Neither, however, can see through clouds, a severe disadvantage in tropical areas. Radar satellites and Space Shuttle systems are still in the future.

Remote sensing techniques are not likely to prove widely useful for quick assessment of disaster damage and needs because the time required for acquisition and analysis is longer than the time normally required for decisive action. Remote sensing techniques have substantially greater potential for hazard and vulnerability analysis and for application during reconstruction.

## Summary of Recommendations

The following is a summary of the Committee's recommendations:

1. Professionals in disaster work should develop techniques for complete, accurate, and timely assessment of damage and needs following disasters, and for the improvement of baseline data on disaster-prone areas.
2. The AID/OUSFDA should promote increased use of field surveys and low-level aerial photography for quick damage assessments in developing countries and regions.
3. The AID/OUSFDA, UNDRO, and other agencies should set up pilot projects combining the use of ground surveys, aerial reconnaissance, and remote sensing to test the effectiveness of these techniques as information-gathering tools.

4. An international, multidisciplinary roster of experts on disaster assessment should be established by the AID/OUSFDA, UNDRO, and other international organizations. These individuals would stand ready to join assessment teams in case of disaster. The roster should include both persons from developed and developing countries.

5. The AID/OUSFDA should promote international distribution of information about disaster-related research conducted in the United States, in the international agencies, and in the developing countries.

6. Bilateral and international disaster assistance agencies should place more emphasis on preparedness programs to be managed by local authorities and professionals and on the establishment of disaster organizations in the developing countries.

7. Bilateral and international agencies should help establish training programs, academic courses, and other programs that will improve the ability of developing countries to deal with disaster. Wherever possible, such programs and courses should be conducted within the countries concerned.

# Introduction

In pursuance of its previous work,[1] the Committee on International Disaster Assistance of the National Academy of Sciences-National Research Council has been asked by the Agency for International Development's Office of U.S. Foreign Disaster Assistance (AID/OUSFDA) to review the uses and possible mixes of remote sensing, aerial assessment, and ground survey technologies for predisaster hazard monitoring and postdisaster assessment of damage and needs. Concurrently the Committee was asked to review international coordination problems related to these topics.

In this report, the Committee attempts to specify information needs tied to various disaster causes and circumstances, to review and compare the various techniques for collecting such information, and to suggest who should use the information at different levels of disaster response.

Both the uses and users of assessment data cannot be readily identified unless the interests and capabilities of various levels of disaster response--local, national, and international--are made explicit. Once these interests and capabilities have been clarified, the Committee can then suggest what groups could use the assessment information, how they could use it, how they might coordinate their activities, and what kinds of preparedness programs they might work on.

This report is addressed to the AID/OUSFDA, as well as to a varied audience in the disaster assistance community

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[1]Reported on in Committee on International Disaster Assistance (CIDA), Commission on Sociotechnical Systems, *The U.S. Government Foreign Disaster Assistance Program* (Washington, D.C.: National Academy of Sciences, 1978).

within the disaster-prone countries, in voluntary agencies, and at the international level.

## Background

The Committee on International Disaster Assistance has a broad mandate. In general, its goals are to review U.S. activities in international disaster work and to determine how scientific and technical knowledge can be used to help in this effort.[2]

During its first year the Committee attempted to define the term "disaster" and identified four different meanings that have historically been assigned to this term. The first meaning refers to disaster *agents* that have the potential for creating unfavorable changes within the environment; the second meaning refers to the *physical impact* of the agent; the third meaning refers to the *social impact* created by the physical impact; and the fourth meaning refers to the *evaluation* of the physical and social impact. No one definition covers the full range of phenomena that have traditionally been included under the rubric "disaster." The overall meaning involves the idea that some agent produces a major change in the environment by creating physical and social impacts. That change has to be defined as unfavorable by the victims, other groups, or by political and administrative units. That definition depends, in turn, on the particular interests and values that characterize the group or organization.[3]

Also during its first year, the Committee made a number of recommendations that need to be restated here as background for what follows. Following its examination of the U.S. government foreign disaster assistance program, the Committee recommended the following changes in emphasis:

- The OUSFDA should give greater consideration to operational and planning needs related to disasters involving conflict or slow onset.
- The OUSFDA should give careful consideration to developing stronger linkages between its disaster assistance program and the broader development programs at the AID.

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[2]See CIDA, *The Role of Technology in International Disaster Assistance* (Washington, D.C.: National Academy of Sciences, 1978).

[3]See CIDA, *The U.S. Government Foreign Disaster Assistance Program, op. cit.*, p. 24ff.

- The OUSFDA should give greater budgetary support to the disaster planning and preparedness activities of its technical assistance program.
- The U.S. government should adopt a multiphased disaster assistance program that ties the commitment of funds to a more systematic evaluation of needs. The assessment of needs should be accomplished under international auspices.

The Committee then made a series of suggestions concerning the value of site visits, information needs, reporting systems, and data banks that were directed primarily to internal operations within the AID/OUSFDA. Finally, the Committee made the following suggestions:

- That the AID/OUSFDA should give high priority to research to develop better and more reliable measurements of disaster impacts and of societal and international responses to these impacts.
- That the AID/OUSFDA should work toward establishing organizational mechanisms at the international level for exchanging policy-related research information on disaster prevention, mitigation, and response.[4]

## The Focus of This Report

Building on the previous work, the Committee here focuses on the role of science and technology in supplying information to assist in assessing disaster damage and needs in developing countries.

When a disaster occurs, important decisions have to be made about evacuation, relief, rehabilitation, and reconstruction. In order to take action, disaster assistance groups need information quickly; yet in the chaos following a calamity, accurate information may be hard to get. First-hand observation may be impaired, channels of communication disrupted, and urgently needed information delayed.

The mass media of communication play an important role in this situation. The news media can transform a local

[4] *Ibid.*, pp. 64-84.

disaster into a national or international event.[5] The media "create" information--often incompletely or inaccurately--that is quickly transmitted around the world, to be used by different groups in different ways. The initial lack of information followed by the excess of contradictory information often leads to inappropriate responses and confusion among the victims and the numerous outside agencies trying to assist them. Improvements in disaster assistance will require more effective use of scientific and technical knowledge by all groups and agencies concerned, as well as the development of predisaster information and implementation of preparedness programs by the disaster-prone countries.

The questions the Committee addressed during its second year were these:

What methods are most effective for collecting information--

- in different types of natural disasters, both sudden (e.g., earthquakes, floods, hurricanes) and gradual (e.g., droughts and famines)?
- during different periods or stages of disaster, from prediction to rehabilitation?[6]
- under different social, political, and technological contexts?

How can the information be assessed--

- for its usefulness in evaluating disaster damage?
- for identifying the needs created by the damage?

How can the information be made most useful to decision makers--

- in the country where the disaster occurs?

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[5]See E. Rogers and R. Sood, "Mass Communication in Disasters: The Andhra Pradesh Cyclone as an Example of Mass Media Coverage of a Disaster," paper presented at a meeting of the Committee on International Disaster Assistance, National Academy of Sciences-National Research Council, Washington, D.C., May 1-2, 1978.

[6]Although the Committee's concern includes all disaster stages, the major emphasis in this report is on the immediate postdisaster period. The Committee identified this task in its first-year report as a basic area both for study and for making decisions concerning the commitment of funds. See CIDA, *The U.S. Government Foreign Disaster Assistance Program, op. cit.*

- in governmental and nongovernmental agencies that might provide disaster assistance?
- in international agencies?

The ultimate goal is to develop a better information system for disaster preparedness and assistance both within the country and by international donors. The broad nature of these questions suggests the necessity of using knowledge and skills from a variety of fields, including the biological, physical, and social sciences, and medicine and engineering. International disaster assistance requires (1) the application of scientific and technical knowledge to human problems and (2) the active participation of experts from both developed and developing countries who have had experience in administering disaster programs (preparedness, prevention, mitigation, relief, rehabilitation, and reconstruction) in different organizational settings. Although in recent years the efforts and resources devoted to assistance have increased and substantial attempts have been made to reduce knowledge gaps, the state of the art of data collection techniques remains uncertain, and the question of how to combine data collection techniques is just beginning to be investigated. Problems related to collecting information on pre- and postdisaster assistance deserve particular attention.

Two basic premises underlie the Committee's work:

*1. A central objective of international disaster assistance is to complement--not supplant--the efforts and resources of developing countries to cope with the effects of disasters.*

The attainment of national self-reliance is a primary goal for disaster assistance programs. External contributors should aim to meet only those needs that the developing nations cannot handle alone. Developing nations, in turn, should aim to strengthen their internal resources and capabilities to reduce their need for future external assistance. The assistance provided by international, bilateral, and voluntary agencies should:

- *support* existing local capabilities by helping disaster-prone countries prepare for and cope with disasters themselves, and
- *complement* local capabilities by providing supplies, financial support, or specialized and technical skills unavailable locally.

*2. External disaster assistance should be adapted to the context and available resources of each country, to the correction of endemic problems, and to the fulfillment of basic societal needs rather than to individual victim needs.*

In many cases, external relief efforts based on the experience and traditions of highly industrialized countries have proved culturally and structurally inappropriate to developing countries. As a consequence, the disaster-stricken society has been doubly disrupted by having to deal not only with internal losses but also with cultural adaptations to an alien system for replacing the losses. Relief and rehabilitation programs should be oriented toward correcting endemic unsanitary conditions, deficient nutrition, inadequate health care, poor housing, and inadequate basic services. Such an approach could help reduce the country's vulnerability to future disasters and its dependence on outside assistance.

# 1 Information Needs in International Disasters

Understanding the problems involved in assessing damage and needs requires a preliminary understanding of the international disaster context and its complexities. When disaster occurs in a developing country, people around the world--individuals, officials in voluntary agencies, officials in government and international organizations--consider ways to help. Different organizations and nations often make independent decisions on how to act--decisions conditioned by the characteristics of the society in which the disaster occurred (its culture, politics, and level of technological development) as well as by the needs created by the disaster. The following discussion elaborates on some of the complexities posed by disaster in an international context.

## Social Behavior After a Disaster

Most of the vocabulary about disasters refers to sudden calamities. Tornadoes, earthquakes, and explosions all generate much media and political attention, because all produce obvious, easily observable results. Conversely, much less attention is paid to slow-onset, "creeping" disasters, such as drought or famine. But research is needed on ways to monitor such disasters and to mitigate their effects.

Speed of onset is, of course, an important variable in collecting information.

Past research has not developed a consensus on how to measure the effectiveness of different types of disaster response--with or without preparedness programs and with or without outside assistance--during different lengths of time. Research has provided, however, a more realistic picture of the pre- and postdisaster environments of communities affected by sudden disasters such as earthquakes, tornadoes, floods, and hurricanes.[1] Research has also helped dispel common misconceptions about human behavior in disasters and has documented problems of implementing disaster preparedness measures in local communities[2]-- and the resilience of local communities when disasters occur.[3] Research has suggested that disasters do not necessarily prompt long-term organizational and community changes.[4] The general picture that emerges from previous research is one of constraints on the development of disaster preparedness programs, of great resourcefulness and

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[1]See C. E. Fritz, "Disaster," *Contemporary Social Problems*, R. Merton and R. Nisbet (eds.) (New York: Harcourt, Brace, and World, 1961); R. R. Dynes, *Organized Behavior in Disasters* (Lexington, Massachusetts: D. C. Heath and Company, 1970); and E. L. Quarantelli and R. R. Dynes, "Response to Social Crisis and Disasters," *Annual Review of Sociology*, Vol. 3 (1977), pp. 23-49.

[2]An important study of the constraints on the development of state and local preparedness programs in the United States is the ongoing research by P. H. Rossi *et al.*, *Research Program on Natural Disasters Recovery Process: Relief, Rehabilitation, and Preparedness* (Washington, D.C.: National Science Foundation Project No. AEN 76-15441, 1977). See also J. M. Weller, *Organizational Innovation in Anticipation of Crisis*, Report Series No. 14 (Columbus, Ohio: The Ohio State University, Disaster Research Center, 1974).

[3]See F. L. Bates, *The Social and Psychological Consequences of a Natural Disaster: A Longitudinal Study of Hurricane Audrey*, Disaster Study No. 18 (Washington, D.C.: National Academy of Sciences, 1963). See also Fritz, *op. cit*.

[4]See Weller, *op. cit.*; and W. A. Anderson, *Disaster and Organizational Change: A Study of the Long-Term Consequences in Anchorage of the 1964 Alaska Earthquake*, Monograph Series No. 6 (Columbus, Ohio: The Ohio State University, Disaster Research Center, 1969). The previously noted Rossi study is also examining the long-term effects of disasters in the United States via analysis of small area census data. See also the ongoing study by F. L. Bates *et al.*, *A Longitudinal and Cross Cultural Study of the Post-Impact Phases of a Major National Disaster: The February 6, 1976, Guatemalan Earthquake* (Washington, D.C.: National Science Foundation Project No. ENV 77-12721, 1977).

adaptability of disaster-stricken communities, and of uncertain long-term effects stemming from disasters.

Perhaps the most noteworthy (but frequently overlooked) characteristic of disaster-stricken communities is the emergence of considerable spontaneous yet highly organized social action.[5] Disaster relief officials tend to describe disaster response in terms either of the community as a whole or of specific individuals. This tendency excludes the numerous discrete, organized responses to disaster, which comprise an element crucial to our understanding. Organized responses may come from small emergent groups or large, complex bureaucracies. These various types of organized responses not only are the primary means through which communities respond to disasters, but also they shape most individual responses.[6]

Research has suggested that the postdisaster environment is extremely complex. A disaster-stricken community faces problems requiring rapid and extensive departures from routine activities. Patterns of group membership and activities change rapidly and significantly. More broadly, the panorama of interlocking groups and organizations shifts as new groups emerge and existing groups undertake new activities, or temporarily cease to act.[7] It is certainly possible to interpret this complexity as "social disorganization."[8]

In this light disaster management becomes primarily a rational tool to impose control in anticipation of chaos. Thus emergency tasks must be clearly thought out ahead of

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[5]See, for example, T. R. Forrest, "Group Emergence in Disasters," and R. A. Stallings, "The Structure and Patterns of Four Types of Organizations in Disasters," *Disasters: Theory and Research*, E. L. Quarantelli (ed.) (London, England: Sage Publications, 1978).

[6]See G. A. Kreps, "The Organization of Disaster Response: Some Fundamental Theoretical Issues," *Disasters: Theory and Research*, E. L. Quarantelli (ed.) (London, England: Sage Publications, 1978); J. M. Weller, "Interorganizational Relations and Organized Response to Disaster Environments," *Proceedings of the Japan-United States Disaster Research Seminar* (Columbus, Ohio: The Ohio State University, Disaster Research Center, 1972); and Dynes, *op. cit.*

[7]See Kreps, *op. cit.*

[8]See Fritz, *op. cit.* See also R. R. Dynes *et al.*, *A Perspective on Disaster Planning* (Washington, D.C.: Defense Civil Preparedness Agency, 1972).

time. Resource requirements must be anticipated, and procedures for acquiring and allocating resources established. Responsibility for continuing assessment of the emergency must be assigned. Communications arrangements and facilities must be set up. Coordination is of paramount concern. In effect, this approach assumes that rational management techniques should be superimposed on the spontaneous, informal social activities that emerge in the disaster's aftermath.

Such rationalistic behavior models, popular in "systems" approaches to problem solving, have been suggested for handling organizational problems in disasters. Research has made it clear that much of the short-term social action in communities struck by disaster, however, simply does not fit the traditional conceptions of organized behavior. Certainly established organizations (military services, hospitals, departments of public works) routinely perform preestablished tasks during disaster situations, but these organizations also engage in a variety of nonroutine disaster-relevant activities. Moreover, many organizations that have no preestablished disaster responsibilities will nonetheless respond actively to disaster if they happen to be in a position to help. A catastrophe will also generate new groups, formed specifically to deal with the effects of the disaster.

The point here is that static organizational concepts are inadequate for describing the spontaneous, but short-lived organizing that a disaster triggers. This organized activity may be nonroutine, irregular, and difficult or impossible to predict with any precision, but there is no reason to assume it is less rational or utilitarian than conventional social arrangements. Indeed, *ad hoc* organizing is a tremendously important resource for societies struck by disaster--a resource generally ignored by the "systems" approach.

## International Disaster Assistance

To collect better data on all phases of disaster, the complex variables and differences among countries should be recognized. Developing countries differ in the degrees to which they are prone to disaster; some have diverse and repetitive disasters, while others only infrequent ones. Disasters vary in terms of their frequency, predictability, controllability, speed of onset, length of forewarning, duration, scope of impact, and disruptive potential. Some countries need and welcome most types of external assistance; others refuse all outside assistance whether needed or not. Moreover, the levels of technology in developing nations differ considerably.

The preceding section provided a general characterization of the local social response in disasters that was based mostly on research conducted in highly developed societies. Caution must be exercised in applying these research findings to the developing countries, whose low resource base may make it exceedingly difficult for them to cope with disasters. Disaster-induced problems in the developing countries may be compounded by overpopulation, by inadequate physical structures and infrastructures, and by basic problems of social, economic, and political development. Lack of resources complicates even minimal prevention and preparedness activities and thus may increase a country's vulnerability to natural disasters. Lack of resources also makes disaster-struck communities less capable of recovering without outside help.

But problems in implementing prevention and preparedness programs are not unique to developing countries. Although lack of resources is an obvious constraint, there are other problems that have little to do with degree of development. Defining a capability to respond to or to recover from disaster depends, of course, on the standards being used, and such standards have not been explicitly stated or employed in either developed or developing societies. Thus the precise relationship between disaster preparedness and response is unknown.[9]

The economic and material resources and technical capabilities of developing countries, taken as a whole, differ in character as well as quality from those of developed nations. It is certainly appropriate on humanitarian grounds to suggest that relatively developed societies have a responsibility to help when they can. Given the lack of agreement about standards for evaluating response

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[9]The recent attention given preparedness programs as a form of international disaster assistance is based largely on the assumption that national and international preparedness is beneficial for solving disaster-generated problems. For a useful discussion of preparedness principles applied to disasters, see F. Krimgold, *The Role of International Aid for Predisaster Planning in Developing Countries* (Stockholm, Sweden: Arkitektursektiones tryckeri, KTH, 1974).

to disasters in varying social, economic, political, and cultural contexts, however, it is hard to make informed judgments about how well different societies can cope with disasters. Moreover, in the absence of systematic research on disasters occurring in developing countries, a discussion of basic societal differences sheds little light on the ways various societies respond to disaster.

The Committee believes that more knowledge of response patterns in developing countries would help external groups understand how they could best help. The Committee believes that generally developing societies, as well as developed societies, respond effectively immediately after sudden natural disasters.[10]

This characteristic "active" response has fortunate policy implications for purposes of international disaster assistance, because, as noted in the first-year report of the Committee on International Disaster Assistance, the assumption that outside foreign assistance can be given quickly in most disasters should be seriously questioned.[11] Also, according to the report, there is usually little need for donor nations to respond with costly, undifferentiated, and uncoordinated international disaster aid. In general, a slower, more studied response to disasters will yield better, more useful aid. Foreign disaster assistance does not usually arrive in time to help during the immediate emergency, it may not be relevant or usable when it does arrive, and its very presence may create further problems. Improved assessment of damage and needs helps minimize these problems and, more important, generates a more realistic and effective response.

Timing is not the only consideration. Organizational problems are compounded by the increased number of participants and interests at local, national, and international levels.[12]

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[10]It must be noted that little social science research exists on so-called creeping disasters.

[11]See CIDA, *The U.S. Government Foreign Disaster Assistance Program, op. cit.*

[12]These problems have been suggested or documented throughout the literature on foreign disasters. See, for example, the following three reports by the Comptroller General of the United States, each published by the U.S. Government Printing Office: *Need for International Disaster Relief Agency* (1976), *Observations on the Guatemala Earthquake Relief Effort* (1976), and *Nicaragua: An Assessment of Earthquake Relief and Reconstruction Assistance* (1977).

The public and private organizations involved in international disaster assistance number in the hundreds. In the past 15 to 20 years, both the volume of international disaster assistance and the number of participants have expanded greatly.[13] Much of this outside assistance has, in fact, become bureaucratically organized. Thus government-to-government assistance entails some formal mechanism, such as the AID/OUSFDA, to keep track of commodities and services being supplied by various agencies of government and the private sector.

This approach is also characteristic of the major voluntary agencies, whether they are cooperating with or working independently of their own governments. In particular, foreign governments and voluntary agencies that have ongoing development operations in the stricken country are able to get information about the disaster reasonably quickly through their own channels. United Nations agencies and the League of Red Cross Societies have their own international communications network. In addition to the Office of the United Nations Disaster Relief Coordinator (UNDRO), UN agencies concerned with disaster-related matters include (1) the United Nations Development Programme (UNDP), which is mainly concerned with development but whose resident representatives in developing countries also represent the UNDRO; (2) the United Nations Children's Fund (UNICEF); (3) the Food and Agriculture Organization (FAO); (4) the World Food Programme (WFP); and (5) the World Health Organization (WHO).[14]

Moreover, many private agencies, both permanent and *ad hoc*, respond to disasters, sometimes without benefit of preexisting operations in the disaster-stricken country and without adequate communication channels to apprise them of the disaster-induced needs.

## Managing International Disaster Assistance

Serious coordination problems usually develop as materials and services reach a disaster-struck country.[15] Yet no

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[13]See CIDA, *The U.S. Government Foreign Disaster Assistance Program, op. cit.*

[14]See League of Red Cross Societies, *Red Cross Disaster Relief Handbook*, Annex 4 (Switzerland: League of Red Cross Societies, 1970).

[15]The reference here is to a set of problems (e.g., unneccessary duplications, irrelevant goods, severe logistics

organization other than the government of the stricken country has the authority to coordinate or control external relief activities, although sometimes coordination is delegated to a quasi-government organization such as the Red Cross. At times, governments refuse to accept outside assistance.

Disaster relief agency professionals generally believe that disaster operations can be improved by applying rational management principles--that local, national, and international disaster responses can be coordinated through improved disaster management and preparedness. Given the complexity of foreign disaster situations, the Committee believes that it is necessary, first, to specify at what levels and for what purposes the management principles can be employed.

The role of external assistance in planning for *local* responses in developing countries is limited by conditions in local communities. All but the smallest and most isolated communities have local disaster-relevant organizations that could benefit from disaster preparedness programs. But these organizations' levels of preparedness cannot be readily influenced by national and international forces. There are simply too many other immediate problems that compete for attention in developing countries. Thus, the feasibility and benefits of preparedness activities at this level are limited.

International disaster preparedness assistance has therefore seldom been offered to local communities in developing societies; for obvious political and practical reasons, such activity has been directed to the national government level and, more recently, to geographic regions. Without a preparedness program within the recipient country, however, it is difficult to get maximum benefit from external disaster aid, because those with authority to coordinate or control outside assistance may not have the ability to do so.

There are obvious disaster management needs at the bilateral donor country and international disaster assistance levels as well. However, coordination problems among local areas, national governments, and the international community are numerous. Preparedness programs and disaster management

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problems) related to the delivery of external goods to the impact country during the emergency period. These are discussed fully in CIDA, *The U.S. Government Foreign Disaster Assistance Program, op. cit.*

generally consist of a shopping list of things to do rather than an evaluation of measures that can be feasibly undertaken at local, national, and international levels.

The Committee believes that the management objective of coordinating the various groups and organizations involved at these levels is too narrow. The diversity of persons, interests, and behaviors involved in disaster response should be taken as *given* and not as problems that can be overcome by rational planning. The *ad hoc*, unique nature of communications and coordination arrangements among public and private relief agencies in each disaster must be assumed. The potential unwillingness of voluntary agencies and governments to coordinate their activities should be accepted as inevitable. The cultural differences and political sensitivities of recipient nations must never be overlooked. And the impossibility of applying efficiency and effectiveness standards should be recognized.

The position taken in the previous report of the Committee uses the U.S. government's disaster assistance program as a case in point. The report concludes that the role of any single donor nation in a foreign disaster is inherently limited during the emergency period, and recommends that the initial commitment of U.S. government funds in any foreign disaster should be held to a fixed and modest limit. The report further recommends that any commitment of funds beyond this modest limit should be tied to a systematic needs assessment accomplished under international auspices.[16]

The principle that the type of disaster assistance should be appropriate to the level of response--in this case, a donor government--suggests at least three activities for the U.S. government's foreign disaster assistance program:

- The U.S. government should technically augment and administratively support needs assessment processes.
- The U.S. government should improve predisaster coordinative relationships with the appropriate international agencies so that needs assessment data can be made readily accessible and interpretable.

[16]See CIDA, *U.S. Government Foreign Disaster Assistance Program, op. cit.*, pp. 69-70. Recommendation 4 reads as follows: "The U.S. government should adopt a multiphased disaster assistance program which ties the commitment of funds to a more systematic evaluation of need. The assessment of needs should be accomplished under international auspices."

- By the policy articulated in Recommendation 4 of the previous CIDA report, any major U.S. government disaster assistance program should be tied to long-term rehabilitation and reconstruction programs in the disaster-stricken society.[17]

Preparedness planning that bases reconstruction programs on disaster prevention principles would enhance the long-term benefits of the U.S. government's aid. Representatives from disaster-prone developing countries should help with such planning.

This policy is proposed in recognition that (1) disaster responses are defined by a multiplicity of interests (including humanitarianism and politics), capabilities, and constraints; and (2) the resulting diversity cannot be accommodated by strategies intended for single organizations having highly focused objectives.

In sum, the Committee believes the best approach is to accept this diversity as given, and then try to determine possible disaster responses according to the interests, capabilities, and constraints of the type of agency responding.

## Questions About External Disaster Assistance

To improve postdisaster decisions about international external assistance efforts, a number of questions need to be asked.

First, does the disaster call for international assistance? The answer might be no, if the disaster is so small in scope that any country could handle it alone, or could ignore it without peril; or if the country is highly developed and can manage on its own; or if the country is confident of its ability to respond to crises and unwilling to accept help from outside. If the country does not have the resources to cope by itself, the answer will probably be yes.

Second, if international assistance is called for, should the United States directly intervene? If the country is of no particular strategic or military interest to the United

[17]It should be noted that, within expenditure limits, the AID/OUSFDA would still channel money and services for short-term emergency relief while it developed its own longer-term rehabilitation assistance program.

States, routine indirect assistance throughout UNDRO, for instance, may suffice. Also, the stricken country's government may deny that any disaster exists--but such denials may not preclude backstage diplomacy through voluntary agencies.

Third, are there any positive inducements for U.S. intervention? There may be pressures to intervene if the United States has sentimental (e.g., Ireland, Philippines) or military-strategic (e.g., Turkey, Iran, Horn of Africa) ties to the affected country; or if there are groups within the United States (Congress, mass media, interest groups, ethnic associations) pressuring for a response.

Fourth, is the disaster likely to disrupt normal institutions, such as the food distribution and health delivery systems, in the affected society? If the answer is no, only a limited response mainly in cash and credit, rather than in kind, may be called for. Limited responses will allow the normal mechanisms within a society to revive. If the answer is yes, the response may require sending materials such as food, medical supplies, and critically needed equipment.

These questions provide a framework for analyzing different disasters and the responses they call for. Another set of specific questions deal with situations in which help is provided and concern the techniques that can be used for assessment of damage and needs. What techniques are particularly reliable and valid? Which methods provide the most relevant information?

The effectiveness of methods is only one part of the picture. Certain methods may be technically effective but require too high a level of technology. At certain stages a combination of methods may be required. A basic question is: How does one measure disaster-induced changes? Technically, what are the indices of change that should be measured--housing damage, damage to crops, death rate, injury rate, level of protein intake, disruption of transportation routes, destruction of food supply, damage to communication facilities, or what? In addition, what measures are capable of showing small gradual changes, perhaps imperceptible to the untrained eye? Can ecological changes in vegetation, water level, or soil moisture signal the onset of famine? Can socioeconomic changes in supply, marketing techniques, and warehousing signal the onset of drought and thus presage famine? Can similar measures be used to measure changes over a shorter period of time? For example, are there signs that presage volcanic eruptions or earthquakes?

For sudden disaster, are the obvious indicators of damage the most important ones? Much is made, for example, of obvious housing damage, but housing may be replaced in a short period of time while the damage to the public utility network may cause more serious, long-term problems. Serious damage to a community's water supply might also be an important indicator, because such damage could trigger not only shortages of water, but also sanitation deficiencies and contamination.

# 2 Information Needs for Predisaster and Postdisaster Decision Making

This chapter focuses on the many different types of information needed for making decisions before and after disaster. The chapter also discusses the special problems of collecting information in developing countries and the role the news media play in disseminating disaster information.

The collection of information on damage and needs is closely related to predisaster and postdisaster data gathering. Problems associated with the predisaster period are discussed first.

## Predisaster Period

*Hazard analysis* and *forecasting* and *warning* require large amounts of data, which are sometimes hard to collect because of inadequate knowledge of the hazard. For instance, climatological studies require collection of considerable data on meteorological conditions and changes in a wide geographical area over a long period of time. Similarly, earthquake hazard analysis requires long-term seismographic monitoring programs to provide data that can be expressed on maps depicting seismicity, seismic risks, earthquake faults, and other geologic hazards. These maps are based on probability estimates developed from frequency analysis of historical data.[1] Thus hazard analysis depends not only on large amounts of data, but also on scientific judgment and a variety of methodological tools.

Even when all these elements are present, as in the United States, accurate forecasting of specific hazards is still difficult. For instance, prediction and detection of tornadoes and destructive wind are still uncertain; tsunami prediction is limited by lack of knowledge of the hazard; avalanche prediction is only partially developed; hurricane forecasting is possible, although prediction of storm movement could be upgraded; and earthquake prediction and forecasting are still in an embryonic stage.[2] Using these partially developed techniques in developing countries is further complicated by limited data, inadequate systems for monitoring and data collection, and inadequate funds, facilities, and personnel to support the necessary research.

Forecasting and warning systems for famines present similar problems. Famine might be considered a creeping disaster insofar as some societies have proved that they can survive several years of low production without experiencing severe social disorganization. Yet when drought strikes unexpectedly, a single crop failure may be enough to produce starvation and a relatively sudden mass migration. Under such conditions a famine becomes a relatively fast,

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[1]See Committee on International Disaster Assistance (CIDA), Committee on Sociotechnical Systems, *The U.S. Government Foreign Disaster Assistance Program* (Washington, D.C.: National Academy of Sciences, 1978), pp. 38-43; United Nations Educational, Social, and Cultural Organization, *Intergovernmental Conference on the Assessment and Mitigation of Earthquake Risk* (Paris, France: UNESCO, February 1976); R. A. Kerr, "U.S. Earthquake Hazards: Real but Uncertain in the East," *Science*, Vol. 201 (September 15, 1978), pp. 1001-1003; and C. Lomnitz, *Global Tectonics and Earthquake Risk* (New York: Elsevier Scientific Publishing Company, 1974).

[2]See G. White and E. Haas, *Assessment of Research on Natural Hazards* (Cambridge, Massachusetts: The MIT Press, 1975); and Working Group on Earthquake Hazards Reduction, Office of Science and Technology Policy, Executive Office of the President, *Earthquake Hazards Reduction: Issues for an Implementation Plan* (Washington, D.C.: Office of Science and Technology Policy, 1978).

sudden-onset disaster.[3] Famine, which may of course be an endemic problem due to long preexisting causes as well as to misguided development policies, requires not only emergency assistance after the disaster, but also implementation of plans ahead of time to avoid these costs.[4] Long-term monitoring of food production and consumption is the key to forecasting this problem, but monitoring has not been done in most developing countries. In addition to meteorological methods and crop surveys, anticipating a famine may also require data on the prevalent food marketing system, on local mechanisms for adjusting to drought, on the degree to which land tenure systems contribute to desertification (e.g., erosion caused by peasants forced out of the valleys to marginal slopes),[5] on the consequences of government policies on nomad settlement, and on the effects of ill-conceived development plans implemented by donar agencies and governments.

*Vulnerability analysis* involves collecting and assessing data on the endangered population and structures, including information on the performance of buildings and lifeline systems during previous disasters.[6] Insufficient financial, physical, and socioeconomic resources tend to increase vulnerability.[7] Because most disaster-prone developing countries have limited financial resources, they cannot afford to build protective structures and undertake other necessary preventive measures.[8] But measures to reduce vulnerability need not be structural; they may include public education,

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[3]See J. Seaman *et al.*, "The Effects of Drought on Human Nutrition in an Ethiopian Province," *International Journal of Epidemiology*, Vol. 7, No. 1 (1978), pp. 31-40.

[4]See H. Sheets and R. Morris, *Disaster in the Desert: Failure of International Relief in the West African Drought*, Special Report (Washington, D.C.: The Carnegie Endowment for International Peace, 1974.)

[5]See R. Sharpe, "Desertification: Another Mirage," *Nature*, Vol. 269 (September 1977), pp. 367-368.

[6]See CIDA, *The U.S. Government Foreign Disaster Assistance Program*, *op. cit.*, pp. 43-47.

[7]See M. Pyke, *Man and Food* (New York: McGraw-Hill, 1970); and N. Scrimshaw, "Ecological Factors in Nutritional Disease," *American Journal of Clinical Nutrition*, Vol. 14 (1966), p. 112.

[8]See United Nations Disaster Relief Organization, *Disaster Prevention and Mitigation: A Compendium of Current Knowledge* (New York: UNDRO, 1977).

environmental management, land treatment, reforestation, erosion control, land use regulation, and coastal zone management. Measurement of vulnerability is hard to achieve, particularly in certain areas. Vulnerability analysis requires data on the size and geographic distribution of the population, buildings, infrastructure, and public utilities in order to measure catastrophic loss potential and vulnerability to secondary losses.[9] Measurements that expose problems may not be acceptable in many countries because of the political repercussions they could generate.

In addition to information on risks and vulnerability, adequate preparedness and programs to mitigate risks require knowledge of standing disaster plans in different disaster-prone countries; operational capabilities to carry out the plans; emergency facilities and equipment; historical patterns of disaster in each area; and existing health, communication, land use patterns, building practices, and transportation systems.[10] Predisaster data requirements also include a baseline profile on each country.

## Postdisaster Period

Ideally, assessment of damage and needs should be based chiefly on the baseline data just described. When insufficient data are available, prior experience in similar situations may prove helpful for making inferences. It is important to remember that the solutions adopted after assessing disaster damage and needs may have long-range consequences. It has been found, for example, that temporary housing tends to become permanent, that the relocation of a rural population may generate a shortage of agricultural labor, and that a program of food distribution may alter the market organization and thereby adversely affect the population. Thus there are two methodological problems: (1) to develop a gross accounting of the damage and a preliminary assessment of needs; and (2) to assess the relationship between immediate needs and long-term development plans.

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[9] See CIDA, *The U.S. Government Foreign Disaster Assistance Program*, *op. cit.*, pp. 43-47.

[10] See United Nations Disaster Relief Organization, *op. cit.*; and National Bureau of Standards, *Building Practices for Disaster Mitigation*, Building Science Series No. 46 (Washington, D.C.: NBS, 1973).

The first problem can usually be resolved quickly by measuring visible disruption and damage. Although mechanisms to provide immediate relief to the victims will be set in motion spontaneously by the stricken community, a systematic inventory of damage is necessary to facilitate an organized relief and rehabilitation operation. This information is essential to the surviving victims, to neighboring communities, to the government of the stricken country, and to the international agencies trying to help. The main objectives of information collection in the post-disaster relief and reconstruction periods are these:

1. To determine immediate damage (e.g., casualties and damage to housing, infrastructure, and public utilities).
2. To identify the needs resulting from the damage (e.g., treatment of injuries, provision of shelter, and provision of water).
3. To determine existing local resources in order to match resources and damage and subsequently assess the unmet needs.
4. To assess relief efforts already under way.
5. To identify continuing and future potential threats and risks to the people and its social system.
6. To gather information for improving future disaster management.
7. To improve future preparedness plans locally and in other disaster-prone countries.

The second methodological problem--to assess the relationship between relief efforts and long-term development plans--will require careful analysis of the influence of specific interests and groups (local, national, international) and determination of which emergency policies may have lasting effects. Thus monitoring and evaluation of relief and reconstruction are essential for understanding and guiding disaster relief,[11] and for examining long-term effects on development.

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[11]See L. Anderson-Burley, "Disaster Relief Administration in the Third World," *International Development Review*, Vol. 15, No. 1 (1973), pp. 8-12.

## Information Collection Problems in Developing Countries

In choosing methods of predisaster and postdisaster assessment appropriate to the developing nations, we must take into account some special information collection problems in those countries. Many forms of technology appropriate for industrialized countries will not work well in developing societies. Techniques and technical standards that assume the existence of an extensive "technological infrastructure" cannot be easily transferred to countries that do not have such resources.

Sophisticated information collection systems require highly technical skills, and efficient maintenance and management systems, resources that developing countries often lack. Furthermore, developing countries may find dependence on management systems from highly developed nations neither beneficial nor acceptable. To avoid such undesirable dependency alternative arrangements need to be considered. A cooperative arrangement might be established between international organizations and the developing countries under which the latter would make decisions on the scene and mobilize local resources, but UNDRO or another appropriate international agency would coordinate external contributions. Another possibility would be to encourage further cooperation among the developing countries. The category "developing countries" encompasses a wide variety in levels of development; some countries could share their technologies, resources, and skills with others that need them.[12]

Another issue is the application of inappropriate standards for measuring problems and implementing solutions. In some instances the standards used to assess problems such as earthquake-safe construction or essential emergency services are formulated in developed countries

[12]The United Nations has convened a conference on "Technical Cooperation Among Developing Countries." The agenda included a proposal for an action-oriented information system on the technical capacities available in developing countries for use by other developing countries, and for measures to strengthen consultancy, engineering, and other technical services as well as supply and procurement of equipment and materials among developing countries. See United Nations, *The Kuwait Declaration on Technical Cooperation Among Developing Countries* (Kuwait: UN, June 1977).

and then transferred without change to developing countries.[13] Following the Nicaragua earthquake, for example, the construction standards adopted for building safety were based on standards developed for California. But because most of the population cannot afford such construction, and the inspection costs for enforcing such regulations are prohibitively high, a large proportion of housing continues to be built without quake proofing. Standards adaptable to local construction materials, techniques, and resources need to be developed.[14]

Inappropriate standards also may complicate the assessment of needs in basic services and infrastructure. Foreign experts unfamiliar with poor rural conditions often tend to overestimate emergency requirements and falsely attribute to the disaster deficiencies in sanitation and water supplies that were there long before.[15]

Similarly, social science concepts and methods from one country should not be applied without question to a nation with a totally different sociocultural setting.[16] In assessing a situation, people imposing their own sociocultural understanding may face a cultural barrier. But if people in the affected community actively participate in the assessment, they can contribute important information about social organization, language, cultural patterns, physical characteristics, and available resources.

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[13]See N. W. Solomons and N. Butte, "A View of the Medical and Nutritional Consequences of the Earthquake in Guatemala," *International Health*, Vol. 93, No. 2 (March-April 1978), pp. 168-169; and I. Davis, "Housing and Shelter Provision Following the Earthquakes of February 4th and 6th, 1976," *Disasters*, Vol. 1, No. 2 (1977), p. 88.

[14]See A. Kreimer, "Post-Disaster Reconstruction Planning: The Cases of Nicaragua and Guatemala," *Mass Emergencies*, Vol. 3, No. 1 (March 1978), pp. 23-40; A. L. Mabogunje *et al.*, *Shelter Provision in Developing Countries: The Influence of Standards and Criteria* (New York: John Wiley and Sons, 1978); and United Nations, *Human Settlements Performance Standards* (New York: UN, December 1977).

[15]See C. de Ville de Goyet, "Assessment of Health Needs and Priorities," paper presented at the Seminar of Emergency Care Following Disasters, Manila, March 1978.

[16]See G. Hursh-César and P. Roy, *Third World Surveys: Survey Research in Developing Nations* (New Delhi, India: Macmillan Company of India Limited, 1976).

All these assessment issues point to basic problems (malnutrition, risk vulnerability, lack of essential services) that can be resolved only by massive improvements in the deprived areas of the world. But these issues also demonstrate the more immediate need to avoid proposing solutions that cannot be achieved under the conditions of life prevalent in many countries.

## The Role of the News Media

The news media usually play an important role in disseminating information about disasters. In the Sahel, for instance, relief agencies with access to several other sources of information regarding the area were directly influenced by the media (especially the prestige press) in finally recognizing that the Sahel drought and famine constituted a major disaster requiring massive outside assistance.[17]

The news media have correspondents and news-gathering facilities worldwide, and often are able to relay news about disasters before the primary information sources of relief agencies and governments can do so. But the news relayed by the media is not always reliable, and fast-breaking natural disasters are often communication disasters too. Communication channels are severely disrupted, and access to the disaster area is frequently difficult or impossible. Thus when information is most needed, the media have the most difficulty in providing it with accuracy, if at all. By their very decisions on whether to cover a disaster, how to cover it, and what play to give it, the media greatly influence authorities' decisions whether to seek more information about that disaster.

Because the public has little access to alternate sources of news about a disaster, media coverage can determine the amount of public concern, and therefore the amount of private contributions from the public to relief efforts.

Inaccurate reports during a disaster can lead to deployment of scarce relief resources to low-priority sectors. Three days after the Andhra Pradesh cyclone, for instance,

[17]See J. W. Morentz, *The Making of an International Event: Communication and the Drought in West Africa* (Ph.D. Dissertation, University of Pennsylvania, 1976); and Sheets and Morris, *op. cit.*

ABC News reported "Cholera has broken out in three villages."[18] Cholera deaths had occurred, it turned out, but the number of deaths was later found to be about average for normal circumstances. Yet scarce cholera vaccines were flown to Andhra Pradesh immediately and mass inoculations carried out, at the expense of more important relief measures. It has been demonstrated, in fact, that mass immunization programs against cholera are not justified because there are more effective control measures that are less expensive.[19]

Cases such as the Andhra cholera "mistake" make it imperative to understand how news correspondents obtain their information under disaster conditions, so as to suggest ways of improving their procedures. The mass media do not necessarily undertake all the functions listed in every disaster, but the potential for doing them does exist.

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[18]See E. Rogers and R. Sood, "Mass Communication in Disasters: The Andhra Pradesh Cyclone as an Example of Mass Media Coverage of a Disaster," paper presented at a meeting of the Committee on International Disaster Assistance, National Academy of Sciences-National Research Council, Washington, D.C., May 1-2, 1978.

[19]See World Health Organization, *Development of a Programme for Diarrhoeal Diseases Control* (Geneva, Switzerland: WHO, May 2-5, 1978), p. 14; and World Health Organization, *Guidelines for Cholera Control* (Geneva, Switzerland: WHO, 1975), p. 2.

# 3 Damage and Needs Assessment

This chapter focuses on the kinds of information required for assessment of damage and needs, with special reference to problems of health and human settlements. It also discusses the priorities to be assigned to different types of information at different times following a disaster, the significance of local disaster preparedness, and the use of predisaster information as a complement to postdisaster assessments.

## Information Required for Assessing Damage and Needs

For the disaster-struck community, information needs pertain to disaster warnings, evacuation directions, damage and casualty estimates, existing resources for relief and rehabilitation, and other means of coping with the disaster. Local authorities and relief agencies need information mainly on the number of casualties, extent of damage, appropriate relief requirements, and availability and distribution of needed relief items.

Postdisaster assessment of damage and needs has not yet received the attention and concern it deserves as a special discipline of its own, with its own rules, techniques, and organized body of knowledge. Essentially postdisaster assessment requires that persons and agencies in charge of collecting information--national and local authorities, international teams, bilateral agencies--know beforehand *what to look at*, *how to look*, *how to establish priorities*, and *who needs what information*.

Many government or voluntary agencies make their own independent assessments of damage and needs following a disaster. Most, however, cannot collect technical information and, consequently, have to rely on such traditional sources as the news media to obtain secondhand data. Even when an agency has considerable expertise and experience, its assessment of needs may be limited to the items relevant to its own specific role. Dissemination of such limited assessment information--in most cases, lists of needed supplies and personnel--may be misleading for officials unfamiliar with relief operations outside the United States. It should be noted that most voluntary agencies do not attempt to provide a comprehensive overview of the entire situation, but try rather to inform potential donors of the particular needs that the agencies will address in performing their own missions. For instance, if the role of the National Red Cross Society is limited to rescue, first aid, and emergency relief (providing clothing, emergency feeding, etc.), the assessment and subsequent appeal from the League of Red Cross Societies will probably not include surgical material or sanitary equipment, regardless of how urgently they might be required.

Therefore, unless a voluntary agency has overall responsibility for the relief operations, its assessment of health and human settlement needs should be regarded as inadequate or incomplete. In most foreign disasters there is considerable duplication of effort and waste of human resources because many different organizations collect the same information from the same sources.[1]

It is probably unrealistic to expect that establishing a single international assessment team and clearinghouse would prevent voluntary agencies and governments from sending their own fact-finding missions. More effective assessment capabilities in disaster-prone countries, together with stronger international coordination efforts, however, should reduce the amount of inaccurate assessment information that is collected and disseminated following disasters.

[1]See L. Anderson-Burley, "Disaster Relief Administration in the Third World," *International Development Review*, Vol. 15, No. 1 (1973), pp. 8-12; and H. Beer, *International Disaster Relief: New Problems, New Solutions*, Document 29 (Geneva, Switzerland: International Council of Voluntary Agencies, 1968).

## Priorities in Assessing Damage and Needs

The type of disaster--its characteristics, speed of onset, and scope--dictates the priorities of data collection. The information required varies from initial, broad assessments of the nature of the disaster--its geographic scope and its effects on people and their environment, conducted in the immediate aftermath--to specific, detailed information on damage and needs gathered in subsequent stages to guide the relief, recovery, and reconstruction efforts.

A wide range of questions have to be posed by the affected government, the local community, the donor agencies, and neighboring communities: Is precise information possible to obtain? Who needs what data and how urgently? Is the information obtainable useful for the disaster in question? Will it contribute knowledge for improving future disaster management?

For sudden disasters, three categories of information, corresponding to the three stages within the emergency period, can be identified:

1. information needed immediately after the impact (first 24 to 48 hours);
2. information needed during the subsequent emergency period (48 to 96 hours); and
3. information needed for recovery and long-term rehabilitation.

### *Information Needed Immediately After the Impact*

On the basis of knowledge of the previous effects of a particular type of disaster (e.g., earthquake or flood) and knowledge of the normal or prevailing conditions in the affected country (e.g., housing characteristics and distribution of population), the following types of information are needed:

1. number of people injured;
2. location of the injured population;
3. accessibility to the disaster sites;
4. type and severity of trauma;
5. age and sex distribution of the injured;
6. extent to which local facilities can treat the injured;
7. support needs (drugs, personnel, leadership, etc.);

8. potential threats to survivors (e.g., aftershocks, further flooding, fire, disruption in services, damage to public utilities);

9. condition of essential lifeline systems (transportation to the affected area, communication facilities, water and sewer systems, etc.);

10. inventory of medical supplies, health facilities, and manpower at the site of the disaster and in the remainder of the country; and

11. housing losses and housing needs.

In sum, after the impact, immediate information is needed on injuries, on essential shortages and losses, on existing resources, and on further threats to the survivors.[2] At this stage, of course, information is collected in parallel with search and rescue activities. Several categories of injuries need to be defined. The most practical classifications are based on the type (e.g., fractures of arms or legs) and on the severity of trauma. A simple measure of severity of injury based on the criterion of "risk to life" has been designed for traffic accidents.[3] A similar classification should be developed for handling mass casualties in natural disasters. The latter classification will be the basis for effective triage in the field.[4] Gross data on the total number of injured are of little value to relief officials unless some indication is provided on the type of treatment required--for instance,

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[2]See A. Romero *et al*., "Some Epidemiological Features of Disasters In Guatemala," *Disasters*, Vol. 2, No. 1 (1978), pp. 39-46.

[3]See J. P. Bull, "Measures of Severity of Injury," *Injury: The British Journal of Accident Surgery*, Vol. 9, No. 3 (1978), pp. 184-187.

[4]Considerable literature exists on field triage and the handling of mass casualties. For example, see V. A. Taylor (ed.), "The Delivery of Emergency Medical Services in Disasters," *Mass Emergencies*, Vol. 2, No. 3 (1977), pp. 135-204; International Civil Defense Organization, "Don'ts and Do's When Handling a Casualty," *Bulletin of the International Civil Defense Organization*, No. 195 (September 1971), p. 9; G. W. Odling-Smee, "Ibo Civilian Casualties in the Nigerian Civil War," *Military Medicine*, No. 124 (1970), p. 505; and J. Raker *et al*., *Emergency Medical Care in Disaster: A Summary of Recorded Experience*, Disaster Study No. 6 (Washington, D.C.: National Academy of Sciences, 1956).

ambulatory treatment or major surgery. Information on the age and sex of the injured is needed because these variables can affect the rate of trauma. For instance, surveys conducted in Guatemala after the 1976 earthquake show that children under age 5 and adults over age 50 have a considerably higher rate of traumatic death. Therefore, such information has direct implications on the type of treatment facilities and material required.[5]

Identification of potential secondary threats--such as dangerous industries, fires, explosions, and aftershocks--must be conducted simultaneously with the assessment of injuries. Measures to prevent further danger from these hazards must also be instituted immediately after the impact.

Shortages and existing resources also should be considered simultaneously. A quick survey of available medical supplies may reveal that urgently needed drugs or other medical materials could be easily salvaged and used. In Nicaragua, a survey of the medical warehouses in Managua following the 1972 earthquake indicated that considerable amounts of medical and surgical supplies were immediately salvageable, although the warehouses had reportedly been totally destroyed.[6] The assessment of available supplies should not be limited to the site of the disaster, but should also be carried out for the nation as a whole, because it will usually be faster to use resources within the country than to acquire them from outside. It is important to assess shortages in essentials --water supply, sanitation system, fuel supply, and the availability of transportation and communication--immediately after the disaster.

In a few instances--such as in places where severe environmental conditions exist (extreme cold or heat, heavy rain, wind), where there is lack of construction materials, or where survivors suffer from very poor health and low morale--shelter will be a matter of primary concern. Such

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[5]See C. de Ville de Goyet, "Assessment of Health Needs Following Natural Disasters," paper presented at the Fourth Annual Meeting for Designated Epidemiologists, Pan American Health Organization, Washington, D.C., May 1978; also in *Caribbean Epidemiology Centre (CAREC) Surveillance Report*, Vol. 4, No. 8 (Geneva, Switzerland: World Health Organization, August 1978).

[6]See C. de Ville de Goyet, "Assessment of Health Needs Following Natural Disasters," *op. cit.*

cases are exceptional. In most societies, existing structures (public buildings, schools, warehouses, and homes of relatives) can be used as temporary shelter and available materials can be used in constructing emergency shelters (e.g., roofs and protective screens).

*Information Needed During the Subsequent Emergency Period*

The following questions can be addressed after the basic information-gathering activities just described have been instituted:

1. How well can the population of the disaster-stricken area cope?
2. What local, national, and international resources are available?
3. What are the risks of increased transmission of communicable diseases?
4. How has the food supply system been affected and what food supplies are needed by the survivors?
5. How many deaths have occurred as a direct or indirect result of the disaster?

Many past assessments have failed to address the abilities of the affected population to cope. *Decision making in past disasters has often moved directly from a survey of damage to the assumption that some form of relief is needed, despite the fact that most disaster-stricken communities may be capable of handling many, if not all, of the disaster-induced problems without outside assistance.*[7]

[7]Previous disaster field studies show that most of the immediate and critical relief tasks--search and rescue, emergency shelter and feeding, and other mutual support activities--are undertaken by people and organizations in the disaster-stricken area without outside assistance. This fact has been clearly established in domestic U.S. disasters and in disaster studies in other highly developed countries. Although the number of systematic studies of disaster response in developing countries is limited, existing evidence supports the proposition that this type of self-help is a universal phenomenon in human communities and that it is an important element in recovery from the damaging and disruptive effects of disasters. For summaries of the relevant literature, see C. E. Fritz, "Disaster,"

The assessment of available resources should not be limited to the immediate area of the impact but should cover the whole country. After the Nicaragua and Guatemala earthquakes, for instance, daily monitoring of beds available in each country's hospitals allowed effective use of scarce resources and thus reduced the number of patients evacuated to hospitals in foreign countries.[8] During the emergency stage it is necessary to collect information relating to the threat of epidemics, such as contamination of the water supply, wells that have overflowed, breeding sites for mosquitoes, types of latrines used, overcrowding from relocation of the population, and presence of dead animals. The signs of a developing epidemic may not be observed until 1 or 2 weeks after the disaster, but monitoring the situation requires rapid institution of an epidemiological surveillance system, including an ongoing reporting system from the health facilities.

An accounting of deaths immediately after the disaster is primarily important for the survivors in the affected area and for informing the media, donor organizations, and the international community (which tends to measure the importance of a disaster by the number of deaths). In the case of earthquakes, empirical evidence has shown that the number of deaths can indicate the number of injured. Table 1

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*Contemporary Social Problems*, R. K. Merton and R. A. Nisbet (eds.) (New York: Harcourt, Brace, and World, 1961), pp. 651-694; A. H. Barton, *Communities in Disaster: A Sociological Analysis of Collective Stress Situations; A Study of the Bureau of Applied Social Research* (Garden City, New York: Doubleday and Co., 1969); R. R. Dynes, *Organized Behavior in Disasters* (Lexington, Massachusetts: D. C. Heath and Co., 1970); D. S. Mileti *et al.*, *Human Systems in Extreme Environments: A Sociological Perspective* (Boulder, Colorado: University of Colorado, Institute of Behavioral Science, 1975); D. Manning, *Disaster Technology: An Annotated Bibliography* (New York: Pergamon Press, 1976); E. L. Quarantelli and R. R. Dynes, "Response to Social Crisis and Disaster," *Annual Review of Sociology*, Vol. 3 (1977), pp. 23-49; and E. L. Quarantelli (ed.), *Disasters: Theory and Research* (London, England: Sage Publications, 1977).

[8]See C. de Ville de Goyet, "Assessment of Health Needs Following Natural Disasters," *op. cit*. Also see R. L. Coultrip, "Medical Aspects of U.S. Disaster Relief Operations in Nicaragua," *Military Medicine*, Vol. 139 (November 1974), p. 881.

TABLE 1 Morbidity/Mortality Observed After Four Major Earthquakes

| | Morbidity[a] | Mortality[a] | Morbidity/ Mortality Ratio |
|---|---|---|---|
| Peru (31 May 1970) | 143,331 | 66,974[b] | 2.2 |
| Nicaragua (23 December 1972) | 20,000 | 6,000 | 3.3 |
| Pakistan (28 December 1974) | 15,000 | 4,700 | 3.2 |
| Guatemala (4 February 1976) | 76,504 | 22,778 | 3.4 |

[a]The numbers of injured (morbidity) and deaths (mortality) given in this figure are based on official figures released by the respective governments. The extent of error in these numbers is unknown.
[b]Of the 66,974 deaths reported, about half were caused by landslides that buried two towns, leaving almost no survivors.

shows the morbidity/mortality ratios that have been established for different earthquakes.[9]

*Information Needed for Recovery and Rehabilitation*

The information needed in subsequent stages depends on rehabilitation and reconstruction objectives and requires an adequate system for monitoring socioeconomic changes. Objectives might include improvement in the health, housing, and nutrition; such goals will require consideration of relations among such different sectors of social life as shelter, health, basic services, production, and employment. The information required for recovery should be defined

[9]See C. de Ville de Goyet *et al.*, "Earthquake in Guatemala: Epidemiologic Evaluation of the Relief Effort," *Bulletin of the Pan American Health Organization*, Vol. 10, No. 2 (1976), pp. 95-109.

early in the postdisaster period, and should take into account the local society's priorities.

Continuous reporting of unique, as opposed to routine, items of information should be used as an important element in disaster monitoring. Such continuous feedback facilitates evaluation of relief programs and adjustment of plans for short-term and long-term recovery. The information also can be used to improve future disaster preparedness and management. Continuous feedback can include maintaining an epidemiological surveillance, monitoring the water supply, following up nutritional status of individuals, reporting failures in logistics, monitoring the flow of patients and supplies in the health system, and identifying special long-term health risks. Monitoring helps correct inefficient performance and define the most feasible plans for incorporation in the recovery and reconstruction program. This process obviously requires systems for collecting and transmitting data, and for using the information to make decisions.[10]

Continuous monitoring is also essential to integrate long-term recovery aims and shorter-term relief programs from the earliest possible time following the disaster. Monitoring can help detect counterproductive relief measures that could hamper recovery or jeopardize the future of the disaster-stricken population. It is doubtful that standard guidelines for developing this information feedback system can be formulated yet. Only close cooperation between outside disaster experts and knowledgeable local leaders--and experience in many disasters--can produce the necessary intimate knowledge of people and environments.

During the period of time immediately following the occurrence of a disaster, it is obviously impossible to provide accurate answers to all the questions that have been raised; thus a crude profile must be generated on the basis of the best available estimates of the situation. Assessments of damage and needs made in other disasters might provide clues to the kinds of inaccuracies and errors that can be expected. The precision of the information available immediately after the disaster depends on such factors as the existence of preparedness plans, the quality of predisaster information about the country and the affected areas, the skillfulness of the assessment team, and the availability of telecommunications to reach the

[10]Romero *et al.*, *op. cit.*

affected zones.[11] When the immediate postdisaster pressures subside, more specific data could be gathered. Initial assessments will provide a basis for selecting the best mechanisms for detailed assessment and continuous monitoring of the situation.

**Assessment of Needs**

It is important to distinguish between *total postdisaster* needs and the *additional* needs brought on by the emergency. In health, for instance, the first concern should be to find out what *additional* resources--doctors, medical supplies, hospital beds, etc.--are needed to meet the problems wrought by the disaster. Requests for outside help should be scaled to deal with only the problems that local resources cannot handle.

Assessing unmet needs entails the following:

- assessment of damage;
- assessment of total needs;
- inventory of resources at hand;
- inventory of resources available from external sources; and
- match of needs and resources in order to determine the *additional* resources required.

Most postdisaster assessments really amount to a definition of *total* needs. Although some donors have tried, with limited success, to match available resources and total needs, requests for donations are generally made on the basis of presumed or assessed total needs. This practice usually results in duplication and waste. There are numerous examples of this kind of total needs assessment in the health field. For instance, earthquakes create a greater need for hospital beds (total needs); but evacuation of the injured or deployment of field hospitals may not be appropriate, because local resources are often available. Following the Managua earthquake, hospital occupancy rates in other Nicaraguan cities were surveyed by epidemiologists from the Center for Disease Control in Atlanta, Georgia. This survey clearly indicated that enough beds were available in Nicaragua to make the evacuation of medical casualties that took place and the use of field hospitals that

[11] *Ibid.*

were sent unnecessary.[12] To cite another example, a need for physicians may be reported following major natural disasters, but often doctors available locally, elsewhere within the affected country, or in neighboring countries, will suffice. In the immediate postdisaster period, therefore, no additional medical assistance from abroad may be needed.

In sudden disasters it is hard to assess health needs soon enough to influence decisions about relief. In major disasters, relief measures are spontaneously carried out by the survivors and the local authorities, albeit in a somewhat uncoordinated fashion in the early postimpact period. In addition, collection and dissemination of information on health needs are likely to take too long to help with emergency care. Most essential care is performed within 24 to 48 hours, mostly by nationals of the affected country, and in some cases by medical personnel from neighboring countries.

Top priority should be given to the assessment of needs for rehabilitation and recovery, and this assessment should start shortly after the impact if it is to contribute to early decision making. The knowledge gained can help relief organizations and governmental officials in their immediate responses to future emergencies.

Some needs must be anticipated before the disaster rather than assessed afterwards. In past disasters the long time lag between identification of needs and delivery of external assistance shows a failure to appreciate the rapidly unfolding events of disasters. In the immediate aftermath of a disaster, it makes little sense to disseminate information about short-lived needs, such as bandages, to donors that are not in a position to react promptly. In Guatemala, first aid relief supplies arrived after the priority had already shifted to hospital follow-up; incoming medical supplies reached a peak when the urgent requirements were for reconstruction materials.[13] Profiles of needs for each type of disaster should be developed by appropriate field investigations to help anticipate future needs.

The needs generated by a disaster obviously will vary according to whether the catastrophe comes suddenly or gradually. For instance, sudden disasters can destroy dwellings, making all members of a family homeless

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[12]Coultrip, *op. cit.*

[13]See C. de Ville de Goyet *et al.*, "Earthquake in Guatemala: Epidemiologic Evaluation of the Relief Effort," *op. cit.*

simultaneously. In such slow-onset disasters as famine, some members of the family, usually adult males, often migrate to other areas in search of a livelihood. Families may be separated for long periods or even permanently.

Following sudden disasters, shelters will be required to provide protection from adverse environmental conditions, but shelters range from protection against a gentle rain, mild wind, or tropical sun (requiring no more than a vertical windbreak or waterproof roof), to shelter from extreme cold and snow (i.e., enclosed structures, with sloping roofs, warm blankets, clothing, and fuel). And not every sudden disaster requires shelter immediately afterwards. Adequate alternatives to temporary shelters include the use of the extended family to house the homeless, the use of such surviving structures as schools and hotels, and the use of family or friendship links in rural areas in countries where urbanization has been rapid.

An inventory of existing alternative emergency shelters and resources will help determine whether additional dwellings are required. For instance, in Nicaragua the extended family provided shelter to the homeless, making the emergency shelter built after the earthquake unnecessary.[14]

Slow-onset disasters pose a different set of shelter needs. Dwellings may be used for long periods by a weak population comprising a disproportionate number of women and children who may need therapeutic health care.[15] Thus construction of sturdy and stable structures can become very important. Whatever shelter is constructed should be flexible enough to accommodate a growing population and changes over time, because shelter tends to be used for long periods of time, whatever the original plan. Affected communities have the ability to rebuild their own homes except when materials are unavailable, when skills are lacking, when local health and morale may be low (e.g., in

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[14]See I. R. Davis, "Managua, December 23, 1971," *The Provision of Shelter in the Aftermath of Natural Disasters. Report on Housing Strategy. December 1972-September 1973* (Oxford, England: Oxford Polytechnic, Research and Development Group, Department of Architecture, January 1974); and R. Kates *et al.*, "Human Impact of the Managua Earthquake," *Science*, Vol. 182 (1973), pp. 981-990.

[15]See J. Murlis *et al.*, *Disaster Shelter and Rehousing: Physiological and Social Factors*, report of the Seminar on Emergency Housing and Shelter (London, England: The Disaster Unit, Ministry of Overseas Development, 1976).

famines), and when the ability--or will--to cope is missing.

## Significance of Preparedness Measures

Emergency preparedness requires coordination and communication between agencies, institutions, and individuals who will act in times of emergency. The implementation of preparedness measures depends on the nature of governments in disaster-prone countries and on the degree of cooperation among their agencies. In developed countries, coordination is understood as an exchange of ideas and information on needs and planned actions. In some of the developing countries coordination has a more authoritarian connotation--that is, various sectors or agencies report to the coordinator and receive his commands for execution. Here it is unclear whether the type of coordination existing in most developed countries is applicable to the disaster-prone developing countries.

Coordination clearly should involve all agencies that are likely to play a significant role in the aftermath of a disaster, but the agency in charge of emergency preparedness often limits its coordination efforts to other government agencies. This agency needs to make provision for the constructive, and sometimes essential, role of the Red Cross Societies and other voluntary agencies.

Emergency preparedness coordination among disaster-prone countries is especially important for small countries that are vulnerable to major disasters but have limited resources for coping with them. Examples are the countries of the Sahel in Africa, where drought and famine are common, as well as the Central American countries, which often suffer severe earthquakes or hurricanes.

A largely neglected aspect of preparedness is the development of the capacity of the community to meet its own immediate needs following a disaster. The ability of local people to deal with injuries immediately after an earthquake, and before external rescue teams can arrive, can significantly decrease the number of fatalities. The large body of sociological observations on the capacity of disaster-struck communities to display unexpected competence in coping with disasters has already been mentioned.[16] Thus far, planners have paid little attention to enhancing local

[16] See Fritz, *op. cit.*

self-rescue capacity by providing appropriate training to communities in the developing nations. In line with the new self-help approach to primary health care now may be an appropriate time to place greater emphasis on self-reliance and on disaster management at the local level. (This suggestion does not mean that the stricken community should not be helped; it means that the community should be prepared to rely on itself until help arrives.)

Implementation of this approach will require information on such topics as the following:

- The type of disasters for which rescue and medical self-help can be most efficient, according to expected proportion of uninjured survivors, type of lesions in the injured, time of survival for the injured and the like.
- The kinds of local persons most apt to perform as efficient rescuers (policemen, firemen, nurses, community workers, teachers, etc.).
- The kinds of rescue, first aid, and simple medical procedures most useful in various types of disasters.
- Appropriate training programs and ways of implementing them. Training potential leaders from disaster-prone developing countries in emergency activities and in the assessment of damage and needs should be an important part of preparedness programs.

## Compilation and Use of Predisaster Information

Predisaster information on the characteristics of a disaster-prone country can facilitate postdisaster assessment of damage and needs. It also can help organize relief efforts, establish priorities for recovery, and anticipate some of the problems that develop in coping with the disaster and its aftereffects. The different kinds of predisaster information needed include data on the country's climate, topography, demography, economy, health standards, and medical facilities.

Much of the information that exists concerning conditions in disaster-prone countries has not been collected specifically for predisaster planning projections. Thus the information required following a disaster may have to be extrapolated from data that are incomplete, not readily available, or arranged in ways not pertinent to disasters. Users of such information need to be aware of possible biases or errors. For example, maps should be carefully checked because they may be out of date; key information such as the location of settlements or access roads may be in error.

The absence of baseline data--such statistics as incidence of disease or malnutrition, birth and death rates, and the like, for a specific place and period of time--is a major problem in measuring the impact of a disaster on the health, sanitation, and housing conditions of a population. Unless predisaster baseline data are available, postdisaster deficiencies in health (a high number of cases of gastro-enteritis or typhoid fever in a drought-affected area), in public utilities (contaminated water), or in housing (crowding) cannot be interpreted as atypical and attributed to the disaster. Indeed, disease, contamination, and over-crowding are conditions typical of chronic poverty that are endemic in many developing countries. In 1973, for example the health services of the Pakistani province of Punjab estimated that 85 percent of the water pumps in use in rural areas showed some degree of fecal contamination.[17] Obviously, a hypothetical finding by a survey team following the severe floods that year that 75 percent of the water supply in affected areas was contaminated would lose its apparent significance as a flood-related phenomenon.

Countries with a history of natural disasters located in risk-prone areas should develop data files on aspects relevant to disaster prevention and assistance. These data files could be developed by the governments of the concerned countries with the assistance, if necessary, of bilateral and international organizations. They should consist of baseline data, information on health conditions and medical facilities, and key thematic maps showing political divisions and topographic, demographic, hydrologic characteristics, transportation routes, and land use.

With respect to health, for example, the following data should be included in a baseline compilation:

1. organization of health services (structure, names of officials, responsibilities, channels of communication), including details of existing contingency plans, if any;
2. local resources by location (health facilities, equipment, personnel, supplies, special services such as epidemiological surveillance), including procedures for mobilizing these resources;

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[17]See C. de Ville de Goyet, "Medical Report of Second Field Visit to Flood-Affected Districts in Punjab, Pakistan," CDC/AID Assessment Team, September 1973.

3. demographic data and vital statistics (age and sex structure of the population, distribution, special characteristics such as nomadism, birth and death rates, infant mortality, etc.);
4. most prevalent communicable diseases;
5. nutritional habits, nutritional status of the population, most common specific nutritional deficiencies;
6. sanitary conditions (water supply, vector control, etc.);
7. existence of national or regional stockpiles;
8. facilities for handling refrigerated medical supplies; and
9. drug import regulations.

With the cooperation of specialized agencies, such as the World Health Organization and the Food and Agricultural Organization, and the governments of the countries concerned, the AID/OUSFDA is currently assembling "country profiles" for disaster-prone areas. These profiles can contribute to advance planning and preparedness before the disaster. They should help decision makers develop guidelines for intervention immediately after a disaster and for as long as feedback from the area is insufficient. And they should provide a directory of experts who may be available to participate in assessment and relief teams. Of course, profile data should be supplemented as much as possible by information from knowledgeable informants.

## Information Gained from Experience

Postdisaster evaluations can provide valuable lessons applicable to other disasters. These evaluations provide information for planning and preparedness. Systematic studies and evaluations of damage and needs experienced in previous disasters may be useful during the first days after a new disaster strikes in order to provide clues as to the kinds of needs likely to be felt in the new situation.

Although the information in each evaluation will vary, case studies may prove useful in predicting what secondary disasters can be expected after different kinds of catastrophe, and in anticipating what types of construction, building materials, and building location will produce certain kinds of injuries and damage. Information from previous disasters can also be used to check for gross errors and inaccuracies in initial reports on new calamities.

Information gatherers should therefore seek data applicable to future disasters as well as to the crisis at hand. Their compilations should enumerate characteristics of the area that could determine what effects disasters have, how the community responds, what resources are needed and available, and how efficiently outside aid can be supplied. Relief and recovery operations, and cases of any mismanagement, should also be evaluated.

The goal is a comprehensive collection of information on all stages of disaster, to replace the usual impressionistic and unsystematic accounts of damage and needs. A standard format for case studies should be developed, because generalizations about the past can be made only if experiences can be compared and summarized.

Too few case histories of past disasters have been assembled, partly because governments, agencies, and international bodies involved in disasters often desire confidentiality, and partly because relief organizations lack the resources and trained personnel to perform studies they may see as unnecessary. To support the development of case studies, part of the resources directed to relief could be used for continuous evaluation and after-action assessment of disasters.

## Reports from Existing Sources

Normal government and agency sources may be used to get an initial estimate of injuries, deaths, and the extent of damage to housing and public utilities. Because government channels are already in existence, in most cases they can be used soon after the disaster has occurred. Although reports from standard administrative channels are needed immediately after the impact, some caution should be used in relying on information from these sources. For instance, political or emotional involvement of the reporting officials may distort the data's accuracy. Also reporting points may not be uniformly distributed throughout the affected area, and reports received during the first hours after a disaster may mention only the casualties and damage in the most accessible areas. Following the Guatemala earthquake, for instance, no specific information on the extent of damage and casualties outside Guatemala City became available until 48 hours after the shock.[18]

In general, the ability of existing agencies to assess damage and needs is closely related to the existence of emergency preparedness and coordination plans and to the abilities of the different governmental departments and institutions to respond to the situation. Because these conditions vary widely among developing nations, the timeliness, accuracy, and completeness of damage and needs assessments will also vary from country to country.

In general, every assessment technique should be examined for its uses, advantages, and disadvantages. The next two chapters examine two broad categories of assessment: (1) field surveys, and (2) aerial reconnaissance and remote sensing.

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[18]See C. de Ville de Goyet *et al.*, "Earthquake in Guatemala: Epidemiologic Evaluation of the Relief Effort," *op. cit.*

# 4 Methods of Assessment: Field Surveys

As noted before, the combination of assessment methods to be used in a given situation will be determined by the type of disaster, the degree of internal development, the amount of internal resources available, the sociopolitical context, the coping abilities in the disaster-struck country, and the possibilities of help from other countries and international organizations. For each case, of course, it is necessary to identify the basic components of the problem and the best ways to collect information about these components. For example, in assessing injuries and earthquake damage the following analysis might be done:

| *Problem* | *Components* | *Assessment Techniques* |
|---|---|---|
| Injuries | Number | Sample survey<br>Reports from hospitals |
| | Type | Clinical evaluation |
| | Location | Ground surveys |
| Damage to structures | Extent | Determination of quake intensity<br>Response of individual buildings to the quake<br>Survey of ground breaks<br>Structural survey using sampling strategies<br>On-the-ground observation<br>On-the-ground photography |
| | Location | Ground surveys<br>Aerial photography |

It is important to note that collecting more information will not by itself necessarily improve the response to a given disaster. In many cases, the voluminous information collected by the affected country and by relief agencies is improperly gathered, analyzed, and used.

Properly conducted field surveys offer a systematic way to compile operational data on the areas affected and to accumulate information that will be useful in dealing with future disasters. No standardized predisaster prediction can equal the predictive value of facts collected at the actual disaster site.

For sudden disasters, field surveys can be used in each of the three periods already identified immediately after the impact, during the subsequent emergency period, and for recovery and long-term rehabilitation. For slow-onset disasters, field surveys provide a tool for prediction and continuous surveillance.

On-site data collection will (1) constitute a basic element for decisions related to short-term and long-term aid, (2) provide an official damage record, (3) establish baselines for further evaluation of assistance, (4) help validate and expand information for use in future planning and preparedness, (5) check the accuracy of country profiles, and (6) supplement information extrapolated from past experiences.

There are two basic ways to gather data: direct, standardized observation and interviews with key informants.[1] Immediate postdisaster assessment requires quick, preliminary reports based on observation and interviews with key informants in sites selected, ideally, by statistical sampling methods. These reports should be updated as new data are collected. More accurate quantitative surveys can be undertaken later on when the emergency pressures are over. Resource and time limitations will, of course, often dictate compromises between a survey that is methodologically sound and one that can be feasibly conducted.

Even the initial assessment requires use of valid sampling devices and consideration of priorities such as where to look, how many people to examine, how to assess damage to structures, and how to adopt precautions against biased samples. For immediate postdisaster surveys to be most effective, the list of priorities should be defined

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[1]Some of the special problems of collecting information in developing countries were discussed in Chapter 2.

before the disaster and designed so that minimal data will yield useful information quickly. Detailed assessment requires more reliable quantitative measurements as well as definition of the units of analysis, the best sampling design (random, stratified, multistage), the relevant variables, and adequate indicators.

The use--and usefulness--of field surveys may be limited by the following factors:

1. Depending on local conditions and survey objectives, the cost can be high in money, time, and expertise.
2. The affected areas may be difficult to reach.
3. Cultural heterogeneity in the area to be studied may make for difficult sampling frame construction.
4. The interview informant may distort the information, on purpose or inadvertently. Purposeful distortion is illustrated by a government official who says he is familiar with an affected area when he is not, or who exaggerates the damage and losses to attract more help to his constituency. Inadvertent distortion is exemplified by a victim who, under emotional stress, declares that he saw 10 people die rather than the 3 he actually saw.[2]
5. Field surveys require considerable baseline data to distinguish damage from impoverished "normal" conditions.
6. Cultural differences between the affected population and foreign or national experts may produce differences in the frame of reference, variations in understanding the problems, and difficulties in communication.

In spite of these factors, field surveys have some important advantages:

1. Obtaining the information through field surveys generally costs less than obtaining it through more sophisticated assessment methods such as remote sensing.
2. Field surveys yield high volumes of information.

In sudden disasters, data collection could include estimates of the number of injured people, type of lesions, number of deaths, availability of health facilities, medical

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[2]Mortality figures reported at precisely 3,000 in Chimaltenango, 7,000 in Tecpan, and 6,000 in Comalapa (in Guatemala, 1976) suggest such nonpurposeful distortion. See C. de Ville de Goyet and E. Jeannée, "Earthquake in Guatemala," *Emergency Planning Digest*, Vol. 4, No. 1 (January-February 1977), pp. 2-8.

and paramedical resources, amount of medical supplies still available, damage to water supply systems, risk of communicable diseases, damage to communication channels, and damage to physical structures. Aerial surveys and remote sensing do not permit assessment of some of these problems. For example, from the air a damaged house in an earthquake-stricken zone may seem to be intact; personal injuries cannot be identified; and damage to pipelines and other underground utilities cannot be detected. Ground surveys also are particularly valuable for inventorying useful resources such as construction materials for temporary and permanent shelter, reusable debris, medical personnel, and drugs.

In slow-onset disasters ground surveys are also more useful than aerial and space satellite observations are for detecting food shortages and their probable effect on the population.

3. If adequate sampling techniques are used, field surveys make it possible to generalize from relatively small samples to the total population under study.

4. Field surveys permit the participation of local personnel who, after a short period of training, may be quite capable of conducting interviews and assisting in other field survey tasks. Skilled personnel are needed, however, to plan, supervise, and analyze the collected data, and persons with these skills may not be available in most developing countries.

5. Field surveys use less sophisticated technologies and equipment than those used in aerial observation and remote sensing methods.

The capabilities for on-the-ground assessment after a disaster are not well developed at present, especially at the international level. The methodology is just being developed, and in many cases local expertise for conducting surveys is scarce. Donor agencies such as the UNDRO and AID/OUSFDA should work to improve ground survey techniques and to train nationals from disaster-prone countries in these techniques.

**Assessment Teams**

The conduct of ground surveys requires organizing teams of experts prepared to move quickly into a stricken area. Governments in disaster-prone countries, and bilateral and international agencies, should make training of expert assessment teams a priority goal. Although existing teams may conduct reasonably adequate assessments of the numbers of injured and dead, they rarely have enough training to make careful surveys on such specific subjects as the age and sex of the injured population, type of injury per number of injured, and links between type of construction and type of injuries.

Organizing the teams poses some practical questions:

- Who is to organize these teams?
- How quickly can they be assembled?
- Who provides transport?
- What skills are needed?

Wherever possible the teams should be composed of people from the affected country who are familiar with its geography, language, culture, and social organization.[3] When the necessary skills are not available locally, the teams have to be at least partially composed of foreign experts. If the teams are organized by international or single nation donors, prerequisites for team members are prior preparation, adequate knowledge of developing countries, and adaptability to different disaster conditions. The teams may also need personnel to translate the information gathered in the field into needs and to coordinate the required action. In the early stages it may be necessary to include in the assessment teams professionals from developing countries who do not have the requisite training or experience in disaster and needs assessment. However, on-the-job training of such professionals should be a major goal of this multinational effort.

At present several foreign disaster assessment teams are in operation, including the International Red Cross, the U.S. Army Southern Command's Disaster Area Survey Team (DAST), the Center for Disease Control (CDC), and the Earthquake Engineering Research Institute (EERI). The United Nations has also established organizations for conducting international assessments--World Health Organization, Pan American Health Organization, Food and Agricultural Organization, Office of the Disaster Relief Coordinator, and the United Nations High Commissioner for Refugees. No single organization yet provides the comprehensive assessments required in most disasters.

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[3]See A. Omololu, "Nutrition and Relief Operations: The Nigerian Experience," *Symposium of the Swedish Nutrition Foundation*, No. 9 (1971), pp. 130-143.

International cooperation is urgently needed to establish an *international* standby assessment team and the AID/OUSFDA, in collaboration with the UNDRO and other UN agencies, should carefully consider this project. Such a standby team could comprise nationals from developed countries. Organizing and training a team of experts in different disciplines relating to assessment would require (1) clarification of the objectives and methods to be used in each specialty, (2) development of appropriate recording techniques and skills, (3) clear understanding of the team's role in the assessment process, and (4) development of an information network, among different agencies and organizations concerned with disasters.

The assessment team should be concerned only with collecting information and assessing damage and needs. The tasks of assisting the victims should be the responsibility of skilled personnel assigned to rescue, relief, and rehabilitation.

Although the skills required for the members of an assessment team are diverse, one person may cover several specialties, thus reducing the total number of team members needed. Furthermore, not all the skills are required at the same time; team members can be selected on the basis of the established priorities. The team should include the following types of persons:

- An epidemiologist specialized in communicable diseases and nutrition.
- Two sanitary engineers, one with expertise in water supply and sanitation in complex systems in urban areas, the other with expertise in rural sanitation problems.
- A hospital administrator (to monitor bed occupancy and flow of patients).
- An expert in emergency medical care (triage, field hospitals, etc.).
- A pharmacist (to determine needed drugs, assess available supplies, and inventory incoming supplies).
- A procurement officer (or logistics officer).
- A statistician (to organize a representative sampling if possible and to direct compilation of data).
- Two housing experts, architects, or engineers (one with expertise in simple construction techniques and one with expertise in more developed techniques).
- An engineer experienced in construction and repair of public works systems (transportation, communications, pipelines, etc.).
- A supplies expert (food, clothing).

- In the case of floods, a hydrologist; in the case of an earthquake, a seismologist and a geologist; and in the case of tropical storms, a meteorologist.

The team should coordinate its work with the appropriate national reconstruction group. To make the best use of local resources and to provide nationals with the necessary experience in disaster assessment, the team should include local personnel or experts from neighboring countries.

## Use of Field Surveys: Selected Examples

The following examples show how field surveys can be used in disasters and what problems may arise in the course of conducting them. These examples are illustrations only; they do not constitute a comprehensive inventory of survey possibilities.

Four topics are discussed:

1. Assessments during gradual disasters (food shortages in famines).
2. The use of field surveys in continuous monitoring (epidemiological surveillance).
3. Assessment of housing damage and needs.
4. Assessment of damage and needs to lifelines after sudden disasters.

### *Assessment of Food Shortages by Ground Survey*

Four general points should be noted about famines:

1. Starvation is not necessarily a simple function of food shortage. Obviously a connection exists between hunger and shortages caused by drought, crop pests, or natural disaster. But both the causes and effects of famine are more complex than is generally believed.[4]

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[4]See, for example, R. H. Faulkingham, "Ecological Constraints and Subsistence Strategies: The Impact of Drought in a Hausa Village, A Case Study from Niger," *Drought in Africa 2*, D. Dalby, R. J. Harrison-Church, and F. Bezzaz (eds.) (London, England: International African Institute, 1977); J. P. W. Rivers *et al.*, "Lessons for Epidemiology from the Ethiopian Famines," *Annales de la Société Belge de Medecine Tropicale*, Vol. 56 (1976), pp. 345-357.

A food shortage can lead to starvation, but the severity of the famine--the number of deaths and speed of onset--depends more on the prevailing socioeconomic structure than on the absolute quantity of food available. The worst effects, starvation and migration, stem from failures of the market and of the normal system of exchange and distribution. Thus disaster can occur even when there is enough food to feed the population.

The reason is that the effects of a food shortage depend on the commercial market; on the normal systems of food distribution, which include reciprocity and loans between kin and within wider social groups; on the degree to which the population can obtain alternative employment; and on the extent of capital accumulation in the form of grain, livestock, or cash.

Ethiopia provides two examples of famines, detailed in Appendix 1. In one case the socioeconomic system could not adapt; in the other it could.

In the northern Ethiopian (Wollo) famine of 1972-73, a single crop failure led to (a) a precipitate rise in market prices, presumably as a result of hoarding by those with food; (b) massive migration by those with no cash to buy food; and (c) subsequent mass starvation by those unsuccessful in finding employment in cities and cash crop areas.

In the pastoral economy in southern Ethiopia, by contrast, drought caused massive livestock losses, a fall in livestock prices, and a rise in the price of grain. Yet, although the food shortage was severe enough to kill one-third of the children under 5 years of age, few people migrated and none of the massive social disruption and starvation that characterized the Wollo famine occurred.

These examples suggest that an unanticipated crop failure can trigger a famine if the distribution system cannot cope with the shortage, or if the failure causes a sudden rise in prices in an area where people have little or no cash. Perhaps 2.5 million deaths occurred in the 1943 Bengal famine, and yet there appears to have been no absolute shortage of food.[5]

Where socioeconomic adaptation is extensive, however, famine may cause widespread hardship and child mortality,

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[5]See A. Sen, "Starvation and Exchange Entitlements: A General Approach and Its Application to the Great Bengal Famine," *Cambridge Journal of Economics*, Vol. 1 (1977), pp. 33-59.

but little social disruption. An example is the Sahel, where much of the agricultural population survived up to 6 years of drought with little or no food relief and little evidence of social and economic collapse.[6]

Food shortages and distribution problems are most likely to occur where there is a high risk of crop failure or livestock loss, as in pastoral economies and in cultivated semiarid areas. Such problems are obviously less likely where food production is more reliable, or where abject poverty makes disruptive hoarding impossible. In some areas mechanisms for coping with the effects of recurrent shortfalls in food production have declined as population pressure on land has grown and as subsistence economies have been forced increasingly to pay taxes and to depend on cash as a medium of exchange.[7]

2. Historically, food shortages have affected isolated small areas, as well as the larger areas more commonly recognized by the international relief community.

3. Increasing population density and pressure on marginal lands are expanding the risk of famine in the world. As noted, the Wollo famine occurred in a recently cultivated area--one that had not previously experienced crop failure from drought.

4. Famine relief has often depended on imported foodstuffs, which may take up to a year to arrive. Preventing starvation requires a more rapid response. Although local purchase of foodstuffs, national and regional stockpiles of food, and market support have all been used in famine relief programs, the effectiveness of each is little researched. Further research is needed into effective means of short-term market support. In the case of drought and famine in southern Ethiopia, subsidized sale of relatively small amounts of grain through a few markets might well have staved off the disaster.

Field assessments of food shortage are conducted by using a simple, rapid nutrition survey. The assumption underlying nutrition surveys is that a severe food shortage will

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[6]See J. Seaman *et al.*, "An Inquiry Into the Drought Situation in Upper Volta," *Lancet*, Vol. 2 (1973), pp. 774-778.

[7]See, for example, G. Nicholas, "Remarque sur Divers Facteurs Socioeconomiques de la Famine au Sein d'une Société Subsaharienne," *Drought in Africa 2*, *op. cit.*; and M. Watts, *The Food Situation in the Sahel* (London, England: International Disaster Institute, 1978).

cause a reduction in food intake for at least part of the population, which will be reflected in a measurable drop in physical nutritional status. Weight and height measuring is usually performed on small children because they have been found to be most vulnerable to malnutrition. The extent to which children from a representative sample of the population are underweight for their heights can indicate the degree of malnutrition in the area.[8]

Such anthropometric data may be hard to interpret, however, because in developing countries malnutrition can be common even in normal times and baseline data, taken from a known and reproducible sample of the population, is a rarity. Even with baseline data for comparison, a survey during a food shortage may yield misleading results--the survey might show fewer cases of malnutrition, not because the children are eating better, but because they have died and are not present to be measured.[9] Thus, there is no threshold to mark the onset of famine. In practice, interpretation of the data is made in one or more of the following ways:

- By repeated survey on a known sample. This practice allows changes in nutritional status to be monitored with time.
- By demonstrating differences in the prevalence of malnutrition within population groups thought to be ethnically, economically, and nutritionally similar in normal times.
- By relating other measured variables to nutritional status. The variables that can be quickly and economically measured are few but include, for example, market prices of staple foods and cash crops, numbers of livestock held, human mortality, and migration rates.

Anthropometric surveys for the assessment of food shortages have not been widely used so far, but in the past decade a few have been conducted in Biafra, Bangladesh,

[8]See J. C. Waterlow, "Notes on the Assessment and Classification of Protein Energy Malnutrition in Children," *Lancet*, Vol. 2, No. 87 (1973), pp. 89.
[9]See J. M. Bengoa, "Recent Trends in the Public Health Aspects of Protein Energy Malnutrition," *WHO Chronicle*, Vol. 24 (1970), p. 552.

the Sahel, Ethiopia, India, and elsewhere in Africa and Asia.[10] The use of such surveys after crop damage caused by sudden disaster is even more infrequent, the only examples being from Bangladesh after the 1970 cyclone[11] and following the 1972 floods.

*Epidemiologic Surveillance of Communicable Diseases*

Epidemiologic surveillance consists of collecting and interpreting data on the risk or the actual occurrence of communicable diseases--and, most important, disseminating

[10]See Center for Disease Control, *Nutritional Surveillance in Drought Affected Areas of West Africa (Mali, Mauritania, Niger, Upper Volta)*, unpublished report (Atlanta, Georgia: U.S. Department of Health, Education, and Welfare, August-September 1973); J. B. Mason *et al.*, "Nutritional Lessons from the Ethiopian Drought," *Nature*, Vol. 248 (April 19, 1974), pp. 646-650; J. Seaman *et al.*, "An Inquiry into the Drought Situation in Upper Volta," *op. cit.*; R. Arnhold, "The 'Quac' Stick: A Field Measure Used by the Quaker Service Team in Nigeria," *Journal of Tropical Pediatrics*, Vol. 15 (1969), pp. 243-247; D. E. Lang, "Epidemiology of Famine in the Nigerian Crisis: Rapid Evaluation of Malnutrition by Height and Arm Circumference in Large Populations," *American Journal of Clinical Nutrition*, Vol. 24 (March 1971), pp. 358-364; J. Seaman *et al.*, *Harerghe Under Drought: A Survey of the Effects of Drought on Human Nutrition in an Ethiopian Province* (Addis Abbaba, Ethiopia: Ethiopian Government Relief and Rehabilitation Commission, May/June 1974); and B. Wisner and P. Mbithi, "Drought in Eastern Kenya: Nutritional Status and Farmer Activity," *Natural Hazards*, G. F. White (ed.) (New York: Oxford University Press, 1974).

[11]See A. Sommer and W. Mosley, "The Cyclone: Medical Assessment and Determination of Relief and Rehabilitation Needs," *Disaster in Bangladesh*, L. C. Chen (ed.) (London, England: Oxford University Press, 1973), pp. 119-132; M. Loewenstein, "The Cyclone: Nutritional Assessment with the 'Quac' Stick," *Disaster in Bangladesh, op. cit.*; and A. Sommer and W. H. Mosley, "East Bengal Cyclone of November, 1970: Epidemiological Approach to Disaster Assessment," *Lancet*, Vol. 1 (May 13, 1972), pp. 1029-1036.

the results to help prevent or control the diseases.[12] In times of disaster, the *objectives* of epidemiologic surveillance remain much the same:

- *Technical objective*: Early detection of communicable-disease spreading, for timely response.
- *Social objective*: Prevention or rebuttal of alarmist rumors on spreading outbreaks.
- *Operational objective*: Avoidance of blanket preventive measures, which are often ineffective and costly, and redirection of resources to productive uses.

Epidemiological surveillance aims at detecting changes in disease occurrence. To detect an increase in the incidence of disease caused by a disaster--or by the relief activities--preemergency baseline data must be available. Because baseline data are often difficult to obtain, data of questionable value have to be used. For instance, assume that a high incidence of gastroenteritis or measles is detected following a disaster. A careful analysis of disease trends during the previous years, along with interviews of field medical personnel and reliable residents, may show this high incidence cannot be attributed to the disaster.

In fact, the epidemiologic surveillance carried out with the assistance of the U.S. Center for Disease Control following the earthquakes in Managua, Nicaragua, in 1972,[13] and in Guatemala in 1976[14] has failed to demonstrate an increase in the number of diagnosed cases of communicable diseases. This finding is particularly impressive because fear of diseases and stepped-up surveillance might be

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[12]See C. de Ville de Goyet, "Surveillance Epidemiologique lors de Desastres," *Bulletin of the World Health Organization*, Vol. 5757, No. 2 (1979); and A. Romero *et al.*, "Some Epidemiological Features of Disasters in Guatemala," *Disasters*, Vol. 2, No. 1 (1978), pp. 39-46.

[13]See G. Faich, "Epidemiological Surveillance and Immunization Following the 1972 Managua Earthquake," paper presented at the American Public Health Association, San Francisco, California, 1973.

[14]See H. C. Spencer *et al.*, "Disease Surveillance and Decision-Making After the 1976 Guatemala Earthquake," *Lancet*, Vol. 2 (July 23, 1977), p. 182. See also Romero *et al.*, *op. cit.*

expected to cause more people than usual to report cases of disease.[15]

The problem of epidemic disease outbreaks following floods, earthquakes, and hurricanes reflects more an irrational fear on the part of the public in disaster areas and in affluent donor countries than an actual increase in the risk of transmission.[16] The news media have contributed to the spread of alarmist rumors and supported this unfounded apprehension.

After the Guatemala earthquake Spencer and his associates wrote the following:[17]

> Rumors of epidemics were rife by the 2nd and 3rd weeks after the earthquake. At various times, outbreaks of measles, typhoid fever, typhus, anthrax, rabies, hepatitis, influenza, and dysentery were reported in the disaster area. More than 30 reports of outbreaks were investigated and proved to be without foundation. Bacteriological laboratories were functioning in Guatemala City, and faecal cultures were used to follow up reports of typhoid fever and shigellosis in the city.
>
> Rumors of epidemic disease came from both Guatemala City and the rural areas but most often concerned the more inaccessible rural areas. Almost all of the reports investigated derived from nonmedical staff and seemed to be based on the conviction that epidemics were bound to occur.

For some well-known diseases or injuries (e.g., tetanus, rabies, and dog bites), researchers can collect baseline data after the disaster has occurred. For diseases with relatively long incubation periods, baseline data can be collected during the emergency, before an outbreak has had time to occur. The average incubation period of typhoid fever, for example, ranges from 1 to 3 weeks, a period long enough to gather some baseline information. During the second week after the earthquake in Guatemala, an increase in the number of dog bites occurred, and data

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[15]See C. de Ville de Goyet *et al.*, "Attitude Face au Risque D'epidemie lors de Desastres Soudains," *Revue d'Epidemiologie et Santé Publique*, Vol. 25 (1977), pp. 185-194.
[16]*Ibid.*
[17]Spencer *et al.*, *op. cit.*

collected during the first week provided the necessary base for comparison.

Three types of diseases need to be placed under surveillance:

1. Diseases that may break out in normal times.
2. Diseases that may spread because of the disaster.
3. Diseases like cholera, malaria, and typhoid fever that are of great concern to the health officials, politicians, and news media even though they are unlikely to occur.

The three principal surveillance techniques are these:

1. Systematic reporting by telephone, cable, or other means, not only of bacteriologically confirmed cases of selected diseases, but also of cases with a suspect clinical syndrome as previously defined. For instance, for malaria any case of fever without other apparent cause (abcess, pulmonary infection, etc.) would be reported.
2. Systematic reporting of symptoms such as diarrhea, diarrhea and fever, diarrhea with blood or mucus, fever (independently of the diagnosis), or rash.[18]
3. Rapid field investigation of any reports or rumors of abnormal incidence of disease. In Guatemala the national government, with the assistance of the Pan American Health Organization/World Health Organization and a Center for Disease Control epidemiologist, investigated almost all rumors (measles, typhoid fever, etc.), however unlikely or vague. Negative findings are as important as positive findings.

Epidemiological data should be expressed in terms of rates or proportions, because data on the number of cases of a disease without reference to the size and characteristics of the population under study are of limited value. Yet in many cases it is hard to find out how large the base population is. To illustrate the problem, consider Guatemala following the 1976 earthquake. There the search for cases of communicable diseases was carried out at the health facilities, not at the village level. But people who seek medical assistance at the health facilities have greater motivation to seek help, greater access to services,

[18]See Romero *et al.*, *op. cit.*

and better education than the population as a whole. In the absence of data on the total population, the relative magnitude of each disease was roughly estimated by the percentage of probable cases among the total consultations on a particular day.[19]

Epidemiological surveillance methods following sudden disasters do not differ significantly from those used in food and nutrition surveys or routine communicable disease surveillance. The potential occurrence of communicable diseases is one of the many pressing problems emergency authorities face, and this concern competes with others for scarce logistic and human resources.[20] In famines, food shortages and nutritional deficiencies are, of course, the main problems.

The following steps in epidemiological surveillance should be taken before and after a sudden disaster:

1. *Identification of a very limited number of diseases to be monitored and selection of suitable indicators*. Ideally, this step should take place before the disaster as a preparedness measure and be part of the normal routine surveillance activities in the country.

2. *Identification of areas affected by the disaster*, possibly with the assistance of remote sensing techniques.

3. *Rapid statistical sampling of sites* (ideally including unaffected localities for control purposes) *to be visited by a multidisciplinary field survey team*. Steps 2 and 3 apply as well to the general multipurpose assessment field survey.

4. *Rapid gross detection of cases or presumptive cases based on the presence of a symptom or complaint*. Depending on time and resources available, an attempt can be made to investigate retrospectively the occurrence of cases before the disaster. This is likely to be more feasible following disasters like floods, which cause few immediate health problems.

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[19]See World Health Organization Bulletin (forthcoming); and H. C. Spencer *et al.*, *op. cit.*

[20]See A. Sommer and W. H. Mosley, "East Bengal Cyclone of November, 1970: Epidemiological Approach to Disaster Assessment," *op. cit.*

5. *Implementation through local health services of simple monitoring and reporting of the selected diseases or symptoms*. Maximum use should be made of health auxiliaries working at the local level.

6. *In a preliminary phase, interpretation of data at the national level* by the organizational unit of the disaster-affected country that is best equipped to handle the large amount of data and that has direct access to the key decision makers in the relief operations.

7. *Investigation of any "unusual" occurrence of disease by local epidemiologists*, assisted when necessary by foreign experts. Ideally, these experts should be chosen and trained prior to the disaster; WHO and PAHO resources should be used for this purpose.

8. *Establishment of priorities for investigating unusual occurrences of disease and for rapid screening of obviously unfounded reports*. Full laboratory support should be provided to confirm the occurrence of a specific disease, to identify its cause, and to determine the best way to control it. Especially alarming situations, such as a high occurrence of disease or a particularly vulnerable environment like overcrowded refugee camps, should receive priority for the use of laboratory resources.

9. *During the rehabilitation phase, interpretation of the data at the local level and integration into the national epidemiological surveillance system*. The existence of an effective epidemiological surveillance system is an important tool to help in the implementation of postdisaster surveillance. The lack of a preexistent system compromises the quality of postdisaster epidemiological surveillance and of the conclusions that can be drawn from it.

*The Assessment of Damage and Needs in Housing*

The extent of damage to housing depends on the type of disaster (earthquake, floods, high winds), the intensity of the impact, the construction materials (adobe, tiles, bamboo, taquezal, timber, masonry, concrete, etc.), and topographic location of buildings.

In earthquakes, the distribution and intensity of damage is influenced chiefly by the type of construction, geometry, mass distribution, and degree of flexibility. During an earthquake, ground motion is transmitted to structures through their foundations. Unreinforced load-bearing walls of masonry or concrete construction are highly susceptible to earthquake damage because of their relatively low inplace shearing capacity. The strength of such walls is further reduced by window and door openings.[21]

Defects in foundations, wall construction, and roofing are a major cause of building failure in earthquakes. For instance, some of the construction defects that can be found in adobe houses--a material widely used in developing countries--are poor adobe-making techniques, use of insufficiently dried adobe, incomplete fill of the vertical points between adobe blocks, poorly aligned walls, poor interlocking wall intersections, and timber tie-beams connected with carelessly executed joints.[22]

The damage associated with tropical cyclones results from the direct action of winds, which may reach surface velocities of 150 miles per hour or more, from rainfall, and from storm surges.[23] The critical wind pressure depends to a large extent on the geometric characteristics of a building, and on the arrangement of buildings in a group. Wind may cause a building to slide or overturn, and the storm surges and heavy rainfall characteristic of typhoons and hurricanes may cause floods that damage the foundation soil or the foundation itself.[24] The wind resistance of buildings can be improved by improving connections between walls and foundations, floors and roofs, by learning more about the effects of wind on buildings, and by avoiding certain shapes or groupings of buildings that cause undesirable aerodynamic effects.[25]

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[21]See S. G. Fattal, "General Structural Characteristics of Buildings and Building Materials," *Design, Siting, and Construction of Low-Cost Housing and Community Buildings to Better Withstand Earthquakes and Windstorms*, W. F. Reps and E. Simiu (eds.) (Washington, D.C.: National Bureau of Standards, 1974), pp. 3-12.

[22]See United Nations, *Low Cost Construction Resistant to Earthquakes and Hurricanes* (New York: UN, 1975), p. 110.

[23]See E. Simiu, "Structural Performance of Low-Cost Housing and Community Buildings Under Windstorm Conditions," *Design, Siting, and Construction of Low-Cost Housing and Community Buildings to Better Withstand Earthquakes and Windstorms*, W. F. Reps and E. Simiu (eds.) (Washington, D.C.: National Bureau of Standards, 1974), pp. 28-37.

[24]*Ibid*.

[25]See National Bureau of Standards, *Building to Resist the Effect of Wind*, Building Science Series 100 (Washington, D.C.: NBS, 1977).

Field reconnaissance teams must conduct preliminary damage surveys to housing immediately after the disaster to facilitate prompt reconstruction and rehabilitation and to prevent decisions that may harm the recovery process. For example, hasty clearance of debris may prevent salvage and reuse of the materials later on. Table 2 illustrates the application of information derived from damage surveys.

No standard methodology yet exists for assessing housing damage and needs in developing countries. The nature of an assessment depends on the expertise of the reconnaissance team. The teams sent by agencies in developed countries--the Earthquake Engineering Research Institute, the National Bureau of Standards, the National Academy of Sciences-National Research Council Committee on Natural Disasters--have generally addressed only the construction problems they are familiar with in their own countries.

A major effort is now needed to improve the methods of assessing damage to buildings of simple construction, of defining necessary improvements in design and in construction techniques, and of estimating real housing needs. Ideally local engineering and architects' professional organizations and key national housing organizations should participate in this effort. Predisaster hazard and vulnerability analyses considerably facilitate postdisaster assessment of damage and needs and complement information obtained in the actual field assessments.

Postdisaster assessment of damage and needs should include (1) housing losses and damage to structures and (2) housing construction, housing management, and economic considerations. The initial examination of housing damage includes a general examination of the extent of damage to structures, detailed examination of the nature of damage, explanation of the damage, and examination of repair design alternatives.

The rapid damage survey should include a general evaluation of how well different structural elements (foundations, frame elements, walls, roofs, and upper floors) and materials held up, and a listing of design characteristics.[26]

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[26]For detailed checklists of the different elements see Earthquake Engineering Research Institute, *Learning from Earthquakes* (Oakland, California: Earthquake Engineering Research Institute, 1977); and the National Bureau of Standards' publications: *Building Practices for Disaster Mitigation*, Building Science Series 46 (1973); *Building to Resist the Effect of Wind*, Building Science Series 100 (1977); and *Development of Improved Design Criteria to Better Resist the Effects of Extreme Winds for Low-Rise Buildings in Developing Countries*, Building Science Series 56 (1974).

TABLE 2 Shelter/Infrastructure: Use of Information Derived from Damage Surveys

| Information Obtained from Damage Surveys | Method of Obtaining Data | Use for Surviving Families | Use for Local and Possibly National Administration | Use for Local Private Sector | Use for External Groups (Governments, Voluntary Agencies, and Other Private Groups) |
|---|---|---|---|---|---|
| 1. Number and location of houses damaged or destroyed.<br>2. Forms of damage.<br>3. Degrees of damage. | A mixture of low-level and high level air surveys coupled with ground survey sampling techniques. | No use | Essential to determine the need for:<br>a. Possibly supplying--in exceptional circumstances--temporary shelter (e.g., tents).<br>b. Financing allocations to survivors.<br>c. Establishing what materials will be needed for reconstruction. | Useful for determining:<br>a. The supply of essential components needed for construction.<br>b. The supply of tools needed. | Needed to determine:<br>a. Whether to provide temporary shelter.<br>b. Whether to provide building supplies (e.g., roofing materials).<br>c. Whether expertise is needed to guide reconstruction. |
| 4. Extent of damage to local stocks of building materials. | Air surveys when damage is to basic materials such as trees coupled with ground surveys of warehouse stockpiles, etc. | Useful, but probably already known to locals. | Essential in determining whether to request supplies of materials from outside. | Essential in determining whether to order supplies from external sources. Also useful in determining stockpiles for future preparedness planning. | Useful in determining what contributions are needed, particularly from adjoining countries. |
| 5. Extent of damage to infrastructures, such as roads/services. | Air surveys of roads, bridges, etc. Ground sampling techniques for well contamination; village-by-village surveys of electrical/sanitation damage. | Useful for avoiding blocked roads/contaminated water supplies, etc. | Essential in preventing secondary disasters such as epidemic diseases due to contamination and in restoring services. | | Useful in the event of major disaster requiring external support to determine the resources needed. |

A subsequent detailed investigation should specify the quality of the materials, their arrangement in the building, and the distribution of cracks, deformations, and so on. Information should also be obtained on the quality of the foundation, soil, peculiarities of the building, interference of neighboring structures, or changes in use that may have contributed to the damage.

These evaluations should indicate the most appropriate construction techniques and structural designs for withstanding future disasters. If the local availability of construction materials has also been investigated, importation of materials may be avoided.

Decisions must also be made on what reconstruction strategy to pursue, since there are many options open to governments and agencies. Temporary housing in many instances has proved more expensive than have the permanent structures built by the local population. Persons assessing housing needs should encourage rapid reconstruction of permanent houses--for example, by locating material for temporary shelter that could be reused in the permanent structures. Early analysis of relocation alternatives should avoid unnecessary evacuation and creation of refugee camps.

Land tenure is a major issue. Land for new houses for the homeless must be secured. Measures should be established to control inflation and speculation in land and construction materials. Policy decisions should be made on whether to enact such programs as subsidized sale of materials, establishment of credit systems, free distribution, and other housing reconstruction schemes.[27]

Planning and management of the housing reconstruction process requires information concerning the following:

- Availability of local construction materials for rebuilding--to avoid the time, money, and effort involved in importing materials and also to avoid disruption of the local construction materials market.
- Availability of skilled construction workers to supervise the construction and train the population in safe construction methods.

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[27]See R. Gersony *et al.*, *Guatemala-AID Disaster Relief Program: Reports on Post-Earthquake Distribution of Building Materials*, report for the Agency for International Development in Guatemala (Washington, D.C.: U.S. Agency for International Development, December 1977).

- Availability of labor that could be used in housing construction if not needed elsewhere (agriculture, industry, etc.).
- Possible use of existing organizations (cooperatives, community organizations) to provide leadership, training, management, and distribution outlets for materials and tools.
- Evaluation of areas in which technical supervision is needed; this may be provided either by professionals within the disaster-stricken country or by outside experts.
- Assessment of the customary forms of housing and settlement in the stricken area.[28] For instance, persons in disaster-struck Peru, Turkey, and Nicaragua found polyurethane igloo-shaped houses provided as temporary dwellings unsuited to their cultures and inappropriate for their environments. In Bangladesh, both Bengalis and Biharis criticized the A-frame modular housing provided to them as cramped and alien.[29]

Thus, to assess housing damage and needs, information on the nature and extent of damage must be collected and reconstruction policies defined in terms of the recipient country's technical needs, economic situation, management capabilities, and culture. International and single-country donors should use assessments in working with governments of disaster-prone countries (1) to improve building practices to withstand disasters, (2) to implement building science and technology education programs, and (3) to promote exchange of information on these subjects between professionals in both developed and developing countries.

### *Assessment of Damage and Needs in "Lifeline" Systems*

"Lifelines" are the public facilities that provide transportation, communication, water, and energy:

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[28]See B. Bode, "Disaster, Social Structure, and Myth in the Peruvian Andes: The Genesis of an Explanation," *Annals of the New York Academy of Sciences*, Vol. 293 (July 1977), pp. 246-274.

[29]See National Bureau of Standards, *Building to Resist the Effect of Wind*, *op. cit.*

| *Water System* | *Energy System* |
|---|---|
| Potable | Gas |
| Sewage and solid waste | Electricity |
| | Liquid fuel |
| *Transportation System* | *Communication System* |
| Roads | Telephone and telegraph |
| Railways | Radio and television |
| Harbor | |
| Airports | |

Lifelines may increase the havoc a disaster creates by failing to perform adequately or by producing additional hazards; for example, fires may develop in an electrical system or a dam may fail. After a disaster occurs, teams of experts should undertake immediate reconnaissance surveys to determine the extent of trouble in each of the lifeline systems. This assessment entails the following steps:

1. Determination of the conditions of the different systems and their components following the disaster.
2. Speculation about the causes of damage, for instance, contamination of a portion or all of the water supply, power outages, communication disruption, transportation failure, plant or facility damage, etc.
3. Definition of the requirements for operating the system.
4. Establishment of immediate recovery objectives.
5. Design of an emergency plan for achieving the objectives.

*Water Systems* The supply of water in disaster-affected areas critically affects survivors. The water supply may be contaminated; extraction problems may result from collapsed wells, blocked or otherwise disabled pumps, or inadequate power to operate the system.

Assessment of water system damage and needs involves the following tasks:[30]

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[30]See Primer Seminario National, *La Ingeniería en Casos de Desastre* (Jalisco, Mexico: Colegio de Ingenieros Civiles del Estado de Jalisco, 1975); and American Water Works Association, *Emergency Planning for Water Utility Management* (New York: American Water Works Association, 1973), p. 37. These steps in assessing water system damage and needs apply primarily to water systems in urban areas. In rural areas

1. Estimation of the impact of the disaster on each component of the system: (a) source, (b) collection works, (c) transmission system, (d) distribution system, and (e) power supply. Components incapacitated by the disaster should be itemized. Components that are interrelated with others so as to make the entire system inoperative should receive special attention.

2. Estimation of water requirements for (a) potable water, (b) fire fighting, (c) decontamination and sanitation, (d) agriculture, and (e) industry.[31]

3. Tests of water for chemical and biological quality.

4. Estimation of the capability of the system to meet the requirements. If the system fails to meet the water requirements, key components that are primarily responsible for the failure should be identified. Unnecessary loss of stored, treated water must be prevented.

5. Specification of priorities, and planning of the best ways of using resources: (a) establish baselines on water quality levels; (b) allocate water under assumed needs for drinking, sanitation, decontamination, fire-fighting, industrial use, and agriculture; (c) prepare guidelines for water allowances, priorities, rationing, and time phasing of estimated water requirements; (d) establish procedures for emergency treatment, pumping, and distribution of water.

5. Design of a feasible plan for operating the system and specification of transportation, manpower, and equipment needed to implement the plan.

*Transportation Systems* A disaster may wash out or block roads, destroy bridges, or cause overpasses to collapse. The assessment team needs to investigate the following matters:[32]

1. The extent of damage and the degree of usability of the different components of the road system: roads, bridges, overpasses, tunnels.

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the water system (wells, cisterns, windmills, etc.) may be more primitive, but a similar set of steps for checking, testing, and determining needs and priorities is required.

[31]In the case of cyclones, agricultural concerns are the damaging effects of saline water on arable land and the provision of freshwater irrigation to leach the soil so that the next crop can be planted.

[32]See Earthquake Engineering Research Institute, *op. cit.*

2. The extent of damage to railroads, including bridges, roadbeds, and tunnels.

3. The extent of damage to harbor facilities, docks and piers, and material-handling equipment, such as cranes.

4. The extent of damage to airports: damage to buildings and control towers, runways, lighting systems, control lights, underground facilities, fuel systems, and emergency electrical power.

5. The availability of temporary emergency runways, control towers, and staging areas.

6. The transportation needs posed by rescue and relief activities: the availability of aircraft, parts, fuels, and other means of transportation, particularly special-purpose transportation such as four-wheel-drive vehicles and helicopters. The availability of local vehicles should be assessed with a view to relying on local transportation as much as possible.

7. The possibility of construction of secondary roads if main roads are blocked.

*Communication Systems* Disasters may disrupt communications through (1) broken lines, (2) damaged equipment, (3) lack of electrical power, and (4) system failures due to overloading. The extent of damage to telephone and telegraph systems needs to be assessed and measures instituted to prevent further breakdown of systems due to overloading. If necessary, the possibility of establishing connection with essential relief centers should be investigated. The extent of damage to radio and television systems should be assessed; to some extent, it will depend on damage suffered by buildings that house studios and transmitters.

*Energy Systems* The assessment of damage to electrical power systems should include checking fossil fuel and hydroelectric generating plants, transmission lines, switchyards and substations, and distribution systems. Assessment of damage to gas systems should include surveys of pipelines, gas lines, conduits, and tanks.

Field surveys, an important tool for assessing damage and needs, have not received enough attention. There is reason to support the idea of an experimental or demonstration approach to the organization of disaster survey operations. National and international agencies, and the scientific community should develop new field survey methodologies, improve the existing ones, and train more disaster experts, particularly in disaster-prone developing countries.

# 5 Methods of Assessment: Remote Sensing

Remote sensing by aircraft and spacecraft is a valuable new information-gathering tool of which relief agencies and donor countries need to be aware. Remote sensing provides a comprehensive, synoptic, and objective view of a large area over a short period of time. In general, remote sensing information is likely to be most valuable in predisaster planning and hazard analysis (including warning of slowly developing disasters) and postdisaster rehabilitation and reconstruction. Theoretically, remote sensing also offers the possibility of acquiring data over regions made inaccessible by disruption of normal transportation and communications systems; in such areas, information may be needed about debris or sediment deposits and similar problems that threaten health and life. In practice, however, remote sensing data may not be obtained soon enough after a disaster to be used for this purpose. Some pilot studies are needed in the uses of remote sensing data.

Field survey investigations should be planned in parallel with pilot studies using remote sensing methods and data to verify and supplement the information provided by remote sensing methods and to ensure that remote sensing data can properly be used to extend ground observations. At this time, only the simplest analyses, such as recognition of surface water, can be conducted without field verification. A portion of this ground verification information can be acquired from local scientists and from previous familiarity with the region, but most disaster assessments require active postdisaster site evaluation.

Responsible use of remote sensing will await both the pilot studies just suggested, and maturation of the technique in both the developed and developing world. Many developing countries have already made significant commitments to using remote sensing in resources evaluation, but the technique has thus far not been used in disasters. Thus some caution is necessary both in assessing untried roles for remote sensing and in recommending use of the technique in disasters. The following pages reflect the concern of the Committee on International Disaster Assistance to strike the proper balance between present caution and future possibilities.[1]

Some observers have suggested that LANDSAT earth resources satellites have considerable potential value in disasters. The Committee notes that, of the developing nations, only those in the Americas and North Africa are now reasonably (but not fully) served by LANDSAT receiving stations. New stations under construction or consideration in Africa and Asia will not become operational for some years. Also the future NASA Tracking and Data Relay Satellite System (TDRSS) will offer an alternative to new stations in the developing world and to reliance on the present expensive and unreliable tape recorders used to obtain coverage outside view of the receiving stations. Again, however, operation of TDRSS is some years hence and, as of this writing, is not an assured system because of both technical and financial difficulties. Nevertheless, using TDRSS and/or Regional Receiving Stations, disaster coverage of most developing nations should be feasible with satellites by the early 1980's.

Given that this will be the case, these problems will still be of concern:

1. Present satellite imagery does not have a high enough spatial resolution (80 meters) or repetitive coverage of the same area (18 days) to facilitate damage assessment in sudden disaster situations. For example, damage to

[1]Two recent National Academy of Sciences studies deal with problems in the use of remote sensing: (1) Committee on Remote Sensing for Development, Board on Science and Technology for International Development, *Remote Sensing from Space: Prospects for Developing Countries* (Washington, D.C.: National Academy of Sciences, 1977); and (2) D. S. Simonett, "Possible Uses of Space Satellites for Disaster Warning, Monitoring, and Damage Assessment," *The Role of Technology in International Disaster Assistance: Proceedings of the Committee on International Disaster Assistance Workshop, March 1977* (Washington, D.C.: National Academy of Sciences, 1978), pp. 79-99.

individual structures and transportation networks cannot be directly determined.

2. While future LANDSAT satellites, such as LANDSAT-D, will have improved spatial resolution (30 meters instead of 80), it is uncertain how much this change will improve the information on disasters from satellites.

3. Future satellites will also produce enormous streams of data. For example, the data volume produced by LANDSAT-D will be 15 times the volume produced by LANDSAT-2. The radar satellites of the mid- and late 1980's that may be launched are likely to produce 20 to 30 times the current volume. Even the meteorological satellites of the future will have substantial data volumes. Such voluminous information will be costly to handle, and developing countries rarely have the large computing facilities needed to process these data.

4. Neither the present satellites nor those of the LANDSAT-D type can see through clouds. Constant cloud cover is a major problem in the many developing countries of the wet tropics. Future radar satellites will eliminate this problem and high-resolution optical sensors that can be focused on specific geographic areas will reduce its severity. Still, it is difficult to predicate the use of remote sensing on LANDSAT sensors that *cannot* deliver data in cloudy conditions, or on untried radar systems.

5. Without the capability to process and interpret imagery, remote sensing will be of little use. Few personnel in developing countries are now capable of using remotely sensed data, though the numbers are likely to increase because major training programs have now begun.

6. The cost of acquiring data will increase as a result of the new policy of the National Aeronautics and Space Administration to recoup a portion of its investment in foreign ground stations. NASA currently charges $200,000 per year per station. How many developing countries will be willing and able to pay their share of these or future increased charges?

Some observers have suggested that aircraft remote sensing will be more suitable than satellite observation for use in disasters. In part this may be true--especially with respect to much more satisfactory resolution. However, few developing countries are expected to be willing to invest in aircraft and sensing systems for disaster-related use alone. Also the national apprehensions and sensitivities of developing countries might be aroused if donor countries were to gather remotely sensed data on disasters.

There are alternatives to remote sensing--procedures that may, in fact, be more cost-effective--for damage assessment. As noted earlier, remote sensing can rarely be used without supporting field observations and samples. Such field data (which are required to substantiate remote sensing data) are of a much lower technological level, are more easily absorbed by developing countries, and in some cases at least may require less highly trained personnel. The question of costs--whether to spend more for incremental or improved ground observations or for remote sensing--remains to be examined.

Relief efforts now proceed in developing countries substantially, if not entirely, without remote sensing, and these efforts can be improved without resort to remote sensing. Land communication can be improved through development of a dependable radio network or disaster-resistant microwave or satellite telephone-based communication systems. Universities and colleges in developing countries can encourage disaster preparation without commitment to sophisticated technologies.

Yet remote sensing technology offers interesting possible applications. As already suggested, it can be employed in predictive modeling, in monitoring slowly developing disasters, in preparedness planning, and in long-term reconstruction and development planning. Aircraft and satellite data also can play large roles in activities unrelated to disaster, such as resource inventories, mapping, and geologic applications. Use of remote sensing for disaster assistance requires some management system already in place, established for purposes other than disaster work. Once a remote sensing system is in operation as part of a resource and land evaluation system, disaster assessment can be added as a modest component.

In essence, remote sensing offers developing countries no easy solutions for dealing with disasters. These countries should weigh their investment choices carefully. Each developing country has a unique combination of likely disasters, talents, financial resources, and ability to use aid from the international community. Each will have its particular problems relating to politics, finance, technology, and geography, and its own capabilities for handling them.

The subsequent sections describe the different systems that could be used in remote sensing.

**Aircraft Imagery**

Multistage aircraft imagery could be very useful in predisaster and postdisaster situations, primarily because of its high resolution. Aircraft imagery would provide detail that satellite imagery cannot yet provide. However, aerial coverage of a large-scale disaster can be quite costly and time consuming, even when high-altitude aircraft are used. Aerial coverage is worthwhile only when the area of interest is relatively small (a few hundred to perhaps ten thousand square kilometers) or if the problem can be addressed only with a high-resolution system. A combination of satellite and aircraft data may reduce the number of low-level flights needed, thereby minimizing the cost.

Aircraft employed to provide disaster coverage could be equipped with a variety of sensor systems according to the location and type of disaster. Conventional camera systems equipped with color-infrared film would be useful for all kinds of disasters. High-altitude planes could be equipped with similar systems or more complex ones, including radar, which would be necessary in areas of persistent clouds.

Aircraft and satellite imagery could be used not only for postdisaster damage assessment but also for hazard and vulnerability analysis within disaster-prone countries. High-risk areas could be mapped: flood plains, vulnerable settlements, areas of wind exposure, coastal flood sites and tsunami dangers, fault zones, and avalanche and landslide risk areas. Aircraft and satellite imagery could also make a valuable contribution to a country's data base. If an area had been covered under normal conditions, damaged areas would be easy to see on postdisaster images.

Most developing countries have small aircraft that could be equipped with cameras to provide low-altitude coverage. In addition, some countries have military or commercial planes capable of medium- to high-altitude coverage. If they do not have these capabilities, special arrangements could be made with international or bilateral agencies to provide for this coverage.

Use of a military aircraft, such as the U-2,[2] RB-57F,[3] or SR-71,[4] could also be used to acquire timely data.

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[2]The U-2 is a single-seat aircraft designed and built by the Lockheed Aircraft Corporation for high-altitude, long-range operation (operating altitude, 65,000-70,000 feet; cruising speed, 740 kilometers per hour (460 miles per hour) at 20 kilometers (65,000 feet). The National Aeronautics

However, marshaling a plane such as the U-2 requires trained pilots, trained ground maintenance crews, technicians, photo-processing facilities, interpreters, and special fuels. Furthermore, because of the stigma associated with the U-2, some countries may either reject any overflight by such a plane, or require special arrangements in advance.

An AID/OUSFDA-sponsored or UN-sponsored commercial jet (such as the Caravelle), mounted with an imaging radar and a 6-inch focal length camera (color-infrared film) and flying at 12,000 meters, could obtain imagery with an acquisition scale of 1:80,000 for photography and with 10-meter resolution (or better, if desired) for radar. A

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and Space Administration U-2 aircraft, based at Ames Research Center, California, routinely fly from Ames and Wallops Island, Virginia, and other staging locations are possible. The planes carry a wide variety of sensors, including aerial mapping cameras, electronic sensors and scanners, and both *in situ* and remote atmospheric sampling devices. The NASA U-2 aircraft are available on a cost-reimbursable basis for research or experimental programs. See National Aeronautics and Space Administration, *High Altitude Perspective* (Moffett Field, California: NASA, Ames Research Center, Airborne Missions and Applications Division, 1977).

[3]The General Dynamics/Martin RB-57F is flown and maintained for the NASA Earth Observations Aircraft Program Office. It is a midwing, 4-engine turbofan/turbojet aircraft. The data acquisition system comprises an airborne sensor platform, various sensors, and ancillary control and data-recording equipment. The service ceiling is 18,900 meters (62,000 feet); maximum cruising speed is 740 kilometers per hour (460 miles per hour) at 18,300 meters (60,000 feet); range, 5,320 kilometers (3,300 miles). See A. P. Colvocoresses, "Platforms for Remote Sensors," *Manual of Remote Sensing*, Vol. 1, R. G. Reeves (ed.) (Falls Church, Virginia: American Society of Photogrammetry, 1974), p. 560.

[4]The Lockheed SR-71 is a U.S. Air Force long-range advanced strategic reconnaissance aircraft. It is capable of worldwide reconnaissance operations, including aerial photographic missions and multiple forms of remote sensing. The service ceiling is over 24,400 meters (80,000 feet); maximum speed is MACH 3, or more than 3,340 kilometers per hour (2,070 miles per hour) at 24,463 meters (80,258 feet); range is more than 3,220 kilometers (2,000 miles). Colvocoresses, *Ibid.*, p. 562.

Caravelle jet requires less specialized maintenance facilities, fuel, and pilots than a U-2 does. It would not have the political stigma of the U-2 and could use commercial pilots, but prior permission for its use in flying over developing countries would still be required. The cost of setting up a single Caravelle aircraft with an imaging radar and an array of cameras could range from $7 million to $15 million, depending on equipment. A careful cost analysis would be required (of initial cost, equipment maintenance, service facilities, crews, and interpreters) to determine whether development of such a system is warranted, even it if were developed principally for uses other than in disasters.

Hiring a commercial firm to provide coverage of a disaster is a costly but viable alternative. There are now two commercial firms in the United States that could provide radar and color-infrared imagery if requested. To fly a radar system outside the U.S. borders requires special licenses, permits, and visas from the countries involved. The cost of the mission itself is from $7,000 to $10,000 per day, depending on the area of coverage. There is also a charge of about $5 per statute mile to fly to the disaster site, as well as the cost of the fuel to return home. As with the military flights, foreign governments must support the flights or they cannot be flown. The Committee recognizes that the AID/OUSFDA already has these options and possibly others under examination. Before a decision is made in this area, experiments need to be carried out and more complete information acquired on costs and benefits.

## Satellite Imagery

For certain disaster problems, satellite imagery may be much more cost-effective than aerial photography. With present technology, images can be obtained of almost any place in the world at scheduled intervals, clouds permitting. Although resolution is modest, the regional view provided by satellite imagery can be useful.

Satellite imagery is available in photographic and digital form. Usable information can be extracted at almost any technical level. Mapping an area inundated by floods by inspecting the pictures requires little or no training.

Use of such high technology as computer processing allows more information to be extracted, based on spectral signatures and changes occurring with time. Computer technology, however, would normally be usable only in the preparedness and reconstruction phases; it is not likely to be readily available during the emergency itself.

A study undertaken by Nanayakkara and Wagner showed that processing systems capable of performing level slicing,[5] gray mapping,[6] and ratio processing[7] could be set up in a developing country or a central facility at a relatively low cost.[8] The United Nations is currently compiling information on low-cost digital computers, associated software, and peripheral equipment that will be useful to developing countries.[9] Such equipment will be intended primarily for resource inventory and monitoring; disaster evaluation could be an added responsibility.

Satellites employable now consist of LANDSAT and a variety of meteorological satellites. Currently, LANDSAT provides the best resolution. Resolution of meteorological satellites is fairly coarse, but imagery from the geosynchronous satellites can be obtained every 30 minutes, an

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[5]In level slicing (or density slicing), the continuous gray tone of an image is converted into a series of density intervals, or slices, each corresponding to a specific digital range. See F. F. Sabins, *Remote Sensing Principles and Interpretation* (San Francisco, California: W. H. Freeman and Company, 1978), p. 407.

[6]Given a distribution of dark and light values (gray values) for an image, features can be emphasized by presenting only those density or gray values that are found for the features in question.

[7]Ratio processing (ratio image) is an image prepared by processing digital multispectral data. For each pixel, the value for one band is divided by that of another. The resulting digital values are displayed as an image. Sabins, *op. cit.*, p. 411.

[8] See C. Nanayakkara and H. Wagner, "Digital Processing System for Developing Countries," *Proceedings of the Eleventh International Symposium on Remote Sensing of Environment, April 25-29, 1977, Ann Arbor, Michigan* (Ann Arbor, Michigan: Environmental Research Institute of Michigan, 1977), Vol. I, pp. 1123-1126.

[9]See H. G. S. Murthy, "United Nations Role in Remote Sensing," *Proceedings of the Twelfth International Symposium on Remote Sensing of Environment, April 20-26, 1978, Manila, Philippines* (Ann Arbor, Michigan: Environmental Research Institute of Michigan, 1978).

excellent interval for monitoring weather and atmospheric conditions. A brief description of these satellites appears below. They are also discussed in detail in the context of floods, earthquakes, and droughts in Appendix 2.

### *NOAA Meteorological Satellites*

The meteorological satellites of the National Oceanic and Atmospheric Administration (NOAA) provide images in the visible and infrared portions of the spectrum. Earth-Synchronous Meteorological Satellites/Global-Observing Environmental Satellites (SMS/GOES) are potentially the most useful, especially when used with the Weather Facsimile (WEFAX) communication system. The same area is viewed every 30 minutes with a resolution of about 1 kilometer in the visible and 8 kilometers in the thermal portions of the spectrum. The satellites can collect and distribute environmental data from remote unattended data collection platforms on land, in water, or in the atmosphere and quickly retransmit these data to ground receiving stations.

### *NASA Earth Resources Satellites*

Three satellites in the LANDSAT series have been launched since mid-1972. LANDSAT-1 is now inoperative for imaging. Both LANDSAT-2 and LANDSAT-3 are still partly operative at the time of writing. They contain a four-channel multispectral scanner (MSS)[10] (0.4 μm to 1.1 μm range) of 80-meter resolution. LANDSAT-3 also had a fifth channel in the thermal region (9 μm to 14 μm region), but it is no longer working. Each satellite also contains Return-Beam

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[10]A multispectral scanner (MSS) is a system on board the LANDSAT satellite series that simultaneously acquires images in four or five wavelength regions of the same scene. LANDSAT-1, LANDSAT-2, and LANDSAT-3 scan in four regions (bands): 0.5 μm-0.6 μm, 0.6 μm-0.7 μm, 0.7 μm-0.8 μm, and 0.8 μm-1.1 μm. Also, LANDSAT-3 has a fifth (thermal) channel (8 μm-14 μm), but the latter was inoperative at the time of writing. The abbreviation "μm" refers to a micrometer or micron. 1 μm = 1/1,000,000 of a meter.

Vidicon (RBV)[11] cameras. LANDSAT-2 has three RBV cameras of 80-meter resolution that cover the same swatch as the MSS (0.5 μm to 0.75 μm range). LANDSAT-3 has two RBV cameras each of 0.5 μm to 0.75 μm range; they provide side-by-side coverage of the same swatch as the MSS, but with improved resolution of 40 meters. All satellites have 18-day repeat coverage and a 9-day repeat when two are used. Problems with the tape recorder on LANDSAT-2 have largely limited that satellite's coverage to line-of-sight operation when in range of ground stations in the United States, Canada, Brazil, and, recently, Italy. Realistically, only LANDSAT-3 is available for widespread use outside the Americas.

In the absence of clouds and when fully operating, LANDSAT satellites can image large areas anywhere in the world at scheduled intervals. Their data are uniform, multispectral, suitable for computer processing, and easily reproduced for interpreters.[12] However, their potential for disaster monitoring is diminished by cloud cover, by the rigid or relatively lengthy repeat time, by incomplete coverage of stations, and by component failures.

Future satellite systems with higher resolution and more frequent coverage may prove of greater use for disaster assistance, but it will be 5 to 10 years before their value for use in disasters is known. A brief description of these planned experimental satellites is provided in Appendix 3.

Several developing countries have built or are planning to build LANDSAT receiving and processing facilities. Three receiving stations are now operable in the United States, two in Canada, and one each in Brazil and Italy. Receiving stations are under construction in Iran, Japan,

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[11]A Return-Beam Vidicon (RBV) is a little-used imaging system on LANDSAT-1 and LANDSAT-2 consisting of three cameras operating in the green, red, and photographic infrared spectral regions. Instead of using film, the images are formed on the photosensitive surface of a vacuum tube. The image is scanned with an electron beam and transmitted to earth receiving stations. In LANDSAT-3, the three cameras are replaced by two side-by-side RBV's of 40-meter resolution, imaging in the 0.5 μm to 0.75 μm region, and covering the same swatch as the MSS.

[12]See P. F. Krumpe, *The Application of LANDSAT Technology to the Problems of Disaster Preparedness (Early Warning) and Relief (Damage Assessment)* (Washington, D.C.: Agency for International Development/Office of U.S. Foreign Disaster Assistance, August 1977), p. 2.

and Sweden and being planned in Argentina, Australia, Chile, India, Indonesia, Romania, Upper Volta, and Zaire.[13] Further investment by the developing countries may not be a cost-effective investment, however, because such future technological developments as the proposed communication satellite link for LANDSAT-D and the launching of the Space Shuttle may make them unnecessary.

### *Roles of Remote Sensing in Various Types of Disaster*

Next, the roles of remote sensing for floods and storm surges, earthquakes, and droughts will be summarized. A more detailed analysis in relation to five time phases--preparedness, warning, emergency, rehabilitation, and reconstruction--is provided in Appendix 2.

*Floods* are amenable to remote sensing because they are continuous and locally confined. Aircraft and satellite data could be used in the preparedness phase to help delineate hazardous areas of floodplains, as well as areas subject to coastal flooding, tsunamis, and dam failure. After a flood, remote sensing can be used to help determine where ground gauges or observers might best be stationed during the next flood. Remote sensing might contribute to flood warnings by improved monitoring of cyclonic storms (typhoons, hurricanes), tsunamis of distant origin, flood crests in large river basins, snowmelt runoff, and stream flow conditions. In all cases, however, financial and operational constraints must be thoroughly examined before a commitment can be recommended.

In the emergency period, the suddenness of storm surges, tsunamis, and other flash floods reduces the time for mobilization of aircraft. It is doubtful whether imagery may be obtained, processed, and analyzed in time to help. Where circumstances permit remote sensing information to be obtained, its value for assessing the regional extent and severity of flood damage should be determined. Data from remote sensing could be used for identifying isolated areas and for monitoring the flood recession. An assessment should be made of the use of these data for positioning ground survey teams, relief supplies, and medical personnel.

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[13]NASA has estimated that the cost of building a ground receiving station could range from $1.9 million (minimum requirement station) to $6 million (full ground station including the capability for quick look).

Rehabilitation may be improved by using aircraft and satellite data to assess damage to agricultural fields, transportation systems, and, to a very limited extent, structures. Other possible uses are for noting areas inundated by flood waters and areas likely to be short of food. It might be possible to locate damage to water supplies and water supply systems, such as areas of heavy debris and blocked irrigation channels, as well as secondary health hazards due to standing water.

During reconstruction, remote sensing could be useful for establishing floodplain boundaries, estimating agricultural losses, evaluating the long-term consequences of increased soil salinity and siltation, and providing a data base for planning reconstruction.

For *earthquakes*, remote sensing could provide varying degrees of information for preparedness planning and postearthquake reconstruction. For the preparedness phase, remote sensing can provide an improvement in delineating linear features that often betray fault lines. The imagery can aid in assessing areas of high risk and provide base information. These data can be used for planning where major structures and buildings--cities, dams, and nuclear installations--will be placed.

Remote sensing is not yet applicable to the warning phase for earthquakes, but as our prediction abilities improve, data collection platforms may monitor seismically active areas. During the emergency phase, remote sensing is of limited use but could help in assessing the regional extent of damage, and in locating affected isolated areas.

Thoughtful application of aerial photography in conjunction with ground surveys during rehabilitation and reconstruction could benefit damage assessments and long-term development plans. Aircraft imagery could help assess damage to transportation systems and structures, and damage resulting from such secondary events as tsunamis, landslides, avalanches, fires, and dam failures. Imagery may also be useful as a planning base for redeveloping urban areas and delineating any new hazardous fractures or faults.

For *drought*-prone areas the synoptic view and ability to detect change through time makes meteorological and other satellite observations a potentially useful evaluative and historical data base for research, hazard analysis, monitoring, and, to a limited extent, rehabilitation. With these data bases, monitoring the water, soil, and vegetation resources as a function of climate can improve understanding of the influence of climate on agricultural production. By identifying ground locations for quantitative sampling that are representative of the region, as well as of soil and topographic variations, the data can be used to make the most of ground surveys and quantitative measurements.

For preparedness applications, remote sensing could provide a mapping base for research and resource inventory of drought-prone areas; develop thresholds in the modeling of drought intensity, as well as extent and duration of the drought; and accumulate global information on cloudiness, temperature, precipitation, radiation budget, and soil moisture, for future research and hazard analysis.

To facilitate warning, remote sensing could be used to monitor the progress of drought and to help estimate crop and range production and livestock mortalities, and, together with ground surveying, may provide data to improve warnings for nomadic herding areas.

At present, however, no system employing satellite data has a proven capability for warning. Many questions remain to be researched; scientists disagree on the interpretation of data. Moreover, the link between drought and famine--and between both and donor country assistance--is not only highly variable, but will undoubtedly change as responses to drought within the developing countries themselves change and improve.

# 6 Recommendations

The following recommendations derived from this study are addressed to the AID/OUSFDA, as well as to a broad audience composed of the scientific community, voluntary agencies, and international organizations. The Committee on International Disaster Assistance hopes that these recommendations also may be of interest to the governments and voluntary agencies in the developing countries and that they will stimulate further internal efforts to improve disaster preparedness programs in those countries.

The recommendations are grouped under the following two general categories: (1) damage and needs assessment and (2) preparedness and training.

## Damage and Needs Assessment

1. *Professionals in disaster work should develop techniques for complete, accurate, and timely assessment of damage and needs following disasters, and for the improvement of baseline data on disaster-prone areas.*

a. *Disaster-related operations.* Better information is needed to improve preparedness programs, to provide warning, to judge the extent of damage, to determine the extent of needs, and to decide what relief and rehabilitation responses are appropriate. Because in a disaster the government of the affected country will make most of the decisions, primary efforts to improve the information base should be directed toward increasing those capabilities and developing sources of information that would be useful to the government of the affected country both in its routine operations and its disaster-related activities.

The early assessment of damage and needs should be made by persons close to the disaster, both culturally and geographically. This early internal assessment may, at the determination of the disaster-stricken country, need to be supplemented with technical expertise and assistance from the international community. The Committee recommends increased efforts toward helping developing countries to improve their own capabilities to assess damage and needs.

b. *Disaster-related research*. There is a critical need to improve background and baseline information on disaster-prone areas. Such data can provide the basis for measuring damage, inferring needs, and guiding the reconstruction process. In addition, data need to be developed on what types of damage specific disaster agents cause and on how their damage potential will translate into needs. In general, the use of field survey techniques can make the greatest improvements in the developing nations' capabilities for gathering predisaster baseline information and postdisaster assessment and monitoring information.

2. *Field surveys and low-level aerial photography for quick damage and needs assessment are not used in developing societies as frequently as they might be. Developing nations should be encouraged to consider adopting these techniques. Applications suggested for these techniques should become key elements of the AID/OUSFDA's disaster preparedness and assistance programs for individual countries and for regions.*

Remote sensing techniques are not likely to prove widely useful for quick assessment of disaster damage and needs because the time required for acquisition and analysis is longer than the time normally required for decisive action. Remote sensing techniques have substantially greater potential for hazard and vulnerability analysis and for application during reconstruction.

Aerial photography can provide valuable information, particularly if supplemented by accurate and well-organized ground surveys. Remote sensing by satellite can be used to develop predisaster background and baseline information. Remote sensing can also help in reconstruction and redevelopment activities. The value of remote sensing methods needs to be tested against and in conjunction with ground surveys, existing institutional information, and the like. Currently, many developing countries lack the interpretation skills necessary to make use of these methods.

3. *The AID/OUSFDA, UNDRO, and other agencies should set up pilot projects combining the use of ground surveys,*

*aerial photography, and remote sensing to test the individual and collective effectiveness of these techniques as information-gathering tools.*

In collaboration with UNDRO, other specialized agencies, and one or more selected developing countries, the AID/OUSFDA should consider funding a pilot project in which all elements needed for adequate hazard monitoring and damage and needs assessment are brought together to test the effectiveness of different methods and combinations of methods. Initially this might take the form of a pilot project in which the effectiveness of various approaches--including training programs for local personnel, the coordinated use of internal and external resources, coordinated use of different methods--are tested in a single country. Based on the results of this test case, one or more demonstration or prototype projects could then be developed.

4. *The Committee recommends the establishment of a multidisciplinary, multinational disaster assessment roster of experts who are ready and willing to participate in assessment teams after disasters occur. The AID/OUSFDA should encourage and support UNDRO and other relevant international organizations in promoting this capability.*

The teams should be composed of representatives of disaster-prone developing countries, donor countries, and international agencies. Agreements should obviously be obtained in advance to ensure cooperation by the host countries. The roster of experts should be organized according to expertise by disaster type, geographic area, and discipline. The experts included in the roster should be prepared to provide prompt, supplemental assessments of damage and needs at the request of disaster-stricken countries. An information exchange on available expertise should be established with professional organizations (in medicine, architecture, engineering) in disaster-prone developing countries.

Assessment teams should be organized and trained in advance to establish standardized data collection procedures so that experiences in different disasters can be compared and a body of useful cumulative knowledge developed to improve future performance. In the early stages it may be necessary to include in the assessment teams professionals from developing countries who do not have the requisite training or experience in disaster damage and needs assessment. However, on-the-job training of such professionals should be a major goal of this multinational effort. Wherever possible, existing regional groupings of developing countries should also be used to monitor hazards and assess damage and needs.

5. *The AID/OUSFDA should monitor research, establish links with domestic and foreign science and research agencies and institutions, and disseminate information about relevant research being done in other agencies and institutions.*

Information on research should be exchanged with research groups in the United States, in the international agencies, and in the developing countries. When appropriate the AID/OUSFDA should establish links with academies of science and research councils in both developed and developing countries. Many nations have a national academy of sciences or some equivalent organization that mobilizes the scientific talents of the country. Full use should be made of these scientific organizations for the following purposes:

- To stimulate disaster-oriented research at the country level.
- To assess the state of the art in monitoring and damage and needs assessment within their own (or neighboring) countries.
- To sponsor training programs, seminars, workshops, and conferences.
- To mobilize experts to help with damage and needs assessment, and to advise on reconstruction plans.
- To select scientific fellows for fellowship programs.

The AID/OUSFDA and UNDRO should consider supporting and participating in joint projects with such scientific organizations. They should also consider funding national projects for improved handling of disasters--in preparedness, monitoring, damage and needs assessments, and reconstruction guidelines. Such funding would generally strengthen the scientific capabilities of these countries as well.

## Preparedness and Training

6. *Bilateral and international disaster assistance efforts should be devoted to winning acceptance for disaster preparedness in disaster-prone developing countries. The objective of these efforts should be to stimulate and develop leadership for the establishment of effective disaster organizations in each country and to develop information useful following disasters.*

Hazard vulnerability in many areas of the world results from conditions of extreme poverty, malnutrition, illiteracy, environmental mismanagement, health deficiencies, rapid urbanization, poor housing, crowding, and lack of essential services. All agencies working in development--including the United States Agency for International Development, United Nations Development Program, World Bank, Inter-American Development Bank, Food and Agriculture Organization, World Health Organization, and World Meteorological Organization--must identify the major areas of vulnerability and include in their development plans measures to improve preparedness efforts. The disaster-prone countries should then undertake their own preparedness programs with support from donor nations, international development organizations, and disaster relief organizations.

As part of preparedness plans, profiles of needs following each type of disaster should be developed by appropriate field investigations.

7. *Bilateral and international agencies should establish training programs, encourage the development of curricula in academic institutions, and support efforts aimed at improving the existing capabilities of disaster-prone countries to handle disaster prevention, relief, and reconstruction.*

As part of the overall preparedness programs, persons from developing countries should be trained in ground survey methods, aerial photo interpretation, and interpretation of remote sensing data.

The training programs might take two different forms:

a. *Specific, detailed programs* aimed at training the technical personnel needed to carry out these activities.

b. *General orientation courses* for disaster officials, voluntary personnel, and others who do not need detailed technical training.

Workshops or regional seminars on monitoring and damage and needs assessment should be sponsored. The AID/OUSFDA is now planning to sponsor a number of workshops and seminars, chiefly for representatives of developing countries, that will tackle some of the following tasks:

- Describing indigenous capabilities for monitoring, warning, and damage assessment.
- Describing their capability to collect and utilize remote sensing data, data for aerial photographs, ground surveys, etc.
- Identifying needed training, facilities, and outside assistance.

- Making plans and preparations for assessing damage and needs in the types of disasters that are most likely to occur in the future.

The AID/OUSFDA should consider giving financial support (either directly or through UNDRO) to UN organizations and voluntary agencies that conduct training courses in disaster preparedness in the developing countries. These courses should include materials about hazard monitoring and damage and needs assessment.

The AID/OUSFDA, in conjunction with UNDRO, should consider establishing a fellowship program for training personnel from developing countries in such techniques. The agencies of the United Nations that already have fellowship programs should be utilized in this program as much as possible. The World Meteorological Organization, for example, currently supports fellowships in upper air measurement; development of marine automatic weather stations; reception, processing, and utilization of meteorological satellite data; and global atmospheric models. The United Nations Environment Program also offers training fellowships in flood control, river management, and bank stabilization. The World Health Organization is promoting and supporting training activities in disaster epidemiology, and the United Nations Educational, Social, and Cultural Organization supports training in earthquake prediction.

International agencies and donor nations should work with the governments of disaster-prone countries to improve building practices to mitigate the risk of damage during disasters, to implement educational programs in building science and technology, and to promote exchange of information on these subjects between professionals in both developed and developing countries. In turn, professional societies in disaster-prone countries should work closely with technical institutes, colleges, and universities to develop curricula on disaster-related housing problems (e.g., location, design, materials, construction).

Educational and training materials should be prepared on subjects such as health services; safe housing construction; construction of sanitation facilities; and the use of ground surveys, aerial photography, and remote sensing. the AID/OUSFDA, in collaboration with UNDRO and other international organizations, should promote disaster prevention and reconstruction among specialists and the public through seminars, pamphlets and posters, and the preparation of TV programs and educational materials for schools.

Literature on methods of hazard monitoring and damage and needs assessment should be translated into the language of the developing countries to make those materials more accessible to the scientific, technical, and engineering communities of those countries. It is recommended that the AID/OUSFDA and UNDRO provide funds to underwrite this project.

# APPENDICES

# APPENDIX 1 Two Examples of Famine

This appendix provides additional information on the two cases of famine in Ethiopia cited in Chapter 4.

## Famine in Ethiopia: Wollo

The famine of 1972-73 was concentrated in the eastern part of Wollo Province (Figure 1), an area comprising a wide valley floor bounded to the east by a secondary range of highlands, from which the land falls away to the Danakil desert. Fewer than 1 million of the estimated 2.5 million total population of the province live in this area; most of the people cultivate the valley floor and highland ridge. The main rains in the agricultural area occur from June to September. The spring rains that occur between February and April are of most importance at higher altitudes; in the northeast they permit 10 percent to 20 percent of annual crop production.

In 1972, the main rains in the northeast failed, and with them the main annual crop. Fifty-two percent of the subdistricts, almost all located in the east (the "famine" area in Figure 1), were reported by a government survey to

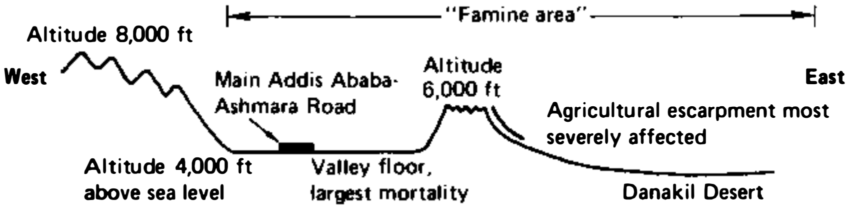


FIGURE 1 Eastern Wollo Province, Ethiopia--topographic profile.

have poor crop production; only 10 percent of all subdistricts in the province were reported to have average crops. By November 1972, therefore, the government had clear evidence that the situation in eastern Wollo was potentially disastrous. Table 3 shows the subsequent chronology of events. Emigration from the area began in January 1973, only 2 months after the crop failure. Starvation peaked between June and August 1973, by which time perhaps 50,000 people had died. Market prices at three northern markets showed that the price of staples rose so rapidly during the first part of 1973 that by the beginning of the mid-year rains they had nearly doubled. Prices fell rapidly after the rains and by the preharvest period in September had returned to prefamine levels, since the rains and the harvest in 1973 were normal.

The government claimed that during 1973 some 4,000 tons of seed grain had been given to farmers on credit; although it is not clear how much of this grain was used as seed, it appears that a majority of farmers had planted their land before leaving their villages. A November 1973 survey showed only one small area on the eastern escarpment denuded of crops. In March 1974, a survey of the northern subdistrict of Raya and Kobbo showed that, although mortality during the famine year had been high (see Table 3), nutritional status was at a level similar to that seen in predrought highland Ethiopia and was probably normal (Table 3). This observation was made at a time when the population in urgent need of relief amounted to no more than 15,000 people in relief camps of whom not more than 1,000 were severely malnourished and before the arrival of international food aid in the area.

For purposes of contrasting this example with the next, the following points should be noted:

1. The famine occurred in an area settled by cultivators in large numbers only since the introduction of malaria control in the early 1950's. Although rains in some parts of the area had been erratic since 1969, the population had had no previous experience of massive crop failure from drought.

2. Emigration from the area began soon after the crop failure (Table 3) and appears to have been triggered by inadequate redistribution measures within the population and a price surge resulting from hoarding. Starvation occurred among the destitute population along the main road.

Deaths during the famine appear to have totaled no more than 50,000, and many of these were caused by epidemic

**TABLE 3 Chronology of Events in Wollo Province, Ethiopia**

| Year | Local | Administrative |
|---|---|---|
| *1972* | | |
| June-Sept. | Big rains fail | |
| Nov. | | Ministry forecasts famine |
| Dec. | Harvest is poor | |
| *1973* | | |
| Jan. | Emigration starts | |
| Feb. | | FAO issues early warning |
| March | Small rains fail | Government plans aid |
| April | Large-scale emigration occurs | Drought Relief Committee requests grain |
| May | Mortality rises in camps | |
| June-July | Big rains fail | |
| July-Aug. | Crisis of starvation occurs in camps | |
| Aug.-Sept. | | Representatives of international news media arrive |
| Sept.-Oct. | Medical teams arrive | |
| Nov. | | First shipment of grain arrives in port |
| Dec. | Harvest is satisfactory | |
| *1974* | | |
| March | Nutritional status is back to normal | Grain is distributed |

| | | | |
|---|---|---|---|
| Percentage of children under 80 percent average weight-for-height (Harvard Standard), March 1974, Raya and Kobbo | 4 years old and under, 10.0% | 5-9 years old, 3-5% | |
| Deaths reported in year prior to March 1974. Crude death rate (CDR) per 1,000 in group | Less than 1 year old, 212 | 1-4 years old, 214 | 5-9 years old, 97 |

disease. This figure, small in relation to the total population, supports the contention that if redistribution mechanisms had existed, food supplies, although severely reduced, might have been sufficient to feed the entire population. Moreover, market prices fell to prefamine levels before the 1973 main harvest; foreign-supplied food aid did not cause this price drop because that aid did not arrive in bulk until 1974.

The implication for famine relief is clear. *In relation to the time necessary to organize and deliver food aid, the period between any possible prediction of famine based on the observation of crop failure and the onset of starvation is very short--in this example, approximately 3 to 6 months.*

**Famine in Ethiopia: Hareraghe Province**

Hareraghe (Figure 2) is in many ways geographically similar to Wollo. The area covers 270,000 square kilometers and has an estimated population of 2.6 million, of whom 2 million live on the highland ridge. This ridge separates the densely populated true highlands above 2,000 meters, which are intensely farmed by Oromo, from the drier marginal highlands (1,500-2,000 meters), where rainfall and crop yields are more erratic. Below the 1,500-meter contour, the terrain is semiarid thorn-scrub plain inhabited by Somali pastoralists, who live from animal products and from grain obtained by trade. A full account of drought and famine in the area has been published elsewhere[1] and only a summary for contrast with the preceding example will be given here (see Table 4).

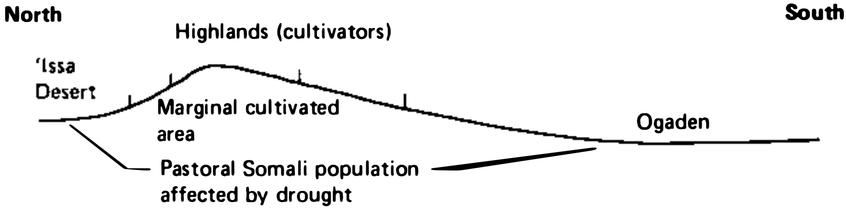


FIGURE 2 Hareraghe Province, Ethiopia--topographic profile.

[1]See J. Seaman *et al.*, *Hareraghe Under Drought: A Survey of the Effects of Drought on Human Nutrition in an Ethiopian Province* (Addis Abbaba, Ethiopia: Ethiopian Government Relief and Rehabilitation Commission, May/June 1974).

**TABLE 4 Chronology of Events in Hareghe Province, Ethiopia**

| Year | Local | Administrative |
|---|---|---|
| *1973* | | |
| Sept.-Oct. | Small rains fail | |
| Oct.-Nov. | | Dead livestock observed in North Ogaden |
| *1974* | | |
| Jan.-Feb. | Large-scale human mortality and livestock losses | |
| Feb.-May | Long rains occur | Small amount of relief grain arrives but no method for distribution exists |
| May | Survey begins | |
| July | Many malnourished groups seen along roads. Stock holdings are too low for survival | |
| Sept.-Nov. | Short rains fail | Attempts are made to distribute grain |
| *1975* | | |
| By March | 80,000 people are in relief camps | |

| | 'Issa | Marginal | Highland | N. Ogaden | S. Ogaden |
|---|---|---|---|---|---|
| Percentage of children under 80 percent average weight-for-height (Harvard Standard) | 8.2 | 12.6 | 17.5 | 23.4 | 10.9 |
| Crude death rate per 1,000 in age-group 1-4 years in year till June 1974 | 304 | 115 | 55 | 278 | 267 |
| Livestock losses (Standard Stock Units/Adult Equivalent) | 9.5 | | | 4.5 | 2.7 |
| Livestock remaining (Standard Stock Units/Adult Equivalent) | 1.9 | | | 1.8 | 1.7 |

1. Although the severity of the drought in the rangelands of Harerghe cannot be compared directly in terms of the size of food deficit to that in Wollo, since these are unknown, the severity of the drought is indicated by the size of the mortality of children and livestock (see footnote, Table 4). The area, however, is one in which people have customarily adapted to drought.

2. Despite the severity of the drought, no large-scale emigration from the rural to urban areas occurred, apparently largely because pastoral groups redistributed their livestock and took other traditional adaptive measures. Grain prices rose sharply while livestock prices fell; these events aggravated food shortage and hardship for many people. But, since the population did not depend upon market exchange for survival, these price rises did not trigger emigration from the area.

3. In late 1974, attempts were made to distribute grain in bulk to the population in rural areas, but by early 1975 this policy was changed to one of feeding in camps. High mortality in relief camps (up to 150 deaths per day) appears attributable mainly to diseases resulting from unsanitary conditions.

For famine relief, the implications of this case contrast with those of Wollo. In Harerghe, famine was all but invisible to outsiders, and no estimate of its severity could be made without use of sophisticated survey methods. To relieve famine the population was concentrated in camps; as a result mortality rates in the camps were comparable with those of the preceding year of drought.

# APPENDIX 2 Roles of Remote Sensing in Different Disasters

The possible uses for remote sensing in freshwater and seawater floods and storm surges, earthquakes, and droughts are here analyzed with respect to the following five disaster-related phases: preparedness, warning, emergency, rehabilitation, and reconstruction.

## Freshwater and Seawater Floods and Storm Surges

In recent years, devastating floods have occurred in areas such as India, Bangladesh, Pakistan, Chile, and the Philippines. Within these countries, millions of people live and work along flood-prone rivers and shorelines. These areas are often heavily populated and greatly prized for agricultural purposes. Floods associated with the tsunami, tropical cyclones (typhoons, hurricanes), tidal surges, and prolonged extra-tropical depressions cause some of the most widespread, frequent, and damaging disasters in the world.

Because floods are continuous and locally confined, satellite sensing would appear to be useful for the following purposes:[1]

- Delineation of areas inundated by an individual flood, cloud cover permitting, even days after the flood's impact.
- Calculation of areas of each type of land subject to flooding and prediction of the economic consequences,

[1]See C. J. Robinove, *Worldwide Disaster Warning and Assessment with Earth Resource Technology Satellites*, Project Report (IR) NC-47 (Washington, D.C.: U.S. Department of the Interior, 1975), p. 10.

particularly in agriculture. (Previously prepared maps of land use would be needed also.)

- Delineation of areas where debris poses health hazards, to facilitate steps against disease.
- Assessment of areas likely to be inundated by floods and documentation of statistical frequencies of classes of floods. (Stream gauge data and topographic maps may also be required.)
- Provision of data for planning for flood control and protection measures.

Because of inadequate resolution, present satellite imagery cannot be used alone to provide knowledge of the discharge of a particular flood or to identify and map damage to individual structures such as factories, houses, bridges, and roads. A synthesis of satellite data, aerial reconnaissance, data collection platforms, and ground observation will be essential for preflood and postflood observation.

*Preparedness*

In the early planning phase, flood studies are useful for defining the inundation zone for a flood of known magnitude. With an accurate record of rainfall, stream discharge, and areas flooded in the past, it is possible to predict future flood zones and the damage that could result from floods of a certain magnitude. The possible destruction is often expressed by statistical frequencies of classes of floods and their destruction. Areas of high risk, such as floodplains, and areas subject to coastal flooding and tsunami run-up may be mapped using remotely sensed data. With an adequate map base, destruction to crops and population areas could be projected.[2] These data can guide the location of ground sampling to yield maximum benefit.

Probable secondary effects of flooding, such as dam failure, should also be considered. While dams do control flood waters, dams also increase the population at risk through encouraging settlement in hazardous areas. Modeling of dam failures, including dynamic wave routing analysis,

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[2]See W. Meyer and R. I. Welch (eds.), "Water Resources Assessment," *Manual of Remote Sensing* (Falls Church, Virginia: American Society of Photogrammetry, 1975), pp. 1532-1545.

is feasible but expensive and uncommon even in developed countries. Knowledge of the likely path of the released water, derived from aerial photographs, would assist in floodplain planning; feasibility and costs should be further investigated.

Data bases are inadequate for many developing countries. Land use maps and low-altitude photography over large urban areas--where they exist--are often outdated or crude. Damage to transportation, crops, housing, and the economy to be expected in case of flooding cannot be estimated until a major flood has occurred. A synthesis of data collection platforms, satellite imagery, and high-resolution aerial photography taken over cities can provide a strong base for hazard and vulnerability analysis. In areas of periodic flooding, such as the Ganges, Brahmaputra, and Indus floodplains, the amount of satellite data and aerial photographs is adequate to start the process. Aerial photography is often available but scattered throughout governmental agencies.

Several developing countries have used LANDSAT data in simple image form for preparedness planning. For example, Bangladesh authorities were able by visual interpretation to predict areas likely to experience major flooding and to choose new lands for development. In the future, computers will be used to assist interpreters and analysts. Several United Nations agencies and the AID/OUSFDA are sponsoring computer facilities employing such software and personnel as part of their development aid. (India, the Philippines, Colombia, and Nigeria, for example, are now developing one or more computer/analysis/display systems that could be employed for interpreting remote sensing data.) Computer processing was used to produce a mosaic of the Orissa area in India; a cartographic overlay shows roads, railroads, towns, rivers, and political subdivisions of the state. From such a composite, large areas of high flood risk may be mapped.[3]

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[3]See Committee on Remote Sensing for Development, Board on Science and Technology for International Development, *Remote Sensing from Space: Prospects for Developing Countries* (Washington, D.C.: National Academy of Sciences, 1977); also D. S. Simonett, "Possible Uses of Space Satellites for Disaster Warning, Monitoring, and Damage Assessment," *The Role of Technology in International Disaster Assistance: Proceedings of the Committee on International Disaster Assistance Workshop, March 1977* (Washington, D.C.: National Academy of Sciences, 1978), pp. 79-99.

Future Space Shuttle missions will be capable of gathering high resolution (5 meters) photography that could be especially useful for flood vulnerability assessment in urban areas in developing countries. Such areas may lack up-to-date large-scale maps. From the Shuttle imagery, urbanized floodplains could be mapped and possible loss of life, loss of homes, and damage to the local economy could be estimated.

*Warning*

Remote sensing in developing countries shows good potential for warning of river floods in large basins and floods associated with large cyclonic storms. The use of remote sensing for tsunami warning, however, is considered experimental and limited to remote data collection systems. An effective warning system requires frequent observations with ground monitoring systems and meteorological satellites, and the cost of adequate warning systems appears too high at present for any one developing country to absorb. A consortium of developing countries could pool their financial resources to set up regional flood monitoring and warning systems.

In the United States, the National Hurricane Warning Center at Miami provides warnings to coastal areas based on data from satellites, aerial reconnaissance, ground-based radar, and data collection platforms. Data from the synchronous meteorological satellites/global-observing environmental satellites (SMS/GOES) can help track developing and mature hurricanes in the Western Hemisphere, reducing the number of aircraft reconnaissance missions needed. When a storm can be tracked over long distances, the Center can issue a watch 36 hours and a warning 24 hours prior to hurricane landfall with location accuracies between 9 and 50 kilometers. The Center has two planes outfitted with Doppler radars and on-board computers that gather information on air temperature, precipitation, wind speed, and so on when a storm is within 36-48 hours of landfall. Every 10 minutes these data are relayed to a central facility via satellite, processed by a computer, and incorporated into a prediction model. In addition, sea conditions, air and water temperatures, wind speed and direction, and rainfall are gathered from buoys in the Gulf of Mexico and depth sounders dropped from aircraft. When the storm is within 200 miles of the coast, wind velocities, rain distribution and intensity, storm movement, and stage of development are monitored by ground-based radar.[4] Current studies indicate that the estimation of hurricane rainfall potential can be improved by computer processing of SMS/GOES thermal infrared data.[5]

Recent studies conducted by the National Oceanic and Atmospheric Administration indicate that in the United States a warning given 36 hours in advance can reduce damage or loss of life by 35 percent, while a 6-hour advance warning can reduce damage or loss of life by 10 percent. This impressive reduction is a tribute to the excellent communication and transportation networks in the United States and the relative readiness of people to evacuate. It is doubtful that the same circumstances and results would obtain in developing countries. Some Caribbean countries, such as the Dominican Republic and Haiti, do not have a weather service, and hence the National Hurricane Warning Center issues the hurricane warnings directly.[6]

In the Indian and western Pacific oceans, cyclones and typhoons are monitored by centers in India, Australia, China, and Japan, and by the U.S. Navy in Guam. These centers rely primarily on data from the TIROS satellites. Soon, Japan and the U.S.S.R. plan to launch geosynchronous meteorological satellites that will add significantly to storm-monitoring capability in these oceans.

Warning of tsunamis is only experimental at present. The Tsunami Warning Center has installed a network of seismographs and tide gauges around the Pacific Ocean and plans to link these instruments to the Center via the SMS/GOES telemetry system. Because of a lack of funds, however, only two gauges have been linked to the satellite thus far. Depending on the location of the earthquake epicenter with respect to coastal areas, warnings provided by the Tsunami Warning Center can range from 2 minutes to

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[4]Oral communication with Robert Clark, National Weather Service, Washington, D.C., May 1978.

[5]See M. P. Waters III, "Operational and Experimental Use of SMS/GOES Digital Satellite Data," *Proceedings of the Twelfth International Symposium on Remote Sensing of Environment, April 20-26, 1978, Manila, Philippines* (Ann Arbor, Michigan: Environmental Research Institute of Michigan, 1978).

[6]Oral communication with the National Hurricane Center, Miami, Florida, May 1978.

22 hours. If a warning is to produce results, however, it must be accompanied by a will to act and a good communication and transportation network.[7]

Data collection systems on board LANDSAT or SMS/GOES can be used with imagery from meteorological satellites and data from ground weather stations for flood warning. Data collection platforms can monitor the volume of runoff, the variability of stream flow, and the depth of snowpacks in mountainous regions. These data can be transmitted to ground stations via the global communication systems or the weather facsimile communication system (WEFAX) to provide early warning of rising water levels and increasing stream flows. Chile is among the few developing countries experimenting with the use of data collection platforms for these and related purposes.[8] Because of their relative unreliability and high cost, data collection platforms are not so suitable for remote stations as might be expected, but future technology is expected to provide greater reliability at lower cost.

The global meteorological satellite system (GMSS), a fully automated water resource data collection system, has recently begun operating in the lower Mississippi River basin. The GMSS consists of automatic measuring equipment, environmental data transmitters, earth satellites, a central receiving site, and a data communications processor (minicomputer) linked with small remote user terminals. Water levels, precipitation, and water quality are reported every 4 hours from 57 stations to a central receiving site via either the SMS/GOES or LANDSAT data collection system. The cost of an environmental data transmitter is about $3,000, but improvements in design and production are expected to cut that figure substantially.[9]

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[7]Oral communication with the Tsunami Warning Center, Washington, D.C., May 1978.

[8]See A. F. Mauricio, "Automatic Collection of Environmental Ground Truth Data in Chile by Employing Earth Orbiting Satellites," *Proceedings of the Twelfth International Symposium on Remote Sensing of Environment, April 20-26, 1978, Manila, Philippines* (Ann Arbor, Michigan: Environmental Research Institute of Michigan, 1978).

[9]See W. L. Sharp, Water Management and Control Via the Global Meteorological Satellite System," *Proceedings of the Twelfth International Symposium on Remote Sensing of Environment, April 20-26, 1978, Manila, Philippines* (Ann Arbor, Michigan: Environmental Research Institute of Michigan, 1978).

The GMSS is highly competitive with other modern data collection systems in terms of cost, timeliness, and accuracy. One central receiving station can collect, convert, and disseminate data from several hundred thousand square miles to many users in real time. A receiving station can also be equipped to receive satellite imagery of cloud cover in the water management area. A GMSS can be designed to varying degrees of sophistication and installed almost anywhere in the world.[10] The AID is investigating the feasibility of a $1.5 million system for Bangladesh to receive TIROS-N and NIMBUS-G data; the proposed facility would be concerned with monitoring cyclone information and movement and forecasting storm surges.[11]

Major floods of the kind that affect the Indus, Ganges, Brahmaputra, Niger, and other great rivers sometimes take weeks to roll down the system.[12] Monitoring of water levels and soil moisture in advance of the flood would greatly improve forecasts of flood crest and subsequent damage. Areas downstream could be warned before the arrival of the flood crest. Because of the cloud problem during the monsoon, radar satellites that may be developed as a result of the Shuttle experiments will be of much interest. Radar satellites could provide data on areas likely to be flooded, including gross information on floodplain soil moisture. The complexities of processing radar data, however, require that such studies initially be made in the United States or some future central United Nations facility. By the mid-1980's, on-board processing may be feasible, in which case radar data might be received by LANDSAT-D ground stations.

*Emergency*

The degree to which remote sensing can actively assist for relief efforts during the emergency period is uncertain. Clearly, for relatively sudden floods, such as tsunami runup and fast-developing floods in coastal plains, it may not

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[10] *Ibid.*

[11] Storm surges often produce 30-foot storm waves capable of running many miles inland. If a storm happens to coincide with major floods running down the Ganges and Brahmaputra, as much as 70 percent of Bangladesh can be under water.

[12] Personal communications with G. Whitehouse.

be possible to marshal aircraft and remote sensing teams from outside the country in a timely manner. Where internal facilities and aircraft are available, however, action may be taken. In slowly developing floods, remote sensing aircraft and evaluation teams might be assembled inside and outside the affected country in time to help with relief operation.

A full-scale commitment to remote sensing during periods of emergency is not appropriate at the present time; rather, careful and limited research seems indicated. Two basic questions remain: Can the imagery be obtained and analyzed quickly enough to be of use during this time? And would the information so gathered be worth the cost and concentrated effort? The appropriate mixes of multiscale imagery and general surveys and the kinds of information that can be extrapolated from these data for relief management should be studied in greater detail. Clearly, no simple prescription for use may be given now, because, to the best of our knowledge, no field trials of such a system or procedures have yet been carried out.

Meteorological satellites have inadequate resolution for damage assessment. The LANDSAT series has greater resolution, but the long intervals between observations (9 days), the modest spatial resolution, and the inability to image through cloud cover (which is often present during flooding) limit the potential applicability of LANDSAT data to floods. LANDSAT receiving stations, which have the capability for "quick look," rapid analysis, and screening of images, can play a more important role, albeit on an *ad hoc* basis. The future Indian LANDSAT station may have the quick-look capability; subsequently, under both cloud-free conditions and coincident satellite coverage, Bangladesh and other neighboring countries may get near real-time imagery of flood conditions.

LANDSAT's greatest utility is in providing a regional view of the extent of flooding. The future Thematic Mapper, with improved spatial and spectral resolution, will add to this capability. Because cloud cover often plagues Bangladesh and other tropical countries during times of flooding, radar imagery would be invaluable. Future radar satellites will be capable of imaging with resolutions of 10 to 20 meters. During the next 3 to 4 years, however, no radar satellites will be operational.

The high-resolution earth-synchronous SEOS satellite of the mid-1980's will be very useful for monitoring flood conditions and damage assessment. Through all stages of flood progression and recession--clouds permitting--this satellite could zoom in on the impacted area and take high-resolution (10-meter) images over an extended period of time. The satellite should identify changes in river channels; ponded water; leakages from dams, levees, and canals; and major inundation in urban areas. Another proposed system of the early 1980's with comparable resolution (10-meter) is the sun-synchronous, French SPOT satellite. With a 1- to 5-day repeat cycle, this satellite would have a cycle midway between those of LANDSAT and SEOS satellites.

*Rehabilitation*

During the rehabilitation phase, aerial surveys of the disaster site are likely to be made. Even when suitable aircraft are available in the affected country, however, it is usually necessary to obtain permission to fly and to make arrangements to secure planes and equipment. In contrast, LANDSAT or meteorological data could be processed in a U.S. or United Nations facility and transmitted via the WEFAX system to a low-cost receiving station in a developing country if needed urgently, or by mail if the need were not pressing. Photo interpreters could make detailed examinations of all available satellite and aircraft imagery and select portions to be enlarged for further study. To assist in relief management, ground survey teams would need to verify information derived from this process and combine it with ground observations.

The large area of coverage provided by LANDSAT imagery would allow (clouds permitting) quick assessment of the magnitude of the disaster and areas of heavy damage. Band-7, the near-infrared band, is the most useful band. Areas affected by the flood waters are readily differentiated by spectral reflectances of saturated and dry soils. If prior LANDSAT imagery of the area under normal conditions exists, a composite image may be made and the flooded area calculated using a suitable hand planimeter or computer algorithm.[13]

[13]See W. G. Rhode *et al.*, "Inventory and Mapping of Flood Inundation Using Interactive Digital Image Analysis Techniques," *Proceedings of the 2nd Annual William T. Pecora Memorial Symposium* (Sioux Falls, South Dakota: American Society of Photogrammetry and U.S. Geological Survey, October 1976), pp. 131-143; and A. N. Williamson, "Mississippi River Flood Maps from ERTS--A Digital Data," *Water Resources Bulletin*, Vol. 10, No. 5 (October 1974), pp. 1050-1059.

High-altitude aircraft color-infrared imagery is also useful in this process. Studies indicate, however, that photographic infrared is limited in dark-colored soils for defining high-water lines. Areas likely to experience food shortages might be inferred by analysis of agricultural conditions on medium to high-altitude color-infrared imagery. Also identifiable would be areas isolated as a result of mudslides, landslides, or washed-out bridges--or areas where extensive damage to crops and pastures occurred. Analysis of damage to agricultural fields can indicate which crops were salvageable and which were completely destroyed. To predict crop damage, multitemporal data collection and analysis would provide information on the length of time certain regions could remain inundated. In conjunction with ground observations a country may then improve estimates of what food supplies it could provide itself and what supplies would have to be imported. Utilization of infrared-sensitive film in some cases has allowed assessment of latent effects of flooding on soils and vegetation as much as 1 month after the flood crest.[14] Use of color-infrared photography in flooded areas in the United States has produced better estimates of potential production than have conventional ground-sketching methods.[15]

The quality of the freshwater supply would also be an important consideration. Areas inundated by a storm surge tidal wave may have serious salinity problems if the saltwater remains long enough to percolate into the groundwater. As was exemplified in Andhra Pradesh, salts left by tsunamis or storm surges must be flushed through the groundwater and back out to sea in order to prevent damage to crops.[16] Evidence concerning the seriousness of salting is ambiguous, however, and should be reviewed before research with remote sensing is undertaken. Contamination of local water supply systems (mainly small streams, diversion channels, and irrigation canals) by heavy sedimentation might be identified on low-altitude color-infrared film. Contamination of

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[14]Meyer and Welch, *op. cit.*

[15]See W. H. Anderson, *Assessing Flood Damage to Agriculture Using Color Infrared Aerial Photography--An Example from the 1975 Red River Valley Flood of North Dakota and Minnesota* (Sioux Falls, South Dakota: EROS Data Center, 1977).

[16]See F. Cuny, *Recent Work in the Aftermath of the Andhra Pradesh Cyclone*, Memorandum to Intertect members and other interested persons (Dallas, Texas: Intertect, January 31, 1978).

small drinking water sources (wells or community water tanks) would not be visible.

Remote sensing is most useful for locating regions where concentrated ground sampling will provide the best information. Regions where communication is deficient can be identified, and the image products can be used as a planning base for a timely and accurate survey. A weakness of aerial photography is that the interior damage to housing and damage to the foundations cannot be assessed. If a structure does not appear to be damaged on the outside, an interpreter would assume that it sustained little if any damage. Accumulation of mud and debris, collapse of weak partitions or walls, or damage to foundations would not be visible on any type of imagery. Photographic interpreters alone generally underestimate the extent of damage to structures, but when photographic measures are combined with a well-distributed sample ground survey, the estimates could be quite accurate. More research is needed to define suitable procedures and accuracies.

Generally, few injuries are associated with floods. Photographic analysis could anticipate secondary health problems. Areas of standing water where waterborne disease may breed could be identified on color-infrared imagery.

*Reconstruction*

If aircraft and spacecraft imagery were not available until the reconstruction phase, it may still be used to determine the extent of damage, floodplain boundaries, silting problems, and reduction in agricultural yield. Damaged areas identified on the imagery could be transferred to topographic maps (if available) and the amount of land damage quantified. Thailand, Australia, and India are among the countries using satellite data for floodplain management.[17] Agencies in Pakistan found satellite imagery of considerable value in postflood surveys. By changing the contrast of LANDSAT imagery of the 1973 Indus River flood and preparing temporal composites, a great deal of hydrologic information was obtained.[18] These images revealed

[17]Personal communication with Paul Krumpe, AID/OUSFDA, April 1978.

[18]See M. Deutsch and F. H. Ruggles, Jr., "Hydrological Application of LANDSAT Imagery Used in the Study of the 1973 Indus River Flood, Pakistan," *Water Resources Bulletin*, Vol. 14, No. 2 (April 1978), pp. 261-274.

information on total flooded area, changes in the river channel, ponded water in the floodplain after recession, leakage under dams, breaks and leaks in canals, and areas of groundwater discharge. This information could be used in designing better hydraulic structures and minimizing flood damage in the future. Studies by Ahmad, Mirza, and Khan showed that LANDSAT imagery of the Indus Basin taken 43 days after the flood peak gave estimates of flood-inundated areas that were only 10 percent lower than figures derived from imagery taken after 7 days.[19]

A computer-assisted approach using LANDSAT imagery could improve this process. Preparation of map overlays showing the extent of flooding on agricultural lands and acreage estimates with known sampling errors could be produced. Rhode, Taranik, and Nelson employed LANDSAT digital data and infrared photos in a multiphase sampling scheme to estimate the areas of agricultural land affected by a flood.[20]

## Earthquakes

Earthquakes are often considered unique among natural disasters because they occur suddenly and without advance warning. Unlike other sudden disasters an earthquake is preceded by no external signs through which members of the public can make their own informal confirmations. At present, the regions where earthquakes are likely to occur and regions where earthquake hazards are very low can be identified, but no reliable method for earthquake prediction has yet been developed.

### *Preparedness*

Remote sensing offers good potential in preparedness planning. The large area covered on a single satellite image provides a basis for lineament mapping. As lineaments are

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[19]See M. S. Ahmad *et al.*, "Floodplain Mapping in the Indus Basin Using LANDSAT Imagery," *Proceedings of the Twelfth International Symposium on Remote Sensing of Environment, April 20-26, 1978, Manila, Philippines* (Ann Arbor, Michigan: Environmental Research Institute of Michigan, 1978).
[20]Rhode *et al.*, *op cit.*

often expressions of faults, mapping these can help delineate earthquake-prone areas. Locations can be risk-rated on the bases of active faults and historical seismicity data.

LANDSAT imagery could be useful in delineating areas of high earthquake hazard. Structural elements that may appear irregular or even discontinuous within a small area may be revealed as lineaments of regional extent on LANDSAT imagery. Closer examination on aerial photographs and by field surveys would reveal if these linear features were faults and if they posed a potential threat. In low-relief areas, the highlight and shadow effect of radar systems enhances subtle terrain features such as lineaments or faults. Where topographic relief is great, however, the oblique illumination angle can cause extensive shadowing that may be detrimental to structural interpretation.

Recent studies have demonstrated the usefulness of spacecraft and aircraft data for delineating seismically hazardous areas. A study conducted in Alaska reported a close relationship between earthquake epicenters and lineaments visible on LANDSAT-1 imagery. In addition, lineaments not known to have existed before were identified.[21] Computer processing techniques were used to enhance linear features on LANDSAT images in a region north of Peking. Earthquake epicenter locations and lineaments were mapped from the imagery and then digitized and recorded on magnetic tape. Correlations are being sought between the fracture density contour map and the epicenter contour map produced from this process. If correlations exist, this method may aid in interpreting the predominant ground movements associated with modern earthquakes in this region and in evaluating seismic hazards.[22] LANDSAT imagery and aerial photographs have also provided useful information in Nicaragua, the Philippines, and

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[21]See Robinove, *op. cit.*

[22]See R. K. Vincent and G. N. Scott, "Correlation Studies Between Linear Features Observed in LANDSAT Imagery and Earthquake Epicenters for a Region North of Peking, Peoples Republic of China," *Proceedings of the Twelfth International Symposium on Remote Sensing of Environment, April 20-26, 1978, Manila, Philippines* (Ann Arbor, Michigan: Environmental Research Institute of Michigan, 1978).

Italy.[23] In these areas mapping linear features has resulted in a better understanding of seismic patterns.

Seismic information obtained with remotely sensed imagery could be included in a data base for future use. Merely adding seismic risk data to such a data base, however, would not significantly improve preparedness planning or postdisaster relief efforts. Before the seismic data could be usefully employed to determine the population at risk, the data base would also have to include updated information on land use, topographic maps, population statistics, and the like.

Future Space Shuttle missions will be capable of gathering photographic and other data with 5- to 10-meter resolution that will be extremely useful for hazard and vulnerability analysis, especially in urban centers. LANDSAT-D imagery (30-meter resolution) could also make a contribution in preparedness planning.

### *Warning*

At present, remote sensing technology shows limited value for monitoring or predicting seismic events. Since seismic activity cannot be visually recorded, satellite and aircraft imagery are of no value. The data collection systems on board LANDSAT and SMS/GOES might be useful, but a better understanding of earthquakes is needed before developing countries are encouraged to invest time and money in such systems.

Seismic activity is being monitored through extensive networks in many parts of the world. An array of instruments can be installed along active faults to measure precursor events (changes in seismic velocity, electrical conductivity, water pressure, ground-tilt direction, and surface elevations in and around the earthquake source) that might be useful in earthquake prediction. Currently, these measurements are collected and relayed by radio to a ground station. LANDSAT and GOES might help gather this

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[23]See B. S. Siegal and F. G. Snider, "Remote Sensing for Nuclear Power Plant Siting, Battan Peninsula, Republic of the Philippines," *Proceedings of the Twelfth International Symposium on Remote Sensing of Environment, April 20-26, 1978, Manila, Philippines* (Ann Arbor, Michigan: Environmental Research Institute of Michigan, 1978).

information, but until more is known about what events foreshadow an earthquake, using costly (about $5,000 each) and not fully reliable data collection platforms would be a questionable investment for a developing country.

It is possible to monitor seismic events associated with volcanic activity. An array of instruments could be installed on a data collection platform to monitor microseismic activity that could precede an eruption. Such platforms could also provide information on the temperature, heat flow, geochemistry of gases, and volcanic tilt prior to eruption. Results to date are encouraging but, as with earthquake prediction, a high level of confidence that the event will occur is necessary if lifesaving protective actions are to be taken prior to a volcanic eruption.

*Emergency*

Remotely sensed imagery is of limited use in the emergency phase of disaster. Ideally, aerial reconnaissance missions should be organized and flown within a few days of the disaster. Although this action may be technically feasible, it is doubtful whether the personnel, equipment, and facilities necessary to do the analysis could be organized within this time frame. Furthermore, research is still needed to determine what system or combination of systems provides the most cost-effective information and what surrogate measures could be used to assess damage.

If available, medium-altitude aircraft imagery could provide a comprehensive and objective view of the disaster. Areas of heavy devastation could be identified on the imagery and personnel and supplies directed to these areas. An estimate of the magnitude of the disaster might also be possible. At present, postdisaster aerial photography is conducted routinely in Turkey and careful examination of the procedures and use of photography there are recommended.

*Rehabilitation*

If available during rehabilitation, aircraft imagery could be thoroughly analyzed, and data in the form of enlarged images and large-scale maps could be provided for relief management teams. Aircraft imagery may also provide information of use to medical teams, but it has never been utilized for this purpose.

Food and water needs in urban areas would be difficult to assess from aerial photography. This information will have to come from ground surveys. In rural areas, damage to water supply tanks, irrigation channels, agricultural fields, and so on might be visible on medium-altitude photography. Although most villages tend to be self-sufficient, they may require imported food if they are isolated by landslides or serious road damage. Imagery might be used to identify undamaged areas nearby where food supplies may be available.

In analyzing U-2 photographs acquired shortly after the Guatemalan earthquake, interpreters generally underestimated the damage to structures (these estimates were between 15 percent and 20 percent lower than assessments made on the ground). Because damage that did not mar the roof of buildings was not detectable on the photography, any damage to foundations, interior walls, or partitions went unnoticed.[24] One of the lessons learned from experience is that this type of damage assessment requires low-altitude oblique photography as well as vertical photography.

Secondary threats resulting from an earthquake--such as dam failure, landslides, or avalanches--might be assessed from aircraft imagery and verified by ground surveys, but remote sensing seems to be more applicable in assessing the damage created by these events. The Guatemalan earthquake imagery revealed many places where land and rock slides had blocked streams, causing lakes to be formed. One such lake covered an area where maps showed a village had previously existed.

The SEOS satellite will have a high-powered telescope with 6-meter resolution and will provide coverage over the Western Hemisphere. In event of an earthquake, this satellite could zoom in and take repeated high-resolution images. Similar earth-synchronous satellites are also planned in India, Japan, and Europe to provide disaster assistance data. The future sun-synchronous French SPOT satellite with a 10-meter pointable panchromatic system could provide coverage of earthquakes within its orbit, cloud cover permitting.

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[24]See the National Photographic Interpretation Center in association with Agency for International Development, *Utilization of U-2 Photography in the Guatemalan Earthquake February, 1976* (Washington, D.C.: NPIC, 1976).

*Reconstruction*

During reconstruction, all information acquired from imagery could help in formulating long-term development plans aimed at better preparedness. The types of damage identified on aerial photographs could be useful in effecting changes in urban areas.

LANDSAT imagery may be useful for identifying lineament patterns in and around the disaster site if they had not been adequately mapped before. With this information, a disaster-prone country may better understand the seismic patterns associated with the area. This information may have some role in developing zoning laws and building codes to prevent future damage.

## Droughts

The synoptic view and ability to detect change through time makes satellite sensing potentially effective for modeling and monitoring droughts.[25] In principle, at least, it appears feasible to use meteorological and other satellite data as inputs to ecosystem and pasture and crop modeling of drought stress. Once a drought has been acknowledged, remote sensing may prove useful in the planning of remedial measures and reclamation activities. Much research will be needed, however, to realize such potentials.

*Preparedness*

For known drought-prone areas, an effective preparedness program requires data on the number and geographic distribution of the population, agricultural crops, rangeland and grazing conditions, and availability and quality of water supplies. Few if any developing countries are adequately mapped in any scale, and most lack basic natural resource inventories. In the context of a management system already in place remote sensing could provide information to help develop such data bases. Many developing countries are already using remote sensing in management programs, and

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[25]See J. B. Bale *et al.* (eds.), *Remote Sensing Application to Resource Management Problems in the Sahel* (Washington, D.C.: Earth Satellite Corporation, 1974).

the speed at which this technology is entering their societies should not be discounted. However, developing countries are often more interested in using remote sensing for purposes that will bring direct economic returns, such as mineral and oil exploration, than for drought, hazard, and vulnerability analysis.[26]

Meteorological satellite images from the National Oceanic and Atmospheric Administration satellites and the declassified U.S. Air Force Defense Meteorological Satellite Program (DMSP) system offer valuable data for studying drought. Cloud-top temperatures at a spatial resolution of 2 to 3 nautical miles are adequate for estimating the likelihood of precipitation from typical cloud formations of the savannah and subtropical desert fringes.[27] The Large Area Crop Inventory Experiment (LACIE), the Center for Climate and Environmental Assessment (CCEA), and others are incorporating a variety of meteorological satellite data into local meteorological and agricultural crop/yield models.[28] Future plans call for the Soviet Union, Japan, a consortium of Western European countries, and the United States to put up a series of synchronous meteorological satellites that will girdle the globe at the equator. All countries subject to drought can then be monitored on a daily basis.

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[26]For a cautionary statement concerning the use of remote sensing for natural resources, see I. Adelman, "Remote Sensing and Equity," *Resource Sensing from Space: Prospects for Developing Countries* (Washington, D.C.: National Academy of Sciences, 1977), pp. 187-190.

[27]See D. S. Simonett, "Roles for Space Sensing in Studying Desertification," *Desertification: Process, Problems, Perspectives* (Tucson, Arizona: The University of Arizona, Arid/Semi-Arid Natural Resources Program, September, 1976), p. 54.

[28]NASA, the U.S. Department of Agriculture (USDA), and the National Oceanic and Atmospheric Administration (NOAA) are currently engaged in a major study to determine the degree of accuracy in crop identification, acreage, and yield that can be achieved by LANDSAT remote sensing. The LACIE project began with monitoring of wheat plantings, yields, and crop conditions in the Great Plains area, checked against ground truth and conventional data collection carried out by USDA personnel. If the results are satisfactory in the United States, the experiment will continue with respect to wheat in other countries and then may be extended to other crops, including rice, soybeans, cotton and peanuts.

LANDSAT data may provide a worldwide data base for mapping drought-prone areas by creating an inventory of the present situation and reinventorying at intervals. Similarly repeated observations may be helpful in determining the extent of surface water, the length of time the water remains on the surface, and the availability of groundwater in semiarid lands for inclusion in a natural resource monitoring system.

*Modeling*

Research is needed to examine and model the thresholds at which droughts become disasters and to identify measurement techniques to determine when such thresholds have been reached. Data from LANDSAT, meteorological satellites, and available aerial photographs may offer a base to develop and test these thresholds. Models must be structured to take into consideration the individual temporal changes and relationships among climate, population, agricultural crop production and rangeland use, and environmental quality. These changes and relationships could affect the estimated measures of the intensities of specific droughts, as well as their spatial and temporal characteristics.

The Center for Climate and Environmental Assessment (CCEA) is carrying out analysis for the AID/OUSFDA in the development and use of weather/crop-yield forecast models in the drought-prone countries of the African Sahel and the Caribbean basin.[29] The aim of these models is to express meteorological information in terms of risk of crop failures or the probabilities of various levels of yield reduction. Monthly data regression-based models of the type now employed by CCEA are very primitive, and future modeling using daily meteorological satellite temperature and precipitation estimates (and other data) will be essential if acceptable accuracies are to be obtained.

The inadequacy of present meteorological models to forecast or predict drought stems in part from insufficient

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[29]See P. F. Krumpe, *The Application of LANDSAT Technology to the Problems of Disaster Preparedness (Early Warning) and Relief (Damage Assessment)* (Washington, D.C.: Agency for International Development/Office of U.S. Foreign Disaster Assistance, 1977).

knowledge of the various dynamic and thermodynamic processes operating in the earth's atmosphere to produce climatic variations. The monitoring of albedo, vegetation coverage, and soil moisture, together with numerical modeling, may enable better prediction or forecasting of drought. As satellite observations fill the data gaps with global coverage of cloudiness, radiation, precipitation, temperatures, and winds, substantial advances are expected in measuring and understanding climatic fluctuations. For example, data related to surface radiation budget could, in principle, provide users with valuable information about soil moisture, crop yield, evapotranspiration, and related topics.[30]

Between 1982 and 1986, NASA plans to acquire a complete climate data set as a contribution to the U.S. climate

[30]Personal communication with Paul Krumpe of the AID/OUSFDA, April 1978. See also, J. Charney *et al.*, "Drought in the Sahara: A Biological Feedback Mechanism," *Science*, Vol. 187 (1975), pp. 434-435; G. L. Potter *et al.*, Possible Climatic Impact of Tropical Deforestation," *Nature*, Vol. 258 (1975), pp. 697-698; P. R. Rowntree, "Response of the Atmosphere to a Tropical Atlantic Ocean Temperature Anomaly," *Quarterly Journal of the Royal Meteorological Society*, Vol. 102 (1976), pp. 607-625; and R. A. Bryson, "Practical Climatic Forecasting for Agriculture," paper presented at the Joint People's Republic of China-United States Symposium on Geographic Perspective on the Environment--American and Chinese Views, Wingspread, the Johnson Foundation, Racine, Wisconsin, October 12-14, 1978. See the following reports of the Institute for Environmental Studies, University of Wisconsin-Madison: P. J. Michaels, *World Climate and World Food Systems XI: A Predictive Model for Winter Wheat Yield in the United States Great Plains*, IES Report 94, January 1978; P. J. Michaels and V. R. Scherer, *World Climate and World Food Systems VII: A Predictive Model for Wheat Production in Sonora, Mexico*, IES Report 73, March 1977; P. J. Michaels and V. R. Scherer, *World Climate and World Food Systems VIII: An Aggregated National Model for Wheat Yield in India*, IES Report 74, March 1977; V. R. Scherer, *World Climate and World Food Systems IX: Models for Wheat Yield in India with Inclusion of Climatically Induced Variability*, IES Report 80, June 1977; and V. R. Scherer, *World Climate and World Food Systems X: Models for National (Aggregated) Wheat Yield in the People's Republic of China*, IES Report 93, June 1977.

program plan. The data will be acquired with an observing system having the following components:[31]

- operational weather-observing system, including TIROS-N, SMS/GOES, GMG, and METEOSAT;
- CLIMSAT, a new polar-orbiting climate satellite;
- ERBSS (Earth Radiation Budget Satellite System), a low inclination (50 degrees) radiation budget stratospheric aerosol satellite; and
- several special observational studies.

It is hoped that this system will facilitate prediction of drought with the minimum set of climatic parameters over a period of several years. Once the system is operational, research will be needed to define its value for drought monitoring.

### *Warning*

The relationship between drought and famine varies among areas with the environmental, social, and economic conditions. The problem of drought mitigation is essentially twofold: (1) to predict areas of potential famine with enough advance warning that corrective measures may be taken to prevent actual occurrences, and (2) in the event of unavoidable drought, to indicate the magnitudes involved and the risk of famine, so that adequate relief supplies may be moved into critical areas before extreme hardship occurs.

Direct and surrogate measures of geographical phenomena associated with drought may possibly be identified and monitored with remote sensing and verified by ground surveys. At present, no system employing satellite data has a proven capability for warning. It has been suggested that with a drought-monitoring system, the following decisions might be derived:[32]

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[31]See J. Spar, "Supplementary Notes on Sea-Surface Temperature Anomalies and Model-Generated Meteorological Histories," *Monthly Weather Review*, Vol. 101 (1973), pp. 767-773.

[32]See the National Aeronautics and Space Administration, *Proposed NASA Contributions to the Climate Program* (Greenbelt, Maryland: Goddard Space Flight Center, 1977), Part 4, pp. 1-36.

- the timing of the removal of livestock in grazing areas or the assistance needed in the form of livestock food to reduce the migration of nomadic peoples with their livestock to less drought-sensitive regions, which, although not overgrazed, cannot withstand the increased pressure;
- preparation of plans to prevent overgrazing and to open up new areas for grazing;
- timely measures to reduce fire hazards; and
- additional investment in land improvements by draining, irrigating, seeding, or fertilizing at appropriate times.

Modeling with inputs from meteorological and other satellite data, in conjunction with ground-based surveys of livestock, rangeland, and crop conditions could potentially aid in famine prediction by providing information about available food supplies. The problem must be defined in terms of the ways drought expands and contracts through space and time; eventually models must be constructed to integrate all factors in a manner corresponding with methods of remote sensing. The need now is for research procedures that describe various stages of drought that can be remotely sensed, measured, and evaluated as inputs to such models.

Landholding systems in developing countries complicate interpretation of remote sensing imagery. Because land parcels are usually small and impermanent, detection of divisions is difficult on LANDSAT imagery. Areas of crop farming along rivers and villages are more discernable, but data on crop vigor and yield are difficult to obtain. Under such circumstances, drought conditions that lead to poor and varying yields do not lend themselves well to most techniques being experimented in the United States. Better estimation of crop acreage over large areas may be obtained by a combination of statistical sampling techniques using ground survey methods and LANDSAT imaging (like the techniques being implemented by the Statistical Reporting Service of the USDA). For famine prediction, such sampling techniques might be used to determine the health conditions of communities involved.[33]

The LACIE project has been trying to determine the level of drought severity in order to calculate the reduction in

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[33]See Rowntree, *op. cit.*

crop yield for a region.[34] At present, spectral data are used only to monitor the geographic extent of drought. Research is under way to use spectral data to quantify the reduction in yield, through indicating drought-induced stress in crops and rangeland. Nalepka, Colwell, and Rice tried to overcome some of the limitations of present approaches by including nonmeteorological factors that affect the growth of wheat but are not considered in traditional yield models (e.g., type of soil, planting density, irrigation, fertilization, planting date).[35] To qualify actual production, however, even a developed country must presently rely heavily on field surveys.

In addition to LACIE methodologies, the methodology of the Statistical Reporting Service of the U.S. Department of Agriculture (USDA/SRS), and Earth Satellite Corporation, as well as others, could form components of a design specifically formulated for forecasting and monitoring the progress of drought. In a report prepared for the AID by the American Technical Assistance Corporation, elements of the three systems were compared in relation to the appraisal and inventorying of tropical agricultural systems.[36] Figure 3 presents a schematic of a spring wheat yield system. A similar agrometeorological model might be used to predict yield in drought-prone areas based on satellite and ground observational data from sample surveys, and data collection platforms.

In the future, the SEOS satellite might improve sampling strategies by providing sample estimates of crop conditions within a stratum chosen from LANDSAT images. The narrower bands and wider spectral range of LANDSAT-D will allow

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[34]Investigations of the application of satellite sensing to U.S. agriculture have dealt principally with the inventory of crop acreage, forecasting of crop yield, soil survey, design and operation of irrigation projects, and flood damage assessment.

[35]See R. F. Nalepka *et al.*, "Worldwide Wheat Production Forecasts Using LANDSAT Data," *Proceedings of the Twelfth International Symposium on Remote Sensing of Environment, April 20-26, 1978, Manila, Philippines* (Ann Arbor, Michigan: Environmental Research Institute of Michigan, 1978).

[36]See D. S. Simonett, *Preliminary Design Requirements for a Research Project in the Tropical Agricultural Inventory and Appraisal* (McLean, Virginia: American Technical Assistance Corporation, 1977).

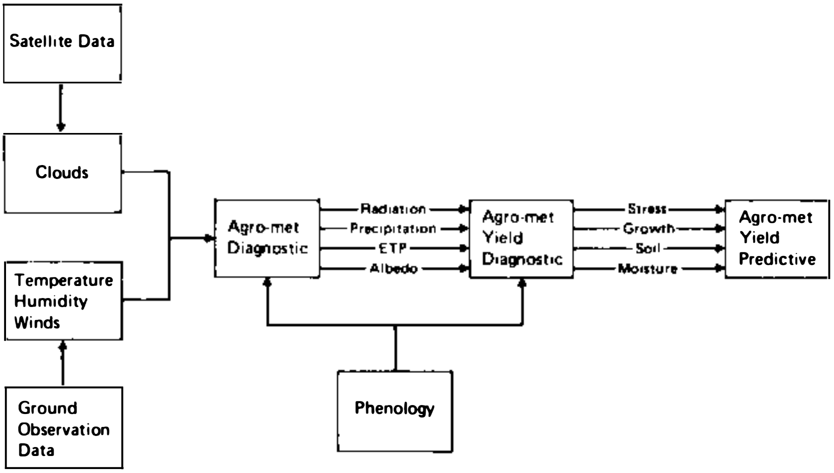


FIGURE 3 Schematic of EARTHSAT spring wheat yield system. SOURCE: E. Merritt *et al.*, *EARTHSAT Spring Wheat System Test 1975: Final Report*, prepared for L. B. Johnson Space Center, Houston, Texas, NASA, Contract #NAS-9-14655 (Washington, D.C., Earth Satellite Corporation, April 1976), p. 2a.

concentration on single energy-matter interaction such as a chlorophyll absorption band, and thus provide a better assessment of yield reduction. Improved spatial resolution will lead to better identification in areas of small field agriculture. Furthermore, LANDSAT-D will have improved drought-related capabilities to perform such functions as the following:

- delineating land/water boundaries;
- detecting surface moisture shortly after rainfall;
- detecting crop stress;
- discriminating active green vegetation and accurately classifying green vegetation with full ground cover;
- estimating moisture in fire-prone grassland vegetation; and
- assessing range feed conditions.

Meteorological satellites, in conjunction with the few rain gauges available, show promise in monitoring the progress of drought. At present prices, operating a system to assess rainfall in near real time over wide areas such as the African Sahel is estimated at $35,000 to $40,000 per year.[37] Information from future meteorological satellites may enhance drought monitoring and, in a limited way, drought prediction. The earth radiation budget experiments on TIROS-N and NIMBUS-G will sample at fixed times of day, adding a diurnal bias to the radiation budget data. Data from the high-resolution multispectral radiometer planned for the TIROS-N series of satellites may better identify cloud types and associated rainfall. Solar radiation and sky-infrared radiation reaching the ground could provide valuable information related to soil moisture, crop yield, evapotranspiration, and energy requirements.[38]

Soil moisture estimating procedures should be quasi-operational by the mid- to late 1980's. If successful, regional assessment of water yield, drought stress, and the like might be possible on much finer spatial and temporal scales. Future satellites with active microwave sensors, meteorological satellites, and LANDSAT-D will play various roles in this estimation process.

Data from operational satellites comparable to the heat capacity mapping mission (HCMM) satellite just launched should facilitate inferences on soil water content and estimates of plant transpiration and plant stress. If the HCMM is successful, it may lead to the development of special purpose satellites for monitoring drought.

### *Emergency*

It is doubtful whether remote sensing can be useful in the emergency phase in droughts, when conditions are rapidly changing and famine exists. Research is clearly needed on the precursors of famine conditions, on the continued spread of drought and its relation to famine, and on the uses, if any, of remote sensing at this stage.

### *Rehabilitation*

To facilitate rehabilitation after a drought, a comprehensive land management and development scheme must be implemented. Remote sensing may potentially be used to

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[37] See Rowntree, *op. cit.*

[38] See the National Aeronautics and Space Administration, *op. cit.*, Part 2, pp. 38-39.

monitor the recovery of the natural ecosystem and to improve development programs. Once the condition of grazing areas has been determined, range quality control may be initiated. In areas where the animals of tribal people share grazing land, major changes in social structure may be required before remote sensing information could be used. The devastating Sahel droughts have produced major relocations of populations, with no guarantee that they will be re-established on traditional grazing lands.

*Reconstruction*

Remote sensing shows essentially the same utility in the reconstruction phase as in the rehabilitation phase. Imagery can be viewed as a data base for development planning and drought preparedness. Reconstruction after a drought is part of the larger resource management and development system within a country. Remote sensing is cost-effective only when it serves as a data base for this management and development. Remotely sensed data may be used to monitor the environment and possibly to prepare an inventory of the major changes resulting from the previous drought. Determination of changes in population distribution and land use could be useful in planning effective development programs to mitigate the effects of future drought.

Although costly, assessment of the stability of rangelands, agricultural areas, and water supplies may be extrapolated from sampled ground information to the region as a whole. With the aid of remote sensing, inventories of vegetation, soils, and geological mapping can be done to assess the conditions of natural resources. A balanced data-gathering strategy that includes field surveys along with remote sensing will be essential.

The research needed to resolve the contribution of remote sensing to drought monitoring will clearly be substantial. At this time it is a distant potential only, not a present reality in terms of operational usefulness. Since drought (as noted elsewhere in this report) is not a sufficient indicator of famine, it will in any case be only one of the items to be monitored in famine-prone regions.

# APPENDIX 3 Probable Future Satellites

Between 1980 and 1990 and beyond, the following experimental satellites are planned:

*LANDSAT-D*: To be launched in 1981, LANDSAT-D will carry a multispectral scanner (MSS) compatible to that of LANDSAT's 1, 2, and 3. It will also carry an advanced multispectral scanner known as a Thematic Mapper. This instrument will have an improved resolution of 30 meters in six spectral bands, plus a thermal channel with 120-meter resolution. Two satellites will be launched 9 days apart. The Tracking and Data Relay Satellite System (TDRSS), if then available, will provide transmission of data from all parts of the world except parts of India, so there may be no need for tape recorders. The TDRSS presently faces major problems of radar interference.

*SEASAT-1*: An indication of *possible* uses of future operational sea and land sensing satellites carrying radar imaging systems may be given from experiments on SEASAT-1. This experimental satellite was launched in mid-1978 and carried an L-band synthetic aperture imaging radar (SAR) with all-weather capability. The radar covered a 100-km swatch with a resolution of about 25 meters every 3 or 4 days for 95 percent of the earth's surface. Although SEASAT was dedicated primarily to studying sea state and ice, the SAR showed promise of providing precise flood maps through cloud cover. No receiving stations were located in developing countries. The satellite operated for a few months only before failure of the power system. Sufficient data were obtained prior to early October 1978, when the short circuit developed, however, to make some contribution on these questions.

*Earth Synchronous Observation Satellite (SEOS)*: The first synchronous earth-observing satellite is designed specifically for disaster monitoring in the Western

Hemisphere. It is planned for launch sometime between 1981 and 1985. It will carry high-powered telescopes (resolution of 6 meters) with a long dwell time and repeated imaging. Instruments include solid state cameras, new generation telemetry, and spectrometers for pollution detection.

*Heat Capacity Mapping Mission (HCMM)*: An indication of *possible* future operative use of improved thermal systems as part of a drought-monitoring program may be obtained from experiments on the HCMM. This research satellite carries a single-channel thermal sensor covering a 700-km swatch with a 500-meter dimension. In order to estimate thermal inertia and surface and near-surface soil moisture, it will take both a day and night pass over the same area at the peak of the heating cycle and at the trough of the cooling cycle.

*Space Shuttle*: To be initiated in the early 1980's, the Space Shuttle will be capable of carrying experimental high-resolution, wide-area coverage imaging radars and cameras. Some missions will carry both radar and cameras, and suitable experiments or operations could be tested. Launched about once a month, each mission will last between 1 and 2 weeks.

*TIROS-N*: This is the prototype of the next generation of polar-orbiting operational meteorological satellites. The system will include two satellites in orbit simultaneously, to provide global coverage and system reliability. It will include a new four-channel sensor, the advanced very high resolution radiometer (AVHRR) that is expected to improve cloud-water discrimination. A fifth thermal channel is planned for a follow-on system to improve thermal mapping. Data will be available in four modes, including on-board recording of limited, selectable portions of each orbit at 1.1-km resolution. In addition, it will have a data collection and platform location system (DCPLS).

*SPOT*: The French earth observation satellite to be launched in the early 1980's in a sun-synchronous orbit will cover an area 60 km wide with 10-meter resolution. At the equator, its sequence of coverage will range between 5 days apart and 1 day apart. At 45 degrees latitude the worst coverage will be 4 days apart and the best will be 1 day apart. In addition, to some extent, the satellite may be pointed at specific earth targets.

*NIMBUS-G*: The most recent satellite in the series of experimental meteorological satellites, NIMBUS-G was developed to provide observations for research and development needs of atmospheric and earth scientists, and to provide global surveillance of the atmospheric structure for worldwide weather services. The satellite was launched in late 1978 and is expected to have a lifetime of 1 year or more. It will include an earth radiation budget and a scanning multichannel microwave radiometer capable of measuring the water content of clouds, a spectrometer for ocean color imaging, a radiometer and scatterometer for sea-state data, and sensors to detect stratospheric pollution.

Another future option open to developing countries is the installation of relatively low-cost receiving stations capable of receiving analyzed data/images. Imagery could be processed and analyzed at a large facility and transmitted to a low-cost receiving station via the WEFAX system on board the SMS/GOES satellite.

In addition to the future satellites listed, many countries are in the process of researching, designing, and planning future satellite platforms for a variety of uses. The European Space Agency has started studies on a space segment with emphasis on microwave payloads for specific European land and ocean sensing applications. Japan, Germany, and the Soviet Union have future plans for synchronous meteorological satellites equivalent to the SMS/GOES. These systems, in conjunction with SMS/GOES, will provide complete, near real-time global weather coverage.

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