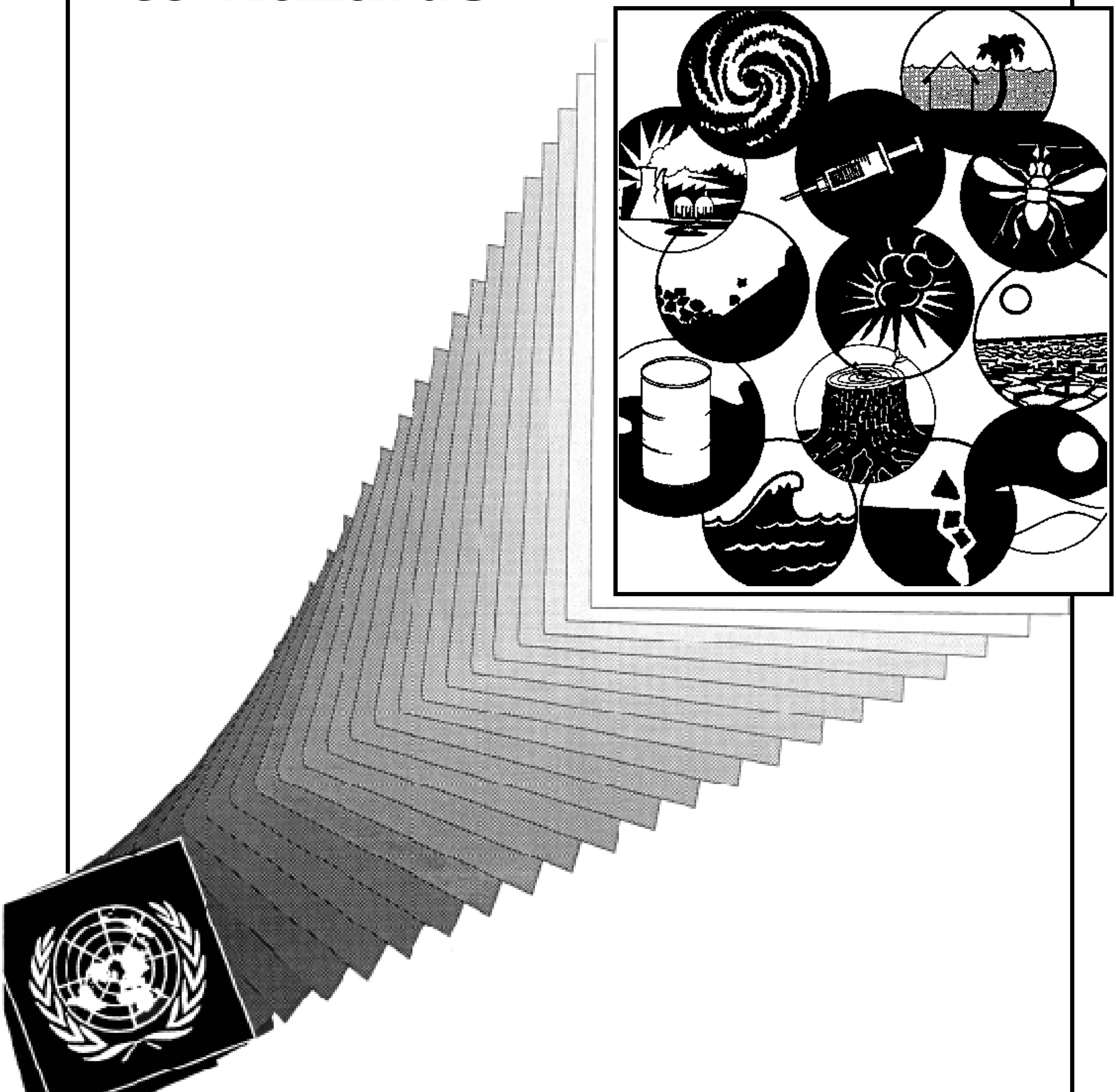
*3rd Edition*

# Introduction to Hazards



**Disaster Management Training Programme**

# Introduction to Hazards

*3rd Edition*

Module prepared by Shelia B. Reed, InterWorks

DHA

**Disaster Management Training Programme 1997**

## ■ TABLE OF CONTENTS

## ■ ACKNOWLEDGEMENTS

This training module has been funded by the United Nations Development Programme in collaboration with the Department of Humanitarian Affairs for the Disaster Management Training Programme (DMTP) in association with the University of Wisconsin Disaster Management Center.

The text was reviewed by: *Andrew Coburn* and *Robin Spence,* Cambridge Architectural Research Ltd.; *Robert L. Southern,* Weather Associates, Western Australia; *Diana Liverman,* Penn State University; *Paula Gori, Jeff Sutton, Gerald Wieczorek,* U.S. Geological Survey; *Gudrun Huden, Allan Showler,* U.S. Agency for International Development; *Kent Elbow,* University of Wisconsin; *Daniel R. Muhs, Richard Z. Poore,* USGS; *Walter C. Dudley,* University of Hawaii; *Stuart Nichenko,* FEMA; *Brad Woodruff,* CDC; *Alessandro Loretti,* WHO; *Donald A. Wilhite, Deborah Wood* and *Michael J. Hayes,* National Drought Management Center.

Editorial services, including design, educational components and formatting, have been provided by InterWorks. Design consultation and desktop publishing have been provided by Artifax.

## United Nations reorganization and the Disaster Management Training Programme

Since this module was written there has been reorganization within the United Nations system. This page is inserted to alert you to the organizational changes and explain the expanded role of the United Nations in disaster management. All module references to UNDRO (Office of the United Nations Disaster Relief Co-ordinator) should now be read as DHA (Department of Humanitarian Affairs).

Following the adoption of General Assembly resolution 46/182, the UN Secretary-General established in April 1992 the Department of Humanitarian Affairs (DHA) in order to strengthen and make more effective the collective efforts of the international community, and particularly those of the United Nations System, in providing humanitarian assistance. The Emergency Relief Co-ordinator, as Under-Secretary-General for Humanitarian Affairs, directs the Department's efforts to ensure both a rapid, integrated and effective international response to humanitarian emergencies, and the implementation of measures for disaster preparedness, prevention and mitigation.

As the UN's lead body for humanitarian co-ordination, DHA operates in the grey zone where security, political and humanitarian concerns converge. The Department has Offices in both New York and Geneva with distinct, though mutually-reinforcing, responsibilities.

The Department focuses in New York on the formulation of policy as well as policy co-ordination, policy planing and early warning functions. This requires the Department to work closely with the deliberative organs of the UN as well as with the political, financial and economic departments of the UN Secretariat to ensure vertical co-ordination.

The Geneva Office (DHA-Geneva) concentrates its activities on providing operational support during emergencies and on co-ordinating international disaster relief activities, as well as all activities related to disaster prevention and mitigation.

An Inter-Agency Standing Committee (IASC) chaired by the Under Secretary-General for Humanitarian Affairs has been established pursuant to General Assembly resolution 46/182. It associates non-governmental organizations, UN organizations, as well as the International Committee of the Red Cross (ICRC) and the International Federation of Red Cross and Red Crescent societies (IFRC). The executive heads of these agencies meet regularly to discuss issues relating to humanitarian emergencies. An inter-agency secretariat for the IASC has also been established within DHA.

As part of the reorganization of DHA, the Special Emergency Programmes (SEP) were consolidated into the Complex Emergency Division (CED), with a desk structure in New York and a support unit in Geneva. CED comprises the former special Emergency Programme for the Horn of Africa (SEPHA), the Drought Emergency in Southern Africa Programme (DESA), the Special

Emergency Programme for Newly Independent States (SEP-NIS), the Special Humanitarian Programme for Iraq (SEP-IRQ) as well as the United Nations Office for the Co-ordination of Humanitarian Assistance to Afghanistan (UNOCHA).

A number of staff members were transferred to New York from Geneva as part of this reorganization. A Complex Emergency Support Unit was created in Geneva to handle liaison with Geneva-based government missions, UN Agencies, international organizations and NGOs to support Appeals preparation and finalization, dissemination of other information and financial tracking. Administrative matters related to CED field operations have also been handled by DHA in Geneva throughout 1994. During the year, DHA established field units in Rwanda, Armenia, Azerbaijan, Georgia and Tajikistan. The humanitarian needs which arose from the events in Chechnya, Russian Federation, led to the establishment of a DHA presence in Moscow at the beginning of 1995.

DHA promotes and participates in the establishment of rapid emergency response systems which include networks of operators of relief resources, such as the International Search and Rescue Advisory Group (INSARAG). Special attention is given to activities undertaken to reduce the negative impact of sudden disasters within the context of the International Decade for Natural Disaster Reduction (IDNDR). A world conference on National Disaster Reduction, held in Yokohama, Japan in 1994, adopted a plan of action for the rest of the decade and a strategy for beyond the year 2000.

The Disaster Management Training Programme (DMTP), which was launched in the early 1990s, is managed jointly by DHA and UNDP on behalf of an Inter-Agency Task Force. It provides a framework within which countries and institutions (international, regional and national) acquire the means to increase their capacity-building in emergency management in a development context.

# ■ *INTRODUCTION*

## Purpose and scope

This training module, **Introduction to Hazards,** is designed to present 13 different hazard types to an audience of UN organization professionals who form disaster management teams as well as to government counterpart agencies, NGOs and donors. This training is designed to increase the audience's awareness of the causal phenomena which underlie the hazards and options for improving performance in disaster preparedness and response.

## Overview of the module

The list of all hazard types is very long. Many of these occur infrequently or impact only very small populations. Some hazards, such as snowstorms, often occur in areas that are prepared to deal with them so that they rarely become disasters. The disasters of interest to the international community are those which affect large populations and which may require outside assistance.

The following hazard types will be addressed in this training module.

***Geological Hazards***

- Earthquakes
- Tsunamis
- Volcanic eruptions
- Landslides

***Climatic Hazards***

- Tropical cyclones
- Floods
- Drought

***Environmental Hazards***

- Environmental pollution
- Deforestation
- Desertification
- Pest Infestation

***Epidemics***

***Industrial Accidents***

Other major hazards such as famine, war and civil strife will be covered in separate modules. Less widespread hazards such as transportation accidents, urban conflagrations, non-tropical high winds, and fires were not within the scope of this module but may be covered in the future.

It is the responsibility of the trainee to determine which hazards are of concern and to read the pertinent chapters. It is important to remember that where different types of disasters occur in combination, such as floods with tropical storms, the combined effects must be considered.

In this module, the basic characteristics of the hazard types and appropriate response measures have been structured as follows.

**Causal phenomena**

**General characteristics**

**Predictability**

**Factors contributing to vulnerability**

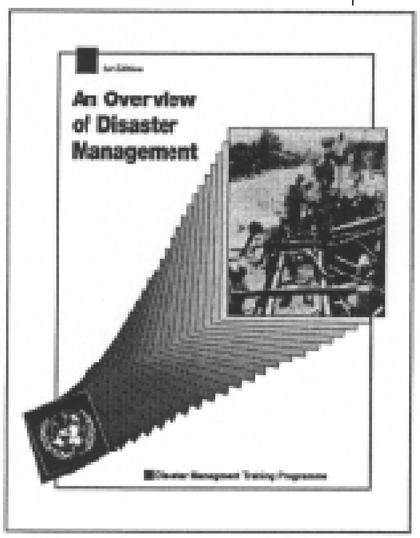
**Typical effects**

**Possible risk reduction measures**

**Specific preparedness measures**

**Typical post-disaster needs**

**Impact assessment tools**




### *Fundamentals of Disaster Management*

Common foundations for selection of hazard preparedness and mitigation measures include risk assessment, vulnerability assessment, and disaster assessment. Another critical concept in program design, is the relationship between disasters and development. These principles may be alluded to but not specified in the chapters, nonetheless, they are fundamental. A summary of key ideas is provided here but further information may be found in “Vulnerability and Risk Assessment”, “Disaster Mitigation”, “Disaster Assessment” and “Disasters and Development” modules in the DMTP series.

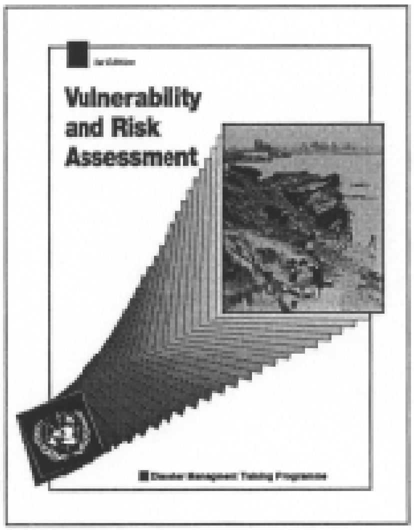
# ■ OVERVIEW OF FUNDAMENTALS

This part of the module is designed to supply some fundamental concepts for hazard mitigation and preparedness in regard to:

- assessment of vulnerability and risk
- types of disaster mitigation options
- choosing disaster mitigation options
- disaster assessments
- relationships between disasters and development.

## Vulnerability and risk assessment

### *Understanding risk*




Effective risk management requires information about the magnitude of the risk faced (risk assessment), and on how much importance society places on the reduction of that risk (risk evaluation). Quantification of the level of risk is an essential aspect of both preparedness planning and mitigation planning.

Risks are often quantified in aggregated ways (e.g. a probability of 1 in 23,000 per year of an individual dying in an earthquake in Iran). Such gross risk estimates can be useful for comparative purposes, but usually conceal large variations in the risk to individuals or different regions. There are 3 essential components to the quantification of risk:

**Hazard occurrence probability** – the probability of occurrence of a specified natural hazard at a specified severity level in a specified future time period.

**Elements at risk** – an inventory of those people or things which are exposed to the hazard.

**Vulnerability** – the degree of loss to each element should a hazard of a given severity occur.

The probability of occurrence of the extreme levels of natural hazards which can cause a disaster may be estimated by statistical extrapolation from data on the normal levels of occurrence. The accuracy of such estimates depends on the amount and completeness of data and the period of time over which it has been collected. Historical records can be an invaluable source of information.

Recurrence frequency and intensity of most natural hazards varies from place to place – hazard mapping may be used to show this variation. For some, notably geological hazards, detailed local mapping (micro-zoning) can be used to establish local variations and assist land-use planning decisions. For others only coarse mapping of geological areas at risk is possible, such as desertification and deforestation.

## Vulnerability assessment

Vulnerability assessment involves first identifying all the elements which may be at risk from a particular hazard. Local knowledge and census data may be used to complete the inventory.

- Loss functions in the form of vulnerability curves or damage probability matrices may be obtained for some elements at risk (buildings, people) based on past experience elsewhere.
- Many aspects of vulnerability cannot be described in monetary terms, such as personal loss of family, home, income and related human suffering and psychosocial problems, but these should not be overlooked.
- Because hazards tend to be uncontrollable, much mitigation work is centered on reducing vulnerability. Improved economic conditions reduce many aspects of vulnerability and a sound economy may in many cases be the best defense against disaster.
- Risk is compiled from hazard and vulnerability data and from the inventory of elements at risk. A variety of ways of presenting risk are available such as f:N curves, senario mapping, potential loss mapping and annualized risk.

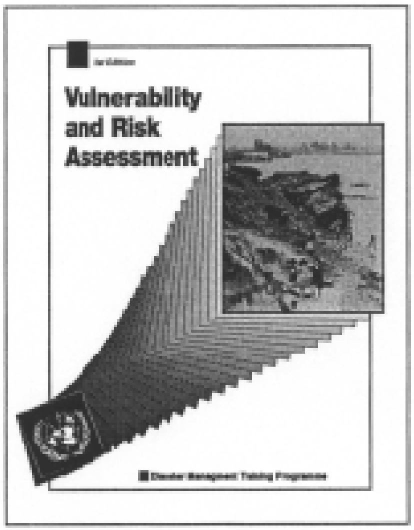
The importance a community places on the risk of a hazard is likely to be influenced by the types and level of other everyday risks it faces. For example, village communities living in the mountain valleys of Northern Pakistan are regularly afflicted by floods, earthquakes and landslides and do not perceive disaster mitigation to be a priority. Instead they choose to protect themselves against the greater risks of disease and irrigation failures. In contrast, in the state of California, where people and their houses are much less vulnerable to natural disasters and the risk of disease is low, communities choose to initiate disaster mitigation programs against natural disasters.

- The process of economic development needs to incorporate a risk mitigation strategy because traditional ways of coping with environmental risks are otherwise likely to be lost.
- Risk is perceived differently by different individuals and different groups. Those with regular access to news media are likely to be more aware of the environmental risks they face than others, but they may, as a result, overestimate the likelihood of uncommon risks such as natural disasters.
- The acceptability of a level of risk to individuals and societies appears to increase with the benefits that are obtained from exposure to it, and to be much greater where exposure to the risk is voluntary (as in sports) than where it is involuntary (like natural disasters). The acceptable level of risk also appears to decrease over time as more people become exposed to particular types of risk.
- For many risks, mitigation can only be handled at the level of the community because the exposure of the community may be greater than that of the individual, and because protection often requires collective, sometimes large scale action.

## Disaster mitigation options

The essential first step in any mitigation strategy is to understand the nature of the hazards which may be faced. Understanding each hazard requires comprehension of:

- its causes
- its geographical distribution, magnitude or severity and probable frequency of occurrence
- the physical mechanisms of destruction
- the elements and activities most vulnerable to destruction
- the possible economic and social consequences of the disaster




Mitigation involves not only saving lives and injury and reducing property losses, but also reducing the adverse consequences of natural hazards to economic activities and social institutions. Where resources for mitigation are limited, they should be targeted where they will be most effective – on the most vulnerable elements and in support of existing community level activities.

Vulnerability assessment is a crucial aspect of planning effective mitigation. Vulnerability implies both susceptibility to physical and economic damage and lack of resources for rapid recovery. To reduce physical vulnerability, weak elements may be protected or strengthened. To reduce the vulnerability of social institutions and economic activities, infrastructure may need to be modified or strengthened or institutional arrangements modified.

For most risks associated with natural hazards, there is little or no opportunity to reduce the hazard. In these cases the focus of mitigation policies must be on reducing the vulnerability of the elements and activities at risk. For technological and human-made hazards, reducing the hazard is, however, likely to be the most effective mitigation strategy.

Actions by planning or development authorities to reduce vulnerability can broadly be classified into two types – active and passive.

> **Active** measures are those in which the authorities promote desired actions by offering incentives – these are often associated with development programs in areas of low income.
>
> **Passive** measures are those in which the authorities prevent undesired actions by using controls and penalties – these actions are usually more appropriate for well-established local authorities in areas with higher incomes.

***"Although they may cost more to initiate, active measures may produce better results in some communities because they 1) tend to promote a self-perpetuating safety culture, 2) do not rely on the economic capability of the affected community, and 3) do not rely on the ability of the local authorities to enforce controls.***

The range of mitigation actions which might be considered can include:

> **Engineering and construction** – Engineering measures range from large-scale engineering works to strengthening individual buildings and small scale community based projects. Codes of practice for disaster protection are unlikely to be effective unless they are accepted and understood by the community. Training of local builders in techniques to incorporate better protection into traditional structures – buildings, roads, embankments – is likely to be an essential component of such measures.

**Physical planning measures** – Careful location of new facilities – particularly community facilities such as schools, hospitals and infrastructure plays an important role in reducing settlement vulnerability; in urban areas, deconcentration of elements especially at risk is an important principle.

**Economic measures** – The linkages between different sectors of the economy may be more vulnerable to disruption by a disaster than the physical infrastructure. Diversification of the economy is an important way to reduce the risk. "A strong economy is the best defense against disaster." Within a strong economy, governments can use economic incentives to encourage individuals or institutions to take disaster mitigation actions.

**Management and institutional measures** – Building disaster-protection takes time. It needs to be supported by a program of education, training and institution-building to provide the professional knowledge and competence required.

**Societal measures** – Mitigation planning should aim to develop a "safety culture" in which all members of society are aware of the hazards they face, know how to protect themselves, and will support the protection efforts of others and of the community as a whole.

## Mitigation strategies

Any successful mitigation strategy should include a range of measures from the menu of possible actions. To obtain political acceptability, the ultimate deciding factor, a mitigation strategy may need to contain a mixture of immediately visible improvements and of less visible but long-term sustainable benefits.

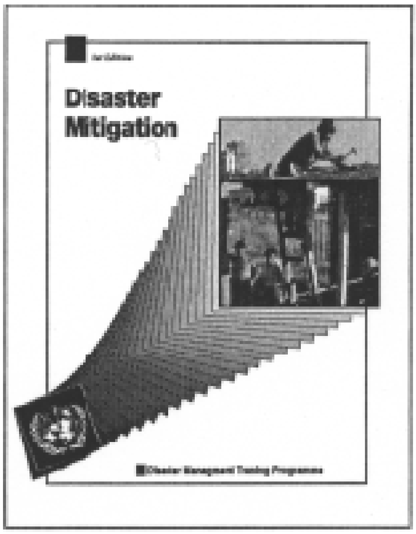
The selection of an appropriate strategy should be guided by evaluating and considering the costs and benefits (in terms of future losses saved) of a range of possible measures. In conducting a cost benefit analysis, either a minimum cost or a maximum benefit/cost ratio criterion may be used. However, this method poses difficulty in assessing the monetary value of human lives.

Alternatively, an acceptable risk may be defined in relation to other risks to individuals or society, the balanced risk criterion. This method is not dependent on the cost element. The most sophisticated approach is to quantify the costs and different types of benefits separately (economic, human) and also calculate the cost effectiveness of each strategy in relation to different objectives of mitigation. This approach is more in keeping with the social and economic realities of decision-making.

Mitigation strategies are much easier to implement in the immediate aftermath of a disaster or near-disaster. Awareness of the impact of similar natural hazards elsewhere can also assist in obtaining public and political support for disaster protection.

Empower the community by promoting planning and management of its own defenses and obtaining outside assistance only where needed.

## Disaster assessment




Assessments must be planned for, systematically implemented and regularly conducted during the recovery process, as a critical component of the disaster preparedness and management continuum. It is through assessment that decision-makers can identify needs that lead to appropriate types of assistance. Equally important, assessment indicates what types of assistance are not needed, thereby decreasing inappropriate assistance. Further, assessments can provide feedback on how the recovery is progressing which will allow for correction of programs that may be falling short of their objectives.

Assessment is most effective when it is pre-designed as part of an overall preparedness plan which is tested and refined. The assessment process will vary with different types of hazards and must take into account the range of possible situations the country might encounter. Information for assessment is best gathered through well designed observation and survey methods. Assessments should be coordinated efforts, taking into account the ideas of a range of “relief actors”.

## The relationship between disasters and development

**Disasters can destroy development inputs** and years of development initiatives. Disasters can delay future development due to loss of resources, need to shift resources to emergency response and depressing the investment climate.

**Development can increase vulnerability of disasters** through, for example, dense urban settlement, development of hazardous sites, environmental degradation, technological failures or imbalance of pre-existing natural or social systems.

**Development programs can reduce vulnerability** by, for example, strengthening of urban utility systems, use of hazard resistant building techniques, institution building, and agricultural and forestry programs.

**Disasters can provide development opportunities** by:

- creating a social and political atmosphere of acceptance to change
- highlighting the sources of underdevelopment that exacerbated the disaster
- focussing international attention and aid on the disaster area.

**Recovery programs should be designed to reduce vulnerability** by:

- targeting areas of high risk
- supporting the private and nonformal sectors
- enhancing management training programs.

PART 1.1

# EARTHQUAKES

This chapter of the module will enhance your understanding of:

- *the geological phenomena causing earthquakes*
- *the characteristics of earthquakes and the possibilities for prediction*
- *the effects of earthquakes on human settlements*
- *the factors which contribute to vulnerability of human settlements*
- *preparedness measures to reduce the impact of earthquakes on individuals, societies and economies*

## Introduction

Earthquakes are one of the most destructive of natural hazards. they may occur at any time of year, day or night, with sudden impact and little warning. They can destroy buildings in seconds, killing or injuring the inhabitants. Earthquakes not only destroy entire cities but may destabilize the government, economy and social structure of a country.

**Earthquake Hazard Data Sheet**

**Estimates of death and damage due to recent major earthquakes**

Deaths due to earthquakes from 1900-1990 total approximately 1.5 million. Almost half this total occurred in China.[3]

| Year | Location | Deaths[1] | Losses[2] (in $ US billions) | % of GNP that year[2] |
|---|---|---|---|---|
| 1972 | Managua, Nicaragua | 10,000 | 2.0 | 40.0 |
| 1976 | Guatemala City | 23,000 | 1.1 | 18.0 |
| 1976 | Tangshan, China | 242,000 | 6.0 | 1.5 |
| 1977 | Bucharest, Romania | 1,570 | 0.8 | 3.0 |
| 1979 | Montenegro, Yugoslavia | 121 | 2.2 | 10.0 |
| 1980 | Campania, Italy | 4,689 | 45.0 | 6.8 |
| 1985 | Mexico City | 8,776 | 5.0 | 3.0 |
| 1986 | Kalamata, Greece | 20 | 0.8 | 2.0 |
| 1986 | San Salvador, El Salvador | 1,100 | 1.5 | 31.0 |
| 1988 | Spitak, Armenia | 25,000 | 17.0 | (USSR – 3.0) |
| 1990 | Loma Prieta, California, USA | 62 | 8.0 | 0.2 |
| 1990 | Manjil, Iran | 40,000 | 7.2 | 7.2 |
| 1990 | Luzon, Philippines | 1,660 | 1.5 | 2.7 |
| 1993 | Maharashatra, India | 10,000 | — | — |
| 1995 | Kobe, Japan | 5,502 | 100.0 | — |

[1] **OFDA Disaster History**, 1996
[2] Martin Centre Earthquake Database
[3] Cambridge University database of damaging earthquakes, 1900-1990.

## Causes

The earth's crust is a rock layer of varying thickness ranging from a depth of about 10 kilometers under the oceans to 65 kilometers under the continents. The crust is not one piece but consists of portions called **plates** which vary in size from a few hundred to many thousands of kilometers. The theory of **plate tectonics** holds that the plates ride upon the more mobile **mantle,** and are driven by some yet unconfirmed mechanism, perhaps thermal convection currents. When the plates contact each other, stresses arise in the crust.

These stresses may be classified according to the type of movement along the plates; boundaries: a) pulling away from one another, b) sliding sideways relative to each other, and, c) pushing against one another. All of these movements are associated with earthquakes.

The areas of stress at plate boundaries which release accumulated energy by slipping or rupturing are known as **faults.** The theory of **elastic rebound** says that as the crust is continuously stressed by the movement of the tectonic plates, it eventually reaches a point of maximum supportable strain. A rupture then occurs along the fault and the rock rebounds under its own elastic stresses until the strain s relieved. Usually the rock rebounds on both sides of the fault in opposite directions.

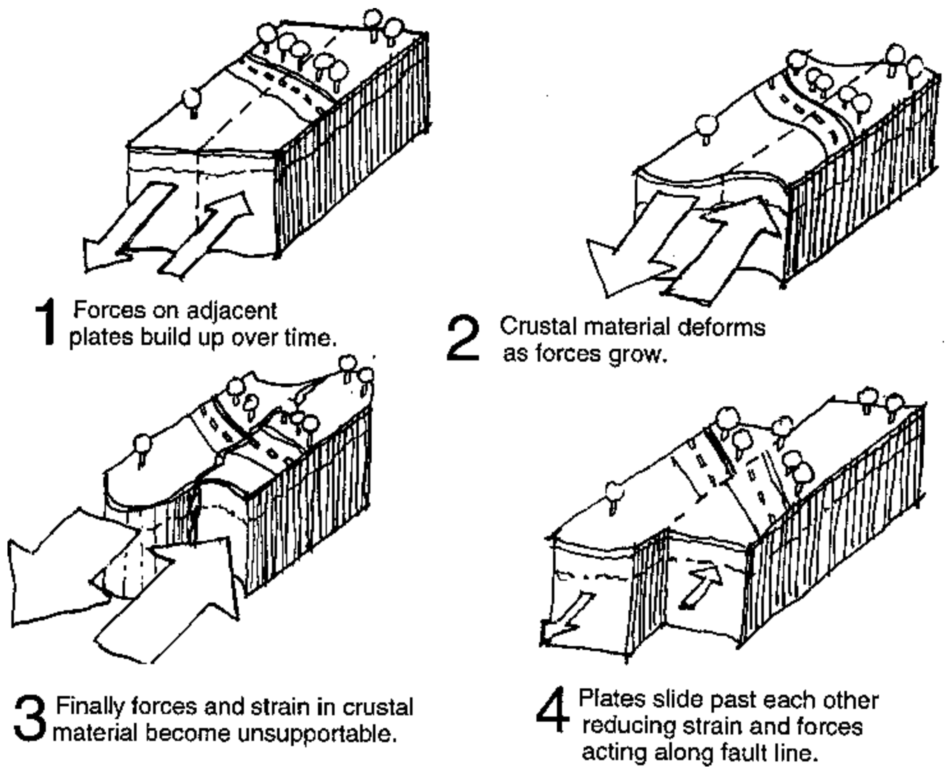



**Figure 1.1.1**
*Elastic rebound process*

The point of rupture is called the **focus** (hypocenter) and may be located near the surface or deep below it. The point on the surface directly above the focus is termed the **epicenter** of the earthquake. The fault rupture generates vibrations called **seismic** (from the Greek seismos meaning shock or earthquake) **waves,** which radiate from the focus in all directions.

The energy generated by an earthquake is not always released violently but in some cases is quite small and gradual. Minor earth tremors are recorded daily in earthquake prone countries but it is not known if they are caused by the same processes as relatively infrequent great earthquakes that may flatten a city. Although some earthquakes are associated with volcanic activity, the most damaging earthquakes appear to be linked with sudden rupturing of the earth's crust. Variations in intensity of earthquakes are related to the amount of energy released at the focus, the distance from and depth of focus and the structural properties of the rock or soil on the surface.

## General characteristics

Earthquake vibrations occur in a variety of frequencies and velocities. The actual rupture process may last from a few seconds to as long as one minute for a major earthquake. Seismic waves generated by the rupture can last from several seconds to a few minutes. An earthquake observer describes the sensation:

> *"First there was a sudden jolt that made me lose my balance for a second. Then I could feel the ground moving, and a second, stronger jolt came. After a few seconds of shaking, a rolling and swaying motion started, like being on a boat. The swaying lasted until the earthquake ended. There was noise all the time."*

Ground shaking is caused by *body* waves and *surface* waves. Body waves (P and S waves) penetrate the body of the earth, vibrating fast. P waves traveling at about 6 km per hour, provide the initial jolt and cause buildings to vibrate in an up and down motion. S waves, traveling about 4 km per second in a movement similar to a rope snapped like a whip, cause a typically sharper jolt that vibrates structures from side to side and typically causes even greater damage. S waves are usually the most destructive.

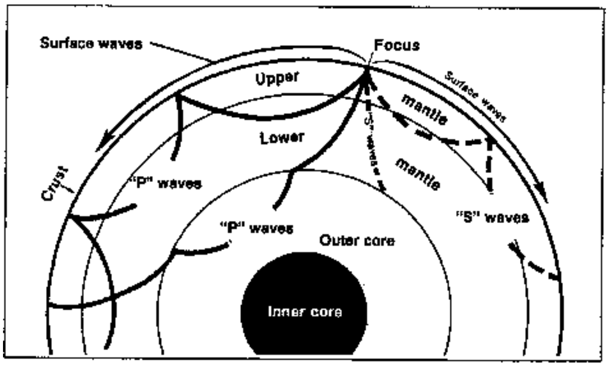



**Figure 1.1.2**
*Propagation of P and S waves*
USGS, *Earthquakes and Volcanoes,* 1989

Surface waves vibrate the ground horizontally and vertically. These long-period waves cause swaying of tall buildings and slight wave motion in bodies of water even at great distances from the epicenter.

Earthquake focus depth is an important factor in shaping the characteristics of the waves and the damage they inflict. The focal depth can be deep (from 300 to 700 km), intermediate (60 to 300 km) or shallow (less than 60 km). **Deep focus earthquakes** are rarely destructive because the wave amplitude is greatly attenuated by the time it reaches the surface. **Shallow focus earthquakes** are more common and are extremely damaging because of their close proximity to the surface.

**Earthquake location** – Certain areas of the world are very susceptible to earthquakes (see map). Most earthquakes occur in areas bordering the Pacific Ocean, called the circum-Pacfic belt and also in the Alpide belt which traverses the East Indies, the Himalayas, Iran, Turkey, and the Balkans. Earthquakes occur along the ocean trenches such as the Aleutians, Tonga, Japan, Chile and the eastern Caribbean. Approximately 95% of earthquake activity occurs at the plate boundaries. Some do occur, however, in the middle of the plates, possibly indicating where earlier plate boundaries might have been.

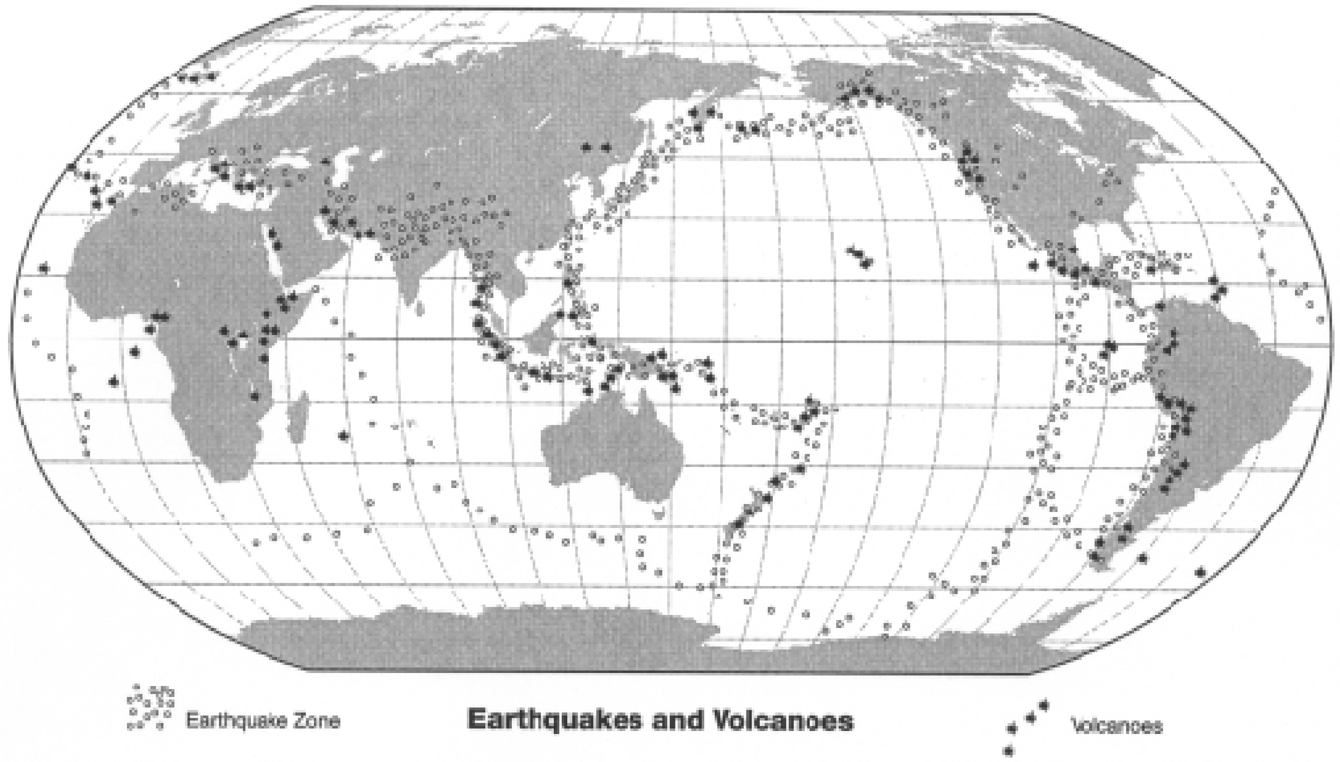



**Figure 1.1.3**
*World map showing distribution of volcanoes and earthquakes. These correlate with the boundaries of the major tectonic plates. The pattern of distribution of these events encircling the Pacific ocean is commonly called "The Ring of Fire".*

## *Earthquake scales*

Earthquakes can be described by use of two distinctly different scales of measurement demonstrating magnitude and intensity.

Earthquake **magnitude** or amount of energy released is determined by use of a seismograph, and instrument that continuously records ground vibrations. A scale developed by a seismologist named Charles Richter mathematically adjusts the readings for the distance of the instrument from the epicenter. The **Richter scale** is logarithmic. An increase of one magnitude signifies a 10-fold increase in ground motion or roughly an increase of 30 times the energy. Thus, an earthquake with a magnitude of 7.5 releases 30 times more energy than one with a 6.5 magnitude, and approximately 900 times that of a 5.5 magnitude earthquake. A quake of magnitude 3 is the smallest normally felt by humans. The largest earthquakes that have been recorded under this system are 9.25 (Alaska, 1969) and 9.5 (Chile, 1960).

**RICHTER SCALE**

A second type of scale, the earthquake **intensity** scale, measures the effects of an earthquake where it occurs. The most widely used scale of this type was developed in 1902 by Mercalli, an Italian seismologist. The scale was extended and modified to suit modern times. Called the **Modified Mercalli Scale,** it expresses the intensity of earthquake effects on people, structures and the earth's surface in values from I to XII. A second even more explicit scale, the **Medvedev-Sponheuer-Karnik (MSK) Scale** is more commonly used in Europe.

**MODIFIED MERCALLI SCALE**

***Q.** What type of earthquake measurement scales for magnitude and intensity are in use in your country? Are you familiar with the various levels of the scale and their meaning?*

***A.*** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

### *Earthquake hazards*

The primary hazards associated with earthquakes are fault displacement and ground shaking. Secondary hazards include ground failure, liquefaction, landslides and avalanches, and tsunamis and seiches.

**Fault displacement and ground shaking** – Fault displacement, either rapid or gradual, may damage foundations of buildings on or near the fault area, or may displace the land, creating troughs and ridges.

Ground shaking causes more widespread damage, particularly to the built environment. The extent of the damage is related to the size of the earthquake, the closeness of the focus to the surface, the buffering power of the location's rocks and soils, and the type of buildings being shaken. Secondary tremors that follow the main shock of an earthquake, called **aftershocks,** may cause further damage. Such tremors may recur for weeks or even years after the initial event.

**Ground failure** – Seismic vibrations may cause settlement beneath buildings when soils consolidate or compact. Certain types of soils, such as alluvial or sandy silts are more likely to fail during an earthquake.

*Liquefaction* is a type of ground failure which occurs when saturated soil loses its strength and collapses or becomes liquefied. During the 1964 earthquake in Niigata, Japan, ground beneath buildings that were earthquake resistant became liquefied, causing the buildings to lean or topple down sideways.

Another type of ground failure that may result from earthquakes is *subsidence* or vertically downward earth movement caused by reduction in soil water pressure.

**Landslides and avalanches** – Slope instability may cause landslides and snow avalanches during an earthquake. Steepness, weak soils and presence of water may contribute to vulnerability from landslides. Liquefaction of soils on slopes may lead to disastrous slides. The most abundant types of earthquake-induced landslides are rock falls and rock slides usually originating on steep slopes.

**Tsunamis and seiches** – These may be generated by undersea or nearshore earthquakes, and may break over the coastline with great destructive force. Other flooding may be caused by seiches (wave action in bays), failures in dams and levees, or changes in ground and water levels.

***Q.*** *What are the primary and secondary hazards associated with earthquakes?*

***A.***

## Predictability

### *Traditional prediction*

There have been several signs noted by earthquake observers throughout history. First, there was a gentle trembling of buildings. Second, the animals and birds became excited. The third omen was a change in the well water. It became cloudy and smelled bad. These warnings have been variously described by survivors of earthquakes all over the world.

### *Scientific methods and instrumentation*

Although some scientists claim ability to predict earthquakes, the methods are controversial. For example, the 1995 earthquake in Kobe, Japan was not predicted. Accurate and exact predictions of sudden fault displacements and the resultant earthquakes are still not possible, however mechanical observation systems make it possible to issue warnings to nearby populations immediately after detection of an earthquake. Reasonable risk assessments of potential earthquake activity can be made with confidence based upon:

1. knowledge of seismic zones or areas most at risk, gained through study of historical incidence and plate tectonics.
2. monitoring of seismic activity by use of seismographs and other instruments.
3. use of community-based scientifically sound observations such as elevation and turbidity of water in wells and recording radon gas escape into well water. (Use of animal behavior as an indicator is subject to controversy as it is often difficult to interpret.)

**Monitoring global seismicity** – Data from seismograph stations in more than 80 countries are routinely to the National Earthquake Information Center of the United States Geological Survey. This information is used to determine the extent of the earthquake hazard problem. The goal is to achieve the capability to detect and characterize all earthquakes greater than 4.0 worldwide.

**Q.** *What are some of the traditional methods used in the prediction of earthquakes? Are these known or used in your country? Are they scientifically valid?*

**A.**

### Factors contributing to vulnerability

Several key factors contribute to vulnerability of human populations:

- Location of settlements in seismic areas, especially on poorly consolidated soils, on ground prone to landslides or along fault lines.
- Building structures, such as homes, bridges, dams, which are not resistant to ground motion. Unreinforced masonry buildings with heavy roofs are more vulnerable than lightweight wood framed structures. Dense groupings of buildings with high occupancy.
- Lack of access to information about earthquake risks.

### Typical adverse effects

#### *Physical damage*

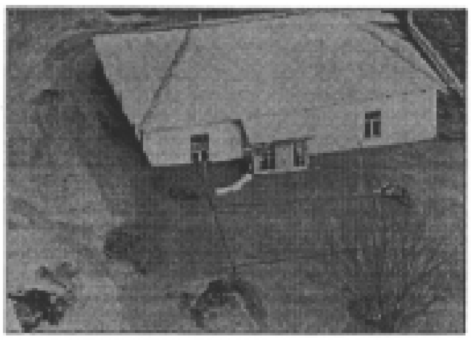
Damage occurs to human settlements, buildings, structures and infrastructure, especially bridges, elevated roads, railways, water towers, water treatment facilities, utility lines, pipelines, electrical generating facilities and transformer stations. Aftershocks can do much damage to already weakened structures.

Significant secondary effects include fires, dam failures, and landslides which may block waterways and also cause flooding. Damage may occur to facilities using or manufacturing dangerous materials resulting in possible chemical spills. There may be a breakdown of communications facilities.

Destruction of property may have a serious impact on shelter needs, economic production and living standards of local populations. Depending on the vulnerability of the affected community, large numbers of people may be homeless in the aftermath of an earthquake.

*Mudflow in Tadjikistan U.S.S.R. January 1989 triggered by earthquake.*

*UNDRO NEWS*, Nov/Dec, 1989.



### *Casualties*

The casualty rate is often high, especially when earthquakes occur in areas:

a) of high population density, particularly when streets between buildings are narrow and buildings themselves are not earthquake resistant, and/or the ground is sloping and unstable; or

b) where adobe or dry-stone construction is common with heavy upper floors and roofs.

Casualty rates may be high when quakes occur at night because the preliminary tremors are not felt in sleep and people are not tuned in to media to receive warnings. In daytime, people are particularly vulnerable if in large, unsafe structures such as schools and offices and casualties may be very high. Casualties generally decrease with distance from the epicenter. As a very rough rule of thumb, there are three times as many injured survivors as persons killed. The proportion of dead may, however, be higher if there are major landslides and other hazards, such as tsunamis. In areas where houses are of light-weight construction, especially with wood frames, casualties are generally very much lower although fires may spread rapidly causing injuries and deaths.

### *Public health*

The most widespread medical problems are fracture injuries. Other health threats may occur if:

a) there is secondary flooding (see chapter on floods)

b) water supplies are disrupted and contaminated water is used (although to date no documented significant outbreaks of water-borne diseases have followed an earthquake); or

c) people are concentrated into high density relief camps.

Although an earthquake is unlikely to cause any new outbreaks, endemic diseases may become virulent if control measures break down and unsanitary conditions develop. The psychological consequences of experiencing an earthquake, including trauma and depression, often last for several months.

***As a very rough rule of thumb, there are three times as many injured survivors as persons killed.***

### *Water supply*

Severe problems are likely because:

- piped (municipal) water systems may be seriously damaged or become contaminated, especially if sewage systems have also been damaged.
- reservoir dams may be broken.
- open wells may be blocked by debris.
- earthquakes can change levels in the water table with the possible effect of drying up wells and surface springs.

### *Food supplies*

Food distribution and marketing systems may be disrupted. Irrigation works may be damaged. In areas where earthquakes give rise to flooding or a tsunami strikes, food stocks and standing crops may be lost. Typically, however, earthqufakes do not reduce the local food supply.

*ANSWER* *(from page 22)*

The major direct ad indirect effects of earthquakes are: fault displacement, ground shaking, ground failure (especially liquifaction), landslides and avalanches, tsunamis and seiches.

***Q.*** *What are the factors affecting vulnerability of human settlements to seismic activity?*

***A.***

***Q.*** *Do these factors exist today in your country or community? Which of these factors can most easily be changed?*

***A.***

## Possible risk reduction measures

Several broad strategies may be incorporated into a general seismic safety program such as reducing structural vulnerability, land use regulation and public information programs. Although these programs cannot guarantee that there will be no loss of life from an earthquake, they can reduce casualties and property damage. The plan should:

1. Define vulnerable geographic zones and vulnerable structures through risk assessment and damage information.
2. Establish an extensive public awareness program disseminating information about earthquakes and related hazards and disaster mitigation and preparedness measures.
3. Establish a technical assistance program including architectural and engineering inputs to improve building design, construction and siting, demonstrating the techniques and training local residents.

*ANSWER* *(from page 23)*

Some traditional methods that have been used in the prediction of earthquakes are: changes in water level in wells, cloudiness or turbidity of well water, and animal behavior. All of these signs have some scientific validity, although it must be pointed out that some of these, especially animal behavior, are no reliable due to difficulty in interpreting the cause of the behavior.

Possible actions to reduce earthquake damage include:

- Developing seismic resistant construction techniques
- Conducting a program to introduce improved construction techniques to the building industry and educating the general public
- Analyzing soil types and geological structure to determine relative safety of construction sites
- Instituting incentives to remove unsafe buildings or buildings on unsafe sites or more feasibly, to upgrade their level of safety
- Instituting incentives to encourage future development on safer sites and safer methods of construction through:
  - land use control or zoning
  - building codes and standards and means of enforcing them
  - favorable taxation, loans, or subsidies for qualified building sites and use of building methods
  - land development incentives
- Reducing possible damage from secondary effects by:
  - identifying potential landslide sites and restricting construction in those areas
  - installing devices that will keep breakages in electrical lines and gas mains from producing fires
  - verifying the capability of dams and other engineering works to resist earthquake forces and upgrading as necessary.

### *Insurance*

In earthquake prone areas, insurance should be obtained for buildings under construction and those in use. Insurance policies for natural disasters should not be offered with other coverages. They should be specifically underwritten, be priced specifically, be based on scientific data of rates of occurrence and perhaps even limited by the event. This procedure is in the interests of the insured as it will provide a realistic determination of risk. A rating structure may encourage parties engaging in construction in high risk areas to reassess the building sites or to incorporate loss prevention measures.

## Specific preparedness measures

**Community preparedness** – Community preparedness is vital for mitigating earthquake impact. The most effective programs are formal and initiated at the community level with support by local or national governments.

**Public education** – Preparedness includes educating the public on the causes and characteristics of an earthquake and what they should do if one occurs. Public officials and services must make contingency plans to react to the emergency. Nearly every country has a means of communicating with its most remotely located citizen either through media or informal communication networks. Public awareness programs can be designed to reach every vulnerable person and may significantly reduce the social and material costs of an earthquake. Some examples of information to be provided include:

- causes of earthquakes and warning signs
- awareness of earthquake risks and ways to minimize personal vulnerability

*ANSWER (from page 25)*

Some factors affecting vulnerability to seismic activity are: location in a seismically active area, location in an area of poorly consolidated soils, location in sites prone to landslides, lack of resistance to ground motions (especially unreinforced masonry structures with heavy roof structures, densely grouped buildings, high building occupancies, and a lack of public information regarding earthquakes and appropriate preparedness and response measures.

- practical ways to reinforce vulnerable houses
- what to do in the event of an earthquake (with possible participation in a drill)
- how to form teams to assist in search for injured and post-disaster recovery activities

**Planning** – Public officials and services must make contingency plans to react to the emergency. Activities the public sector may undertake include:

- reviewing the structural soundness of facilities that are essential for disaster response such as hospitals, fire stations, communications installations and upgrading them if needed
- training teams for search and rescue operations or ensuring the rapid availability of detection equipment
- training teams for disaster assessment
- identifying safe sites where vulnerable populations could be relocated.
- training personnel in trauma care
- planning for an alternative water supply
- preparing plans to clear streets for emergency access
- preparing emergency communication systems and messages to the public regarding their security
- training teams to determine if buildings are safe for reoccupancy
- preparing flood plans for susceptible areas
- coordinating preparations with voluntary organizations

***Public awareness programs can be designed to reach every vulnerable person and may significantly reduce the social and material costs of an earthquake.***

## Typical post disaster assistance needs

The immediate impact of an earthquake affects all sectors of the community and local authorities should initially emphasize **search and rescue** of victims. Secondly, **emergency medical assistance** must be provided especially during the first 72 hours.

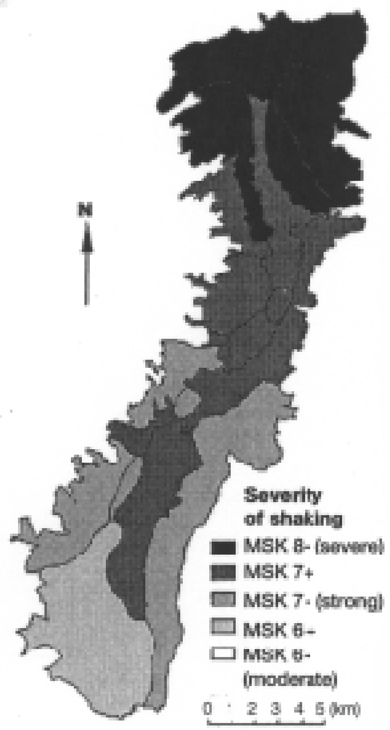
Third, a **damage and needs assessment survey,** should be conducted to inform local and international agencies of needs.

Fourth, the survivors will require **relief assistance** such as food, water and emergency shelter. Attention should be given to reopening roads, re-establishing communications, contacting remote areas and conducting disaster assessments.

At the end of the emergency period, long-term recovery needs to take priority. The post earthquake period presents an opportunity to minimize future risks through enactment or strengthening of land use and building codes as rebuilding takes place. The focus should be on:

- repair and reconstruction of water, sewer, electrical services and roads
- technical, material and financial assistance for repair and reconstruction of houses and public buildings
- programs to rejuvenate the economy
- financial assistance for loans to individuals and businesses for economic recovery.

# ■ CASE STUDY




*Ground shaking intensities in Quito resulting from the local earthquake.*

## Quito, Ecuador Earthquake Risk Management Project

Ecuador's capital, Quito, is becoming increasingly vulnerable to earthquake disasters. Quito has experienced many strong earthquakes in its history. One of these occurred in 1868, when Quito had only 45,000 inhabitants living in about 4 square kilometers. Quito's population has grown to 1.2 million and covers 70 times the area today.

Quito's growth has resulted in a proliferation of poorly constructed buildings and development in hazardous areas. Earthquake-resistant design has not been widely used and many structures are built on unstable sites and steep hillsides. A recent damaging earthquake which affected Quito occurred in 1987 with 1,000 deaths and $700 million damage, most occurring outside the city. If a destructive earthquake directly affects the city, the impact will be dramatic on lives and property.

The Quito Earthquake Risk Management project was created in 1992 to assist government officials, business leaders and the general public to reduce damage and injury in the next earthquake. The project had three objectives: to improve the understanding of Quito's earthquake hazard, to raise the awareness both in Ecuador and internationally about the earthquake risk, and to design sustainable programs for managing earthquake risk. The three phases of the project are:

1. ***First phase – Analysis of future earthquakes and their effects on Quito.*** A team of experts estimated the magnitudes and locations of future earthquakes, the level of ground shaking and the damage to Quito's buildings and infrastructure. Three different earthquake scenarios, coastal, inland and local, were examined for their potential. Buildings were classified into 5 categories according to the materials and design, and potential damage was estimated. Computer imaging was used to map the intensity of effects in Quito based on Geographic Information Systems (GIS).
2. ***Second phase – Description of the impact on life in Quito following a damaging earthquake.*** A story-like narrative of the aftermath of an earthquake was created to help the people of Quito to visualize the possible consequences. The description covers the immediate response up to a month later and was based on a vulnerability study performed by officials of 17 city organizations. The locations of critical facilities were mapped.
3. ***Third phase – Recommendations for managing Quito's earthquake risk are formulated.*** The following recommendations were developed by a panel of experts based on the first and second phase analysis.
   a) Create a Quito Earthquake Safety Advisory Board.
   b) Adopt and enforce a building code.
   c) Support scientific research to further evaluate the earthquake risk.
   d) Develop a workplace earthquake preparedness program.
   e) Improve emergency response equipment and facilities.
   f) Establish a proper insurance tariff with underwriting guidelines.

**Quito School Earthquake Safety Project** – The earthquake risk management project's assessment concluded that many of the 700 public schools in Quito were vulnerable to collapse in an earthquake. In response, a project was initiated to strengthen the design of a sample of the schools. Fifteen high risk schools were selected to be "retrofit", or improved for earthquake resistance. The retrofit designs chosen were affordable and utilized local materials and construction techniques.

The next step s to involve Quito's teachers, parents and community leaders in raising awareness of the earthquake hazards.

*The Quito, Ecuador Earthquake Risk Management Project*

*Source:* Escuela Politécnica Nacional; GeoHazards International; Ilustre Municipio de Quito; ORSTOM, Quito and OYO Corporation, **The Quito, Ecuador Earthquake Risk Mangement Project: An Overview,** GeoHazards International, 1994

Escuela Politécnica Nacional; GeoHazards International, **Investing in Quito's Future: The Quito, Ecuador School Earthquake Safety Project,** GeoHazards International, 1995

## ■ REFERENCES

Berz, Gerhard, “Natural Disasters and Insurance/Reinsurance”, in *UNDRO NEWS,* Jan/Feb. 1990. p. 18–19.

Coburn, A. and Spence, R. **Earthquake Protection,** John Wiley and Sons, England, 1992

Disaster Management Center, **Natural Hazards: Causes and Effects,** University of Wisconsin, 1986.

Degg, Martin R., “Earthquake Hazard Assessment after Mexico (1985)”, in **Disasters,** Vol. 13, No. 3, 1989, p. 237.

Dudley, Walter C. and Min Lee, **Tsunami!,** University of Hawaii Press, Honolulu, 1988.

Erickson, Jon, **Volcanoes and Earthquakes,** Tab Books Inc., Blue Ridge Summit, PA, 1988.

Gere, James M., and Haresh C. Shah, **Terra Non Firma,** W.H. Freeman and Company, New York, 1984.

Hays, W.W., editor, **Facing Geologic and Hydrologic Hazards,** U.S. Government Printing Office, Washington, D.C. 1981.

Office of Foreing Disaster Assistance, Disaster History: Significant Data on Major Disasters Worldwide, 1900–1995, Washington DC, June 1996

Rosenblueth, Emilio, “Public Policy and Siesmic Risk”, in **Nature and Resources,** Vol. 27, No. 1, 1991, p. 10–17.

UNDRO, **Mitigating Natural Disaster: Phenomena, Effects and Options,** United Nations, New York, 1991.

United States Geological Survey, **Earthquakes and Volcanoes,** Volume 21, Number 1, 1989.

## ■ RESOURCES

Seismic Alert Bulletins available from:

National Earthquake Information Center
Box 25046
Denver Federal Center, MS 967
Denver, Co 80225-0046 USA
Phone: 303-273-8501
24 Hour Earthquake Information Line: 303-273-8516
E-mail: quake@gldfs.cr.usgs.gov
sedas@neis.cr.usgs.gov

# NOTES

PART 1.2

# TSUNAMIS

This chapter of the module is designed to:

- *enhance your knowledge of the causes and characteristics of tsunamis*
- *contribute to your understanding of the threat to human lives and settlements*
- *expand your awareness of the predictability of tsunamis and the importance of warning systems*
- *provide options for reducing the impact of tsunamis on humans, structures and infrastructure.*

## Introduction

Tsunami is a Japanese word meaning “harbor wave”. Tsunamis are popularly called tidal waves but they actually have nothing to do with the tides. These waves, which often affect distant shores, originate from undersea or coastal seismic activity, landslides, and volcanic eruptions. Whatever the cause, sea water is displaced with a violent motion and swells up, ultimately surging over land with great destructive power.

TSUNAMI

### Tsunami Hazard Data Sheet

**Casualties and damage for selected tsunamis**

In 1992 and 1993 alone, tsunamis caused nearly US $1 billion in property damage.

| Year | Location | Number of deaths | Damage |
|---|---|---|---|
| 1945 | Pakistan[1] | 4,100 | |
| 1960 | Hawaii[2] | 61 | 537 buildings destroyed |
| 1960 | Chile[2] | 2,000 | |
| 1976 | Celebes Sea | 7,000 | |
| 1987 | Papua New Guinea | many | 3,000 people homeless |
| 1992 | Nicaragua | 170 | 1,500 houses destroyed |
| 1992 | Flores Island, Indonesia | 2,080 | many villages destroyed |
| 1993 | Okushiri Island, Japan | 185 | 700 houses destroyed |
| 1994 | Java, Indonesia | 222 | 1,226 houses destroyed |

[1] A non-Pacific tsunami

[2] This tsunami originated in Chile

## Causes

The geological movements that cause tsunamis are produced in three major ways. The most common of these is fault movement on the sea floor, accompanied by an earthquake. A fault is defined as a planar zone of weakness passing through the earth's crust. To say that an earthquake causes a tsunami is not completely correct. Rather, both earthquakes and tsunamis result from fault movements.

Probably the second most common cause of tsunamis is a landslide either occurring underwater or originating above the sea and then plunging into the water. The highest tsunamis ever reported were produced by a landslide at Lituya Bay, Alaska in 1958. A massive rock slide produced a wave that reached a high water mark of 535 meters above the shoreline!

The third major cause of tsunamis is volcanic activity. The flank of a volcano, located near the shore or underwater, may be uplifted or depressed similar to the action of a fault. Or, the volcano may actually explode. In 1883, the violent explosion of the famous volcano, Krakatoa in Indonesia, produced tsunamis measuring 40 meters which crashed upon Java and Sumatra. over 36,000 people lost their lives as a result of tsunami waves from Krakatoa.

Although tsunamis caused by landslides and volcanic activity may be very destructive near their sources, most have relatively little energy, decreasing rapidly in size and becoming almost unnoticeable at great distances. The giant tsunamis that are capable of crossing oceans are nearly always created by movement of the sea floor associated with earthquakes which occur beneath the sea floor or near the ocean. The degree of motion depends on how fast the earthquake occurs and how efficiently energy is transferred to the ocean water.

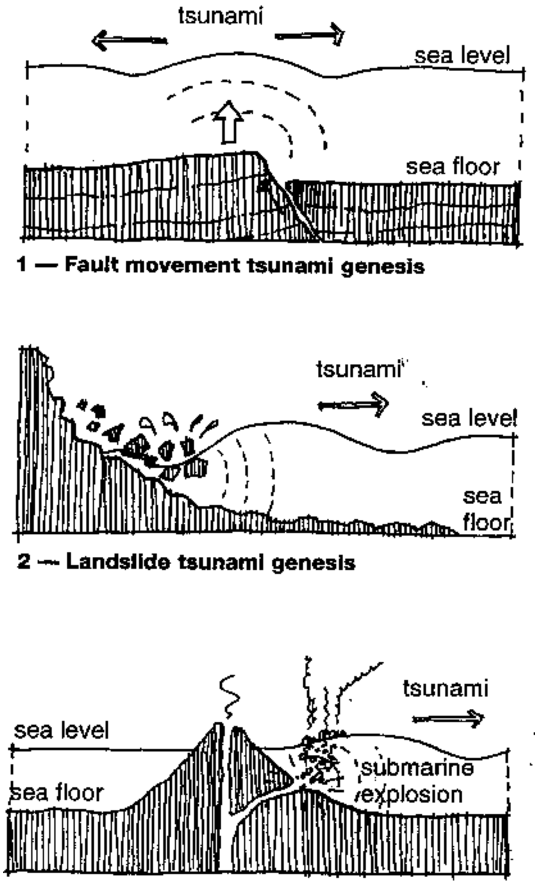



**Figure 1.2.1**
*Genesis of tsunamis*

***Q.*** *What are the three main causes of tsunamis?*

***A.*** ______________________________________________

## General characteristics

Tsunamis differ from ordinary ocean waves, which are produced by wind blowing over water. Normal waves are rarely longer than 300 m from crest to crest. Tsunamis, however, may measure 150 km between successive wave crests. Tsunamis travel much faster than ordinary waves. Compared to normal wave speed of around 100 km per hour, tsunamis in the deep water of the ocean may travel the speed of a jet airplane – 800 km per hour! And yet, in spite of their speed, tsunamis increase the water height only 30–45 cm and often pass unnoticed by ships at sea. In 1946, a ship's captain on a vessel lying offshore near Hilo claimed he could feel no unusual waves beneath him although he saw them crashing on the shore.

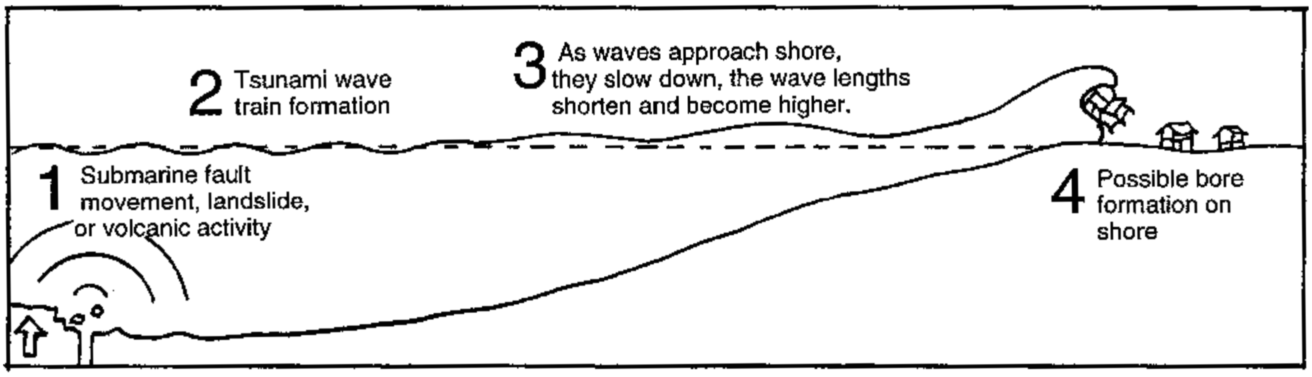



**Figure 1.2.2**
*Tsunami wave train formation*

Contrary for to popular belief, the tsunami is not a single giant wave. It is possible for a tsunami to consist of ten or more waves which is then termed a "tsunami wave train". The waves follow each other between 5 and 90 minutes apart.

As the waves approach the shore, they travel progressively slower. The final wave speed depends on the water depth. Waves in 18 meters of water travel about 50 kph. The shape of the nearshore seafloor influences how tsunamis will behave. Where the shore drops off quickly into deep water, the waves will be smaller. Areas with long shallow shelves, such as the major Hawaiian islands, allow formation of very high waves. In the bays and estuaries, the water may slosh back and forth (these phenomena are called *seiches*) and can amplify waves to some of the greatest heights ever observed.

The initial onshore sign of a tsunami depends on what part of the wave first reaches land: a wave crest causes a rise in the water level and a wave trough will cause a recession. The rise may not be significant enough to be noticed by the general public. Observers are more likely to notice the withdrawal of water which may leave fish floundering on the seafloor. A tsunami does not always appear as a vertical wall of water, known as a *bore,* as typically portrayed in drawings. More often the effect is that of a incoming tide that floods the land. Normal waves and swells may ride on top of the tsunami or the tsunami may roll across relatively calm inland waters.

The flooding produced by a tsunami may vary greatly from place to place over a short distance due to a number of variables. These include submarine topography, shape of the shoreline, reflected waves, and modification of waves by seiches and tides. Flooding may extend inland by over 300 meters and may affect one coastal community while others see no wave activity.

The Hilo tsunami of 1946, originating in the Aleutian trench, produced 18 meter waves in one location and only half that height a few kilometers away.

The sequence of the largest wave in the tsunami wave train also varies and the destructiveness is not always predictable. The first wave may not be the largest in a series of waves. In 1960 in Hilo, many people returned to their homes after two waves had passed only to be swallowed up in a giant bore which, in this case, was the third wave.

***Tsunamis have occurred in all oceans and in the Mediterranean Sea, but the great majority of them occur in the Pacific Ocean simply because the rim of the Pacific Ocean Basin is the most geologically active region in the world.***

## Predictability

Tsunamis have occurred in all oceans and in the Mediterranean Sea, but the great majority of them occur in the Pacific Ocean. The zones stretching from New Zealand through East Asia, the Aleutians and the western coasts of the Americas all the way to the South Shetland Islands are characterized by deep ocean trenches, explosive volcanic islands and dynamic mountain ranges. Between 1900 and 1996, tsunamis caused casualties and significant damage on the Pacific coasts of Mexico, Guatemala, El Salvador, Nicaragua, Indonesia, Costa Rica, Panama, Colombia, Ecuador, Peru, Chile, The United States, Japan, Papua New Guinea, Kamchatka, the Philippines and even along the coasts of Pakistan and Puerto Rico.

Since scientists cannot predict when earthquakes will occur, they cannot predict exactly when a tsunami will be generated. However, studies of past historical tsunamis indicate where tsunamis are most likely to be generated, their potential heights, and flooding limits at specific coastal locations. shortly after the 1946 Hilo Tsunami, the Pacific Tsunami Warning System (PTWS) was developed with its operational center at the Pacific Tsunami

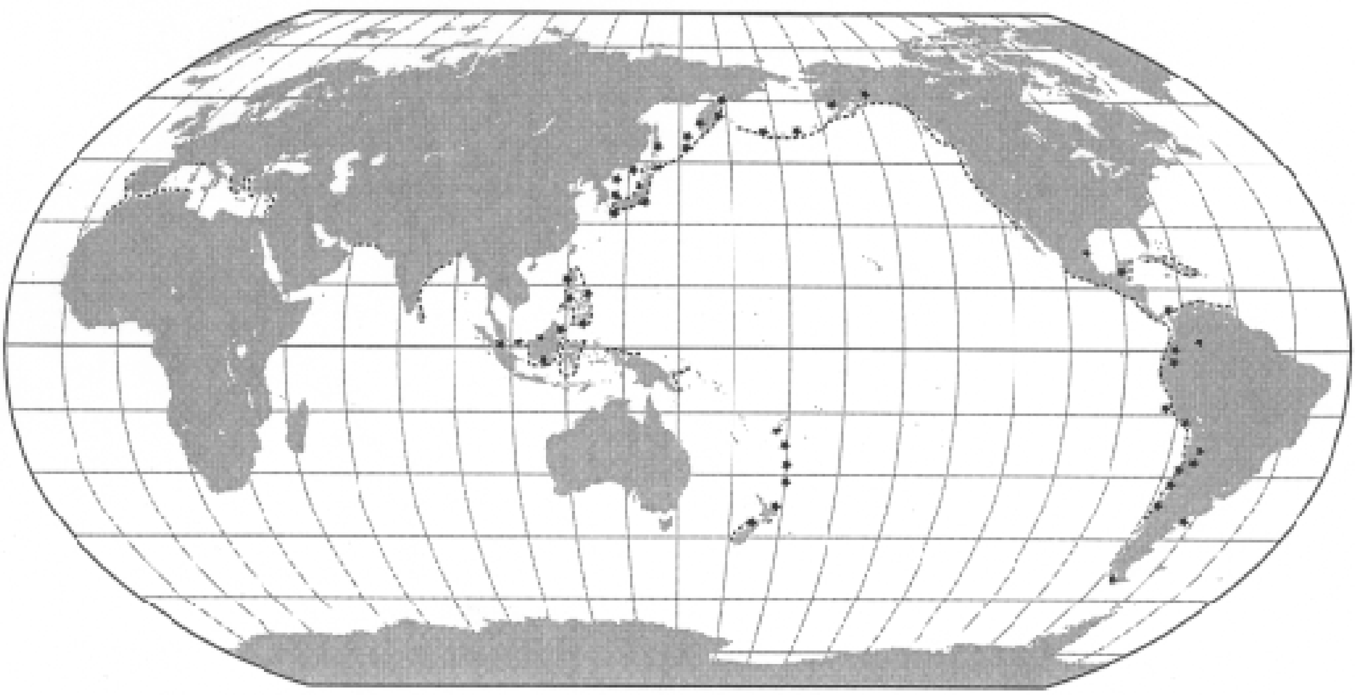



**Figure 1.2.3**
*Tsunami origins and vulnerable shorelines.*

Warning Center (PTWC) near Honolulu, Hawaii. There are 26 member countries in the Pacific Basin. The objective of the PTWS is to detect, locate and determine the magnitude of potentially tsunami-producing earthquakes in the Pacific basin or its margins. Earthquake information is provided by internationally cooperating seismic observatories.

The PTWC is able to alert countries several hours before the tsunami strikes. A tsunami warning is issued when the location and magnitude of an earthquake meet the criteria for tsunami generation. The warning includes predicted arrival times at selected coastal communities where the tsunami could travel in a few hours. A tsunami watch is issued with subsequent arrival times to other geographic areas.

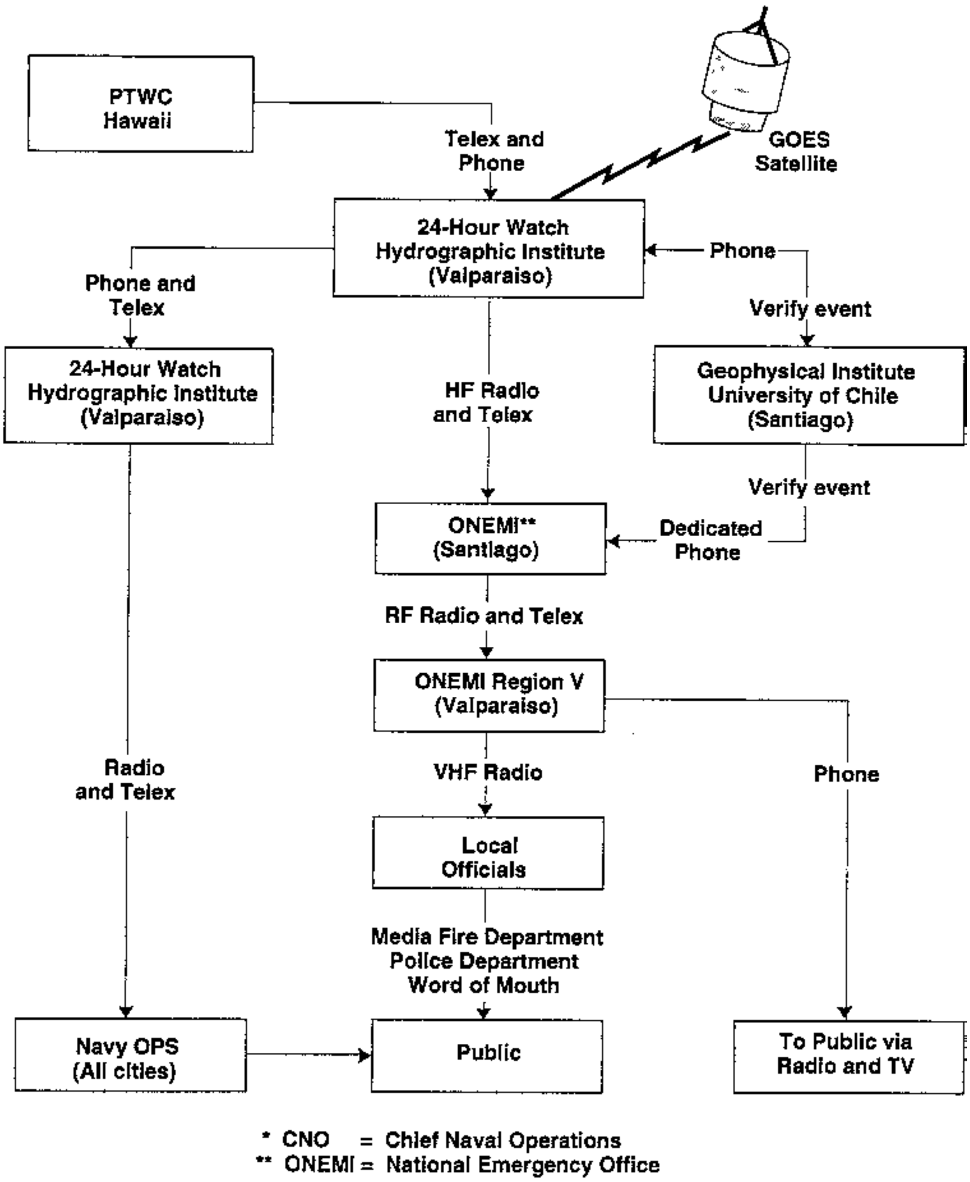



**Figure 1.2.4**

*National Tsunami Warning System Communications of Chile*

*ANSWER (from page 32)*

The three main causes of tsunamis are:

1. Fault movement on the sea floor
2. Landslides, either above or below water
3. Volcanic activity

The Chilean Government in recent years has experimented with use of satellite technology to provide nearly immediate warnings of potentially tsunamigenic earthquakes. Project THRUST (Tsunami Hazards Reduction Utilizing Systems Technology) can provide lifesaving tsunami hazard information in an average elapsed time of two minutes within its communication radius. In conjunction with this satellite communications network, historical data, model simulations and emergency operations plans are used (more details are provided in the preparedness section of this chapter).

*These broken utility pole and bent parking meters were the result of tsunami waves which occurred May 22, 1960 at Hilo, Hawaii.*

U.S. Navy photo.

### Factors contributing to vulnerability

The major factors contributing to vulnerability to tsunamis are:

- Growing world population, increasing urban concentration, and larger investments in infrastructure, particularly on the coastal regions. Some of these settlements and economic assets sit on low-lying coastal areas likely to be affected by tsunamis.
- Lack of tsunami-resistant buildings and site planning.
- Lack of a warning system or lack of sufficient education for the public to create awareness of the effects of a tsunami and unpredictable intensity. For example, having observed relatively moderate tsunamis in 1952 and 1957, citizens at Hilo in 1960 actually converged on the coast to watch the waves come in with catastrophic results.

### Typical adverse effects

#### *Physical damage*

Local tsunami events or those less than 30 minutes from the source cause the majority of damage. The force of water in a bore (a steep fronted wave which moves inland at high speed) can raze everything in its path with pressures of up to 10,000 kg per square meter. It is the flooding effect of a tsunami, however, that most greatly effects human settlements by water damage to homes and businesses, roads and infrastructure.

Withdrawal of tsunamis also causes significant damage. As the waves withdraw towards the ocean, bottom sediments are scoured out collapsing piers and port facilities and sweeping out foundations of buildings. Entire beaches have disappeared and houses carried out to sea. Water levels and currents may change unpredictably and boats of all sizes may be swamped, sunk or battered. Damage to ports and airports may prevent importation of needed food and medical supplies.

#### *Casualties and public health*

Deaths occur principally from drowning as water inundates homes or neighborhoods. Many people may be washed out to sea or crushed by the giant waves. There may be some injuries from battering by debris and wounds may become contaminated. Some people may develop pneumonia from aspirating polluted water. There is little evidence of tsunami flooding directly causing large scale health problems.

### *Water supply*

Sewage pipes may be damaged causing major sewage disposal problems. Open wells and other groundwater may be contaminated by salt water and debris or sewage. Normal water supplies may be inaccessible for days due to broken water mains.

### *Crops and food supplies*

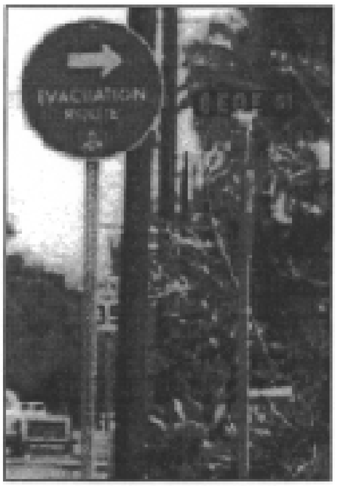
Flooding and damage by tsunamis may result in the following:

- an entire harvest may be lost, depending on time of year
- land may be rendered infertile due to salt water incursion from the sea
- food stocks not moved to high ground will be damaged
- animals not moved to high ground may perish
- farm implements may be lost hindering tillage
- boats and fishing nets may be lost
- facilities to import food may be destroyed.

## Possible risk reduction measures

Some systematic measures to protect coastlines against tsunamis include:

1) Site planning and land management for development of coastal areas.
2) Establishment of building codes or guidelines such as construction of houses on stilts to survive the waves, or use of reinforced concrete structure. Buildings, such as the hotels in Hilo bay are specially constructed with first floor living area elevated above potential wave height. Ground floor and basement will be inundated. Structural columns resist the impact while other walls are expendable.
3) Building barriers or buffers such as special breakwaters or seawalls. Potential inundation areas may be designated as a park or sports area.



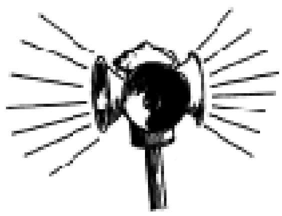

*Tsunami evacuation route sign.*
Dudley and Lee, *Tsunami!*

## Specific preparedness measures

### *Hazard mapping and evacuation routes and procedures*

Historical incidence may be studied to determine the areas most vulnerable to tsunamis. A hazard map should be created designating areas expected to be damaged by flooding or waves. Evacuation routes should constructed if necessary and mapped. Detailed plans should be made for actual evacuation procedures.

### *Early warning systems*



Tsunami watch, warning and information bulletins are issued by PTWC and disseminated to local, state, national and international users as well as the media. These users then disseminate the information to the public generally over the radio and television channels. Local authorities and emergency managers are responsible for formulating and executing evacuation plans for areas under a tsunami warning. The public should stay tuned to the local media for evacuation instructions should a warning be issued. The public should not return to low lying areas until the tsunami threat has passed and the “all clear” is announced by local authorities.

One weakness in the warning system may be at the local level where capacity to disseminate the information may be limited. In addition, sometimes tsunamis follow earthquakes in less than 15 minutes. There exists sufficient knowledge and technical expertise to develop early 'real-time' tsunami warning systems. A real-time seismic network permits accurate and almost instantaneous determination of the source parameters of all damaging earthquakes all over the world. Many difficulties arise, however, in transferring scientific results to operational procedures.

It has been of great concern to experts that tsunamis occurring in areas of the globe other than the Pacific have not been focused on. Some of these tsunamis, such as those striking Greece and surrounding areas, were disastrous and resulted in loss of lives. The PTWC encourages establishment of similar organizations and warning systems in other tsunami prone areas.

### *Community preparedness*

In areas where modern communication networks do not exist, the local population must be educated to recognize the signs of an approaching tsunami and what action to take. However, even in areas where modern networks exist, people may not understand the warnings or choose to ignore them. The following information should be disseminated:

- Ground shaking signals the occurrence of an earthquake. Move away from low lying coastal areas since a tsunami may accompany the earthquake. Do not wait for a tsunami warning to be announced. A local or regional tsunami could strike some areas in a few minutes.
- Stay away from rivers and streams that lead to the ocean.
- Some tsunamis are preceded by a sudden drop in sea level.
- The waves at one beach may be much larger than at adjacent beaches.
- A tsunami may have a dozen or more destructive waves. Stay away from the area for at least two hours. Do not stay to watch the waves, or you may not escape them.
- Advice for mariners: if you are at sea and a tsunami warning is issued for your port, do not return to it. Move your boat to deep water and return to the harbor when safe conditions are verified.
- Have respect for tsunami warnings issued and follow emergency evacuation plans and procedures.

## Typical post disaster needs

The initial response by local authorities includes:

- Implement warning and evacuation procedures
- Perform search and rescue in the disaster area
- Provide medical assistance
- Conduct disaster assessment and epidemiological surveillance
- Provide short term food, water, shelter.

Secondary responses include:

- Repair and reconstruct buildings and harbor and airport facilities.
- Reestablish employment.
- Provide assistance for agricultural areas.

# ■ *CASE STUDY*

## Project THRUST

Earthquakes in Chile result from subduction of the Nazca plate beneath the South American plate. The seismic potential in the Chilean trench is not completely known. In the past, tsunamis generated by local seismic activity, have struck the coast of Chile within 10 minutes. The National Tsunami Warning System in Chile could not be activated in less than 30 minutes. This situation led to an experimental installation of Project THRUST (Tsunami Hazards Reduction Utilizing Systems Technology) to upgrade the warning and response capacity. The benefits resulted from a systems approach to tsunami hazard mitigation and included:

1. **Preparedness measures,** including historical base studies, numerical model simulations and emergency operations plan development.
2. **Instant local hazard assessment** by using seismic triggers which activate a satellite to transmit signals to a ground station processor. (The average cost of hardware for the most basic system configuration consisting of a seismic station and a tsunami warning station was US$ 15,000.)
3. **Rapid dissemination of information** to local officials. The professor alerts the station manager and can also activate lights, alarms, telephone dialers and other emergency responses, thus providing rapid dissemination of information to local officials.

Using tsunami hazard maps of probable inundation areas combined with street maps to identify security areas, hospitals and evacuation routes, a THRUST Project Tsunami Emergency Operations Plan for Chile was devised. The plan listed measures to be taken upon issuance of the tsunami warning and long term relief efforts to be taken after the tsunami had receded, including responsibilities and functions of every disaster agency involved in a tsunami emergency.

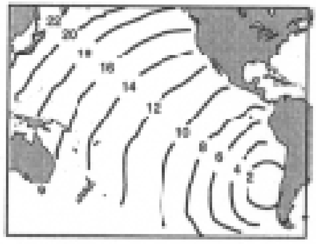
This plan was tested by means of an exercise scenario and a control team which generated news or problems to the participants. A lack of coordination between several agencies was revealed by this exercise and necessitated a detailed revision of the plan which was later adopted. Emergency operations in Chile are organized on a regional, provincial and community basis and each administrative level has an Emergency Operating Center. It was found to be more advantageous to move the coordinating responses from the regional to the community level. Other weaknesses in the plan, such as lack of baseline inundation studies in some communities, were discovered.

What strong points this project, as described, have in preparing for tsunamis?

1. Improved technology was incorporated into an already existing system which might have resulted in lower costs and more local acceptance than a completely new system.
2. The plan touched on the entire emergency system, not just technological areas.
3. Representatives of every concerned government and non-government agency were consulted about the plan and had an opportunity to test it in the simulation.
4. The simulation identified weaknesses in the emergency management system which may eventually save lives.

What are the weak points?

1. The project lacked a research component to work on further defining the seismic zones in Chile and conducting inundation studies on all of the villages.
2. The plan did not address issues of future planning and development in the inundation zones, or methods to lower risks to buildings and infrastructure.
3. No means of educating the general public about the tsunami hazard and emergency plan were mentioned.



*Calculated tsunami travel times for an earthquake occurring off the coast of Chile. Each concentric curve represents two hours of tsunami travel time.*

After an illustration in "Tsunami – The Great Waves", 1995.

*Source:* Bernard, Eddie N., "Assessment of Project THRUST: Past, Present, Future", **Natural Hazards,** 4: 285-292, 1991.

## ■ REFERENCES

Disaster Management Center, **Natural Hazards: Causes and Effects,** University of Wisconsin Board of Regents, 1986.

Dudley, Walter C., and Min Lee, **Tsunami!,** University of Hawaii Press, 1988.

Erickson, Jon, **Volcanoes and Earthquakes,** Tab Books, Blue Ridge Summit, PA, 1988.

Gere, James M., and Haresh C. Shah, **Terra Non Firma,** W.H. Freeman and Company, New York, 1984.

**Land Management Guidelines in Tsunami Hazard Zones,** Urban Regional Research for the National Science Foundation, 1982.

Lockridge, Patricia, "Tsunamis: The Scourge of the Pacific", in **UNDRO NEWS,** Jan/Feb. 1985, p. 15–16.

Lorca, E., "Integration of the THRUST Project into the Chile Tsunami Warning System", **Natural Hazards,** 4: 293–300, 1991.

**Tsunami Hazard: A practical guide for tsunami hazard reduction,** edited by E.N. Bernard, Kluwer Academic Publishers, The Netherlands, 1991.

**Tsunami–The Great Waves,** International Tsunami Information Center, 1995.

Verney, Peter, **The Earthquake Handbook,** Paddington Press, New York and London, 1979.

## ■ RESOURCES

The International Tsunami Information Center sends materials around the world to assist in tsunami preparedness education programs. Materials may be obtained by writing to:

International Tsunami Information Center
737 Bishop Street, Suite 2200
Honolulu, Hawaii 96813-3213 USA
Phone: 808-532-6422 Fax: 808-532-5576
E-mail: itic@itic.noaa.gov

or

Intergovernmental Oceanographic Commission
UNESCO
1, rue Miollis
75015 Paris Cedex 15
France

PART 1.3

# VOLCANIC ERUPTIONS

This chapter of the module aims to increase your understanding of:

- *the geological phenomena that cause volcanic eruptions*
- *the characteristics of volcanic eruptions and their adverse effects*
- *progress and problems in predicting volcanic eruptions*
- *the elements needed for a volcanic emergency plan.*

## Introduction

A volcano is a vent or chimney to the earth's surface from a reservoir of molten rock, called magma, deep in the crust of the earth. Approximately 600 volcanoes are active (have erupted in recorded history) in the world today and many thousands are dormant (could become active again) or are exstinct (not expected to erupt again). On average, about 50 volcanoes erupt every year. Since the year 1000 A.D., more than 300,000 people have been killed directly or indirectly by volcanic eruptions and at present, about 10% of the world's population live on or near potentially dangerous volcanoes.

VOLCANO

**Volcanic Eruptions Hazard Data Sheet**

| Year | Volcano | VEI[1] | Cause of Casualties | Deaths |
|---|---|---|---|---|
| 79 | Vesuvius, Italy | 5 | pyroclastic flow | 3,360 |
| 1783 | Laki, Iceland | 4 | tephra and starvation | 9,500 |
| 1792 | Unzen, Japan | 2 | avalanche and tsunami | 15,000 |
| 1815 | Tambora, Indonesia | 7 | tephra, tsunami, starvation | 92,000 |
| 1883 | Krakatua, Indonesia | 6 | tsunami | 36,400 |
| 1902 | Pelee, Martinique | 4 | pyroclastic flow | 28,000 |
| 1951 | Lamington, New Guinea | 4 | debris avalanche, pyroclastic flow | 2,942 |
| 1985 | Nevado del Ruiz, Columbia | 3 | mudflows | 22,000 |
| 1986 | Nyos, Cameroon | NA | $C0_2$ gas cloud | 1,746 |
| 1991 | Pinatubo, Philippines | 5 | tephra collapses roofs, disease in evacuation camps | 932 |

[1] Volcanic Explosivity Index

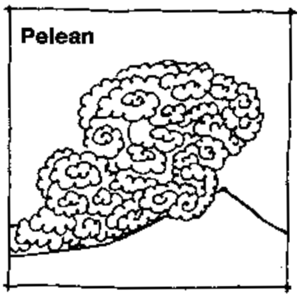
Compiled from: Barberi, et al, 1990; **OFDA Disaster History**, 1996.

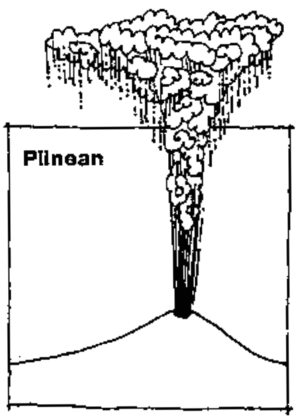
## Causes

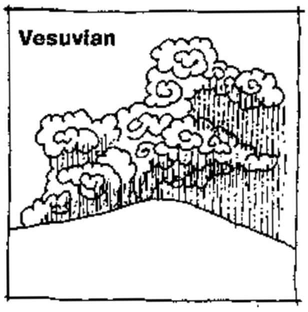
**Magma** – The basic ingredients for a volcanic eruption are molten rock (magma) and an accumulation of gases beneath an active volcanic vent, which may be either on land or below the sea. magma is composed of silicates containing dissolved gases and sometimes crystallized minerals in a liquid-like suspension. Driven by buoyancy and gas pressure, the magma, which is lighter than the surrounding rock, forces its way upward. As it reaches the surface, the pressures decrease enabling the dissolved gases to effervesce, pushing the magma through the volcanic vent as they are released. The volcano releases fluid rock called lava and/or ash and stones called tephra.

Figure 1.3.1

**Eruption types**




The chemical and physical composition of the magma, determines the amount of force with which the volcano erupts. Magmas which are less viscous will allow the gas to be released more easily. More viscous magma, perhaps containing more solid particles, may confine these gases longer allowing greater pressures to build up. This greater pressure may lead to more violent eruptions. Volcanic eruptions may be described as follows in descending order of intensity.

***Pelean type*** – This is the most disastrous type of eruption. The hardened plug at the volcano's throat forces the magma to blast out through a weak spot in the volcanic flank. The great force of the blast devastates most objects in its path as occurred in the Mt. St. Helen's eruption of 1980.

***Plinean type*** – As the pressure on the magma is released, a violent upward expulsion of gas in produced which can extend far into the atmosphere. In 1991, Mt. Pinatubo sent a plume of tephra 30 km above the surface.

***Vesuvian type*** – As in the eruption of Mt. Vesuvius, Italy in 79 AD, this type is very explosive and occurs infrequently. The explosion of built-up magma discharges a cloud of ash over a wide area.

***Vulcanian type*** – Lava forms a crust over the volcanic vents between eruptions, building up the volcano. Subsequent eruptions are more violent and eject dense clouds of material. The Paracutin, Mexico volcano which originated in a corn field in 1943 grew and eventually affected 260 square km and a major eruption occurred in 1947.

***Strombolian type*** – Gases escape through the slow moving lava in moerate explosions which may be continuous. Volcanic "bombs" of clotted lava may be ejected into the sky, as occurred in the 1965 eruption of Irazu in Costa Rica.

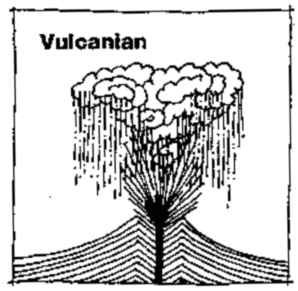
***Hawaiian type*** – The lava is mobile and flows freely and gases are released relatively quietly as in Kilauea, Hawaii volcano which continues to erupt since 1983.

***Icelandic type*** – Similar to the Hawaiian type, the lava flows from deep fissures and forms sheets spreading out in all directions as in the Laki, Iceland eruption of 1783.

## General characteristics of volcanic eruptions

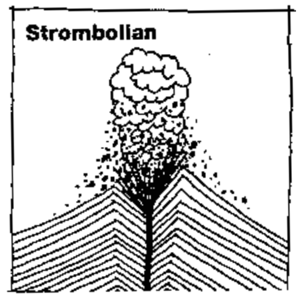
There is no internationally agreed upon scale to measure the size of volcanic eruptions, as for earthquakes. The volcanic explosivity index (VEI) presents an idea of the energy released in a volcanic eruption which is based on measurements of the ejected matter and the height of the eruption cloud, among other observations. The VEI scale ranges from 0 to 8. However, the largest eruption recorded was in Tambora, Indonesia in 1815 which was assigned a VEI of 7.

The primary volcanic hazards are associated with products of the eruption: pyroclastic flows, air-fall tephra, lava flows and volcanic gases. The most destructive secondary hazards include lahars, landslides and tsunamis.

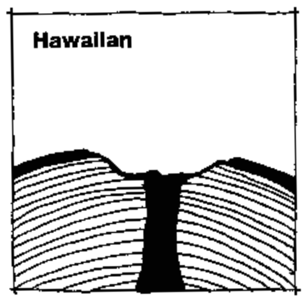



### *Pyroclastic flows*

Pyroclastic (meaning "fire-broken" in Greek) flows are the most dangerous of all volcanic phenomena because there is virtually no defense against them. They are horizontally directed explosions or fast moving blasts of gas containing ash and larger fragments in suspension. They travel at great speed and burn everything in their path. The flows move like a snow or rock avalanche because they contain a heavy load of dust and lava fragments which are denser than the surrounding air. Gas continues to be released as they travel, creating a continuously expanding cloud.




Pyroclastic flows destroy everything in their paths and they are responsible for the majority of deaths associated with volcanic eruptions. In the blast of Mt. Pelee, Martinique in 1902, 30,000 people were killed in the town of St. Pierre, 6 km away. The pyroclastic flows at the Mt. St. Helens eruption in 1980 moved at rates up to 870 km per hour, and pyroclastic deposits found two days after the blast at the foot of the mountain registered temperatures of more than 700 degrees centigrade. The greatest distance recorded by such flows is 35 km.




### *Air-fall tephra*

Tephra smaller than 2 mm is classified as ash. Almost all volcanoes emit ash, but emissions vary widely in volume and intensity. Heavy ash falls can cause complete darkness or drastically reduce visibility. Fine material from great eruptions may travel around the world and even effect world climate. Clouds of dust and ash can remain in the air for days or weeks and spread over large distances, causing difficulty in driving and breathing as well as contributing to building collapse and air traffic disruption. The largest tephra are rocks or blocks, sometimes called bombs, which have been known to travel over 4 km. Tephra may be hot enough to start fires when it lands on structures or vegetation.


### *Lava flows*

Lava flows are formed by hot, molten lava flowing from a volcano and spreading over the surrounding countryside. Depending on the ground slope and viscosity of the lava, a flow may move as fast as 54 kph; however, it is usually slow enough that living creatures can move to safety. Sometimes edges break off, causing small hot avalanches.

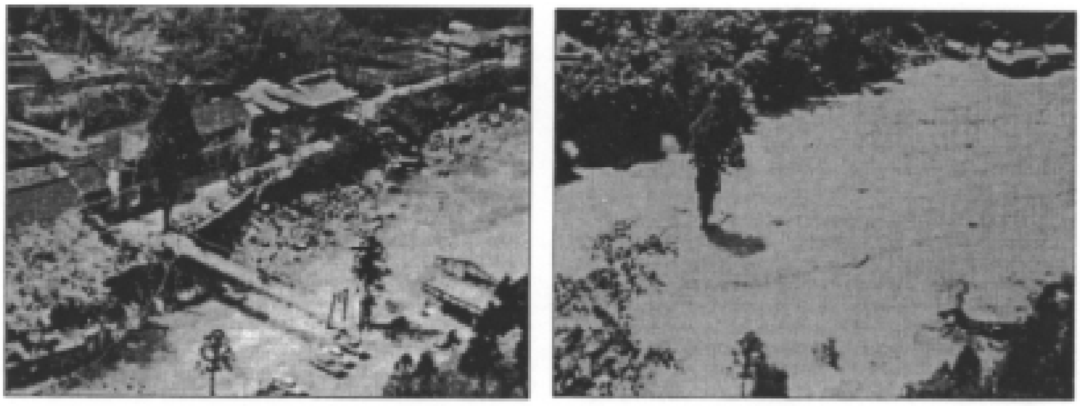
### *Volcanic gases*

Gas is a product of every eruption and may also be emitted by the volcano during periods of inactivity, either intermittently or continually. Volcanic gas is composed mostly of steam, although there are often large amounts of toxic sulfur dioxide, hydrogen sulfide, and smaller but measurable amounts of toxic hydrochloric and hydrofluoric acid gases. Carbon dioxide is often a major component of volcanic gas and is an asphyxiant because it is much denser than air and tends to travel to and through low-lying areas and valleys. Several mountain climbers and skiers in Japan were overcome by volcanic fumes in a valley near the Kusatsushirane volcano, and eventually, an alarm system was installed. In 1986, 1,746 people and 8,300 livestock were asphyxiated by carbon dioxide gas bursts from Lake Nyos crater in Cameroon, which affected a total area of 60 km.

### *Lahars and landslides*

Enormous quantities of ash and larger fragments will accumulate after an eruption on the steep slopes of a volcano, sometimes to a depth of several meters. When mixed with water, the volcanic debris is transformed into a material which flows easily downhill, like wet concrete. "Lahar" is an Indonesian term for debris flows or mudflows. A "primary" debris flow is caused by eruptive activity such as melting of snow and ice by hot volcanic materials, and a "secondary" debris flow results when heavy rainfall saturates the deposits.

**Befor** **After**



*Ohmachi village Japan located in bottom of valley affected by volcanic debris flow.*

*UNDRO NEWS,* March/April, 1986.

The rate of flow is affected by the volume of mud and debris, its viscosity and the slope and character of the terrain. Velocity may reach 100 km per hour and distance travelled may exceed 100 km. Mud and debris flows can be very destructive. They have buried entire towns, such as Armero, Colombia. They can silt up waterways causing floods and changing river courses.

Landslides and debris avalanches are common where stress from intruding magma causes fractures along cracks in the volcano. Ground deformation from swelling and hardening of volcanic material can produce landslides.

### *Tsunamis*

Tsunamis are generated by movement of the ocean floor possibly caused by a volcano. (See chapter on tsunamis.) In a study of volcanic eruptions in the past 1000 years, human fatalities resulting from indirect tsunami hazards are as significant as those from pyroclastic flows and primary mudflows.

***Q.*** *What are the primary and secondary hazards associated with volcanic eruptions?*

***A.*** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

***Q.*** *Which of these if any, could be predicted for your community or country?*

***A.*** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

## Location of Volcanoes

The distribution of volcanoes, like earthquakes, is determined by the location of geological forces involving the tectonic or crustal plates. About 80% of active volcanoes are located near subduction boundaries. **Subduction volcanoes** occur where dense oceanic crustal plates are shoved beneath less dense continental plates, around most of the Pacific Ocean, known as the "Pacific Ring of Fire". Subduction volcanoes are found in the Aleutian islands stretching from Alaska to Asia, Japan, the Philippines, Indonesia, and the Cascade Range in the US. Many volcanoes are located beneath the ocean and submarine eruptions may cause tsunamis and other effects.

**Rift volcanoes** occur at divergent zones where two distinct plates are slowly being separated. Rift volcanoes, such as those in Iceland and East Africa, account for about 15% of active volcanoes. **Hot spot volcanoes** are located where crustal weaknesses allow molten material to penetrate, not necessarily on the plate boundaries. These isolated regions of volcanic activity exist in about 100 places in the world. The Hawaiian Islands, in the middle of the Pacific plate and Yellowstone Park, within the North American plate, are good examples.

***Short term forecasts, within hours or months, may be made through volcano monitoring techniques including seismic monitoring, ground deformation studies and observations and recordings of hydrothermal, geochemical and geoelectrical changes.***

## Predictability

Systematic surveillance of volcanoes, which began early in this century, indicates that most eruptions are preceded by measurable geophysical and geochemical changes. The study of volcanoes has intensified following five recent major eruptions: Mt. St. Helens, USA (1980), El Chichion, Mexico (1982), Galunggung, Indonesia (1982), Nevado del Ruiz, Columbia (1985), and Mt. Pinatubo, Philippines (1991). Short term forecasts within hours or months may be made using information derived from volcano monitoring techniques including seismic monitoring, ground deformation studies and observations and recordings of hydrothermal, geochemical and geoelectrical

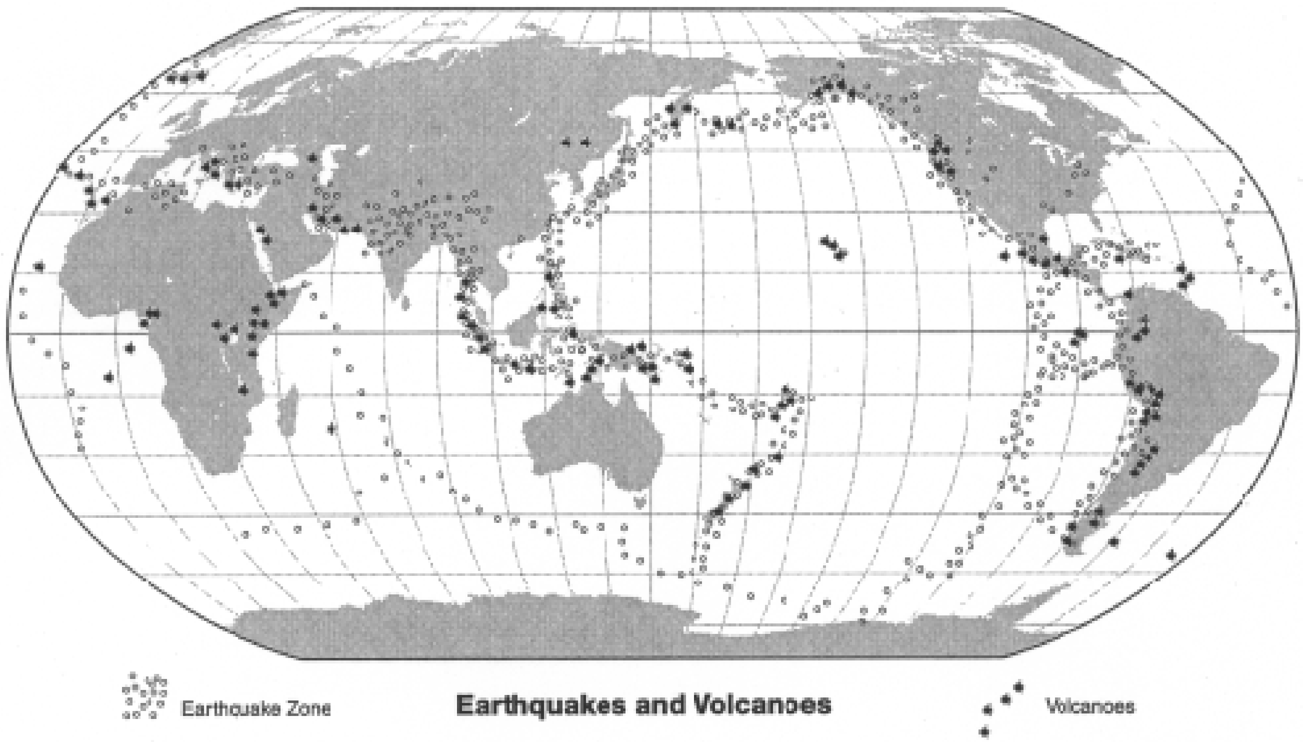



**Figure 1.3.2**

*World Distribution of active and high-risk volcanoes.*

changes. By carefully monitoring these factors, scientists were able to issue a high confidence forecast of the 1991 Mt. Pinatubo eruption allowing a largely successful evacuation.

The best basis for long term forecasting (within a year or longer) of a possible eruption is through geological studies of the history of each volcano. Each eruption leaves records in the form of lava beds and deposits layers of ash and tephra which can be studied to determine the time of eruption, the extent of the flows and length of time between eruptions.

### *Problems in eruption forecasting and prediction*

Although significant progress has been made in long term forecasting of volcanic eruptions, monitoring techniques have not progressed to the point of yielding precise predictions. For the purposes of warning the public, and avoiding false alarms which may create distrust and chaos, ideal predictions should provide precise information concerning the place, time, type and magnitude of the eruption. The importance of enhanced communications between scientists and authorities is also emphasized. In spite of sufficient warning, evacuation orders were not issued by local authorities, which resulted in more than 22,000 deaths from lahars produced by Nevado del Ruiz. The eruption of Mt. St. Helens was adequately monitored and forecasted, yet the main explosion took authorities by surprise as it did not exhibit expected signs prior to eruption and the blast was lateral rather than vertical. Thus, 57 people who had been allowed to enter the danger area were killed.

The greatest constraint to predictability is lack of baseline monitoring studies, which depict the full range of characteristics of the volcano and its history. Especially pressing is the problem that most of the world's most dangerous volcanoes are in densely populated countries where only limited resources to monitor them exist. The vast majority of deaths due to eruptions since 1900 have occurred in developing countries. In 1982, El Chichon erupted, killing 1877 people. El Chichon was assumed to be an extinct volcano, perhaps because it was not studied in detail, although its history included frequent and violent eruptions. No monitoring was conducted before or during the eruption.

## Factors contributing to vulnerability

Rich volcanic soils and scenic terrains attract people to settle on the flanks of volcanoes. These people are more vulnerable if they live "down-wind" or in the path of historically active channels for mud or lava flows or close to waterways likely to flood because of silting. Structures with roof designs which do not resist ash accumulation are vulnerable even many kilometers from a volcano. All combustible materials are at risk.

***For the purposes of warning the public, and avoiding false alarms which create distrust and chaos, ideal predictions should provide precise information concerning the place, time, type and magnitude of the eruption.***

## Typical adverse effects

### *Casualties and health*

Deaths can be expected from pyroclastic and mud flows and to a much lesser extent from lava flows and toxic gases. Injuries may occur from impact of falling rock fragments and from being buried in mud. Skin burns and burns to breathing passages and lungs may result from exposure to steam and hot dust clouds. Ash fall and toxic gases may cause respiratory difficulties for people and animals. Non-toxic gases of densities greater than air, such as carbon dioxide, can be dangerous when they collect in low lying areas. Water supplies contaminated with ash may contain toxic chemicals and cause illness. Deaths have also occurred from eruption-induced starvation and tsunami waves.

### *Settlements and infrastructure*

*Complete destruction of everything in the path of pyroclastic, mud or lava flows should be expected,* including vegetation, agricultural land, human settlements, structures, bridges, roads and other infrastructure. Structures may collapse under the weight of ash particularly if it is wet. Falling ash may be hot enough to cause fires. Flooding may occur due to waterways filling up with volcanic deposits or melting of large amounts of snow or glacial ice. Rivers may change course due to oversilting. Ashfalls can destroy mechanical systems by clogging openings such as those in irrigation systems, airplane engines and other engines. Communication systems could be disrupted due to electrical storms developing in the ash clouds. Transportation by air, land and sea may be affected. Disruption in air traffic from large ash eruptions can have serious effects on emergency response.

### *Crops and food supplies*

Crops in the path of mud, pyroclastic or lava flows will be destroyed and ash falls may render agricultural land temporarily unusable. Heavy ash loads may break the branches of fruit or nut bearing trees. Livestock may suffer from inhaling toxic gases or ash. Ash containing toxic chemicals such as fluorine may contaminate the grazing lands.

*ANSWER* *(from page 45)*

The primary hazards are pyroclastic fows, airfall tephra, lava flows, and volcanic gases. Secondary hazards are lahars and landslides, and tsunamis.

## Possible risk reduction measures

**Long term planning** – For long term planning of human settlements near volcanic areas, knowledge of the volcanic hazard is essential. Through study of the history of the volcano, hazard maps may be prepared illustrating the zones around each volcano where there is a risk to life and property. These maps are of great use as part of the hazard assessment as they portray the pertinent information in a summary fashion understood by planners, decision makers and scientists.

**Protective measures** – The following protective measures may be taken to provide temporary or permanent protection against specific destructive phenomena.

*House on Heimaey buried by ashfall, but roof is still intact due to strong design and steep slope.*

Volcanic Emergency Management; U.N., 1985.

### *Protection against ash falls*

a) Protect buildings by use of roofs that are ash resistant. The roofs should have sufficient strength to hold the weight of the ash. Sloped roofs help to facilitate removal of the ash. Metal sheeting is advised for fire resistance and can be used to cover windows in defense against large particles. It is crucial that ash is periodically removed from rooftops to prevent collapse.

b) Wear filters over the nose and mouth to protect against breathing the dust. Fine mesh might protect engine openings. Fire hydrants and other emergency resources should be protected from being buried by the ash.

### *Protection against pyroclastic flows*

In areas subject to blasts and flows, the destruction will be nearly total and very rapid. The only real protection against these phenomena is advance evacuation from the area.

### *Protection against mudflows*

a) Plan evacuation routes for escape to higher ground.

b) Erect diversion barriers to divert mud flows away from settlements.

c) Lower the water level of reservoirs or lakes in the path of the flows to accommodate the volume of the flows.

d) Build dikes or channelworks along river banks to divert flow.

e) Build check dams to prevent downstream movement of large boulders.

f) Build no permanent settlements in known or predicted mudflow paths.

### *Protection against lava flows*

a) Plan evacuation routes for escape to higher ground.

b) Erect a lava barrier.

c) Bombardment from airplanes has broken up lava flows, but historically has been largely ineffective and risks diversion of the lava in an unintended direction.

d) Cool the lava by spraying with large quantities of water. (This strategy, though costly, was effective in Iceland in saving a harbor town.)

e) Build no permanent settlements in known or predicted paths of lava flows.

*Note:* Many strategies are fraught with danger and costs that may not be practical in most countries. Thus, the only real protection against lava flows is evacuation.

***Q.*** *What specific mitigation measures are appropriate for use against volcanic hazards?*

***A.*** ______________________________________________

## Specific preparedness measures

### *Volcano monitoring*

The past decade has brought improvements in instrumentation, data collection and transmission, and data analysis for volcano monitoring and eruption forecasting. Methods include:

1. Seismic monitoring – to precisely locate earthquakes associated with magma movement.
2. Geodetic studies – using laser-ranging instruments and electronic tiltmeters to measure changes in slope and distances on the volcano that are induced by magma movement.
3. Gas emission studies – to measure type and quantity of gases escaping from the volcano.
4. Geoelectric and geomagnetic studies – to measure electrical and magnetic property-changes associated with magma movement.
5. Space-based techniques – using satellites to measure changes in slope and distance, and gas and ash emissions and trajectories.

Not all monitoring techniques must be expensive or highly sophisticated. For example, manual measurements were made across small thrust faults at Mt. St. Helens which successfully predicted dome-building eruptions.

Careful field observations can be made repeatedly to detect signs of change such as:

- Audible rumblings or ground shaking, indicating an increase in earthquake activity
- Swellings or uplifting of the volcanic edifice, changes in ground slope
- Increased discharge or rise in temperature of hot springs, and steam vents
- Melting of snow or ice on the volcano
- Withering of vegetation on the slopes of the volcano
- Unusual smells, such as odor of sulphur

## The development of volcanic emergency plans

The emergency plan for each volcano usually contains the following elements:

- Identification and mapping of the hazard zones; registration of valuable and movable property (including easily portable personal effects)
- Establishment of an alert sequence which identifies alert levels in order to simplify communications to public officials as a framework within which emergency responses are planned
- Identification of safe refuge zones to which the population will be evacuated in case of a dangerous eruption
- Identification of evacuation routes, and maintenance and clearance of those routes
- Identification of assembly points for persons awaiting transport for evacuation
- Means of transport and traffic control
- Shelter and accommodation in the refuge zone
- Inventory of personnel and equipment for search and rescue
- Hospital and medical services for treatment of injured persons
- Security in evacuated areas
- Emergency alert procedures
- Formulation and communication of public warnings and procedures for communication in emergencies
- Provisions for revising and updating the plan

***Because there is often a long lapse of time between volcanic events, government officials and geoscientists face a particularly difficult but necessary challenge in increasing public awareness of volcanoes and their potential hazards.***

## Community preparedness

Because there is often a long lapse of time between volcanic events, government officials and geoscientists face a particularly difficult but necessary challenge in increasing public awareness of volcanoes and their potential hazards. Their role includes:

- Constant improvement of monitoring techniques and interpretation of data, thereby avoiding false alarms, by investment in equipment and training.
- Preparation of instructive materials for the public, including videotapes, training manuals, and posters.
- Tapping into and promoting national and international programs to promote volcano research and professional training.
- Gaining cooperation of the local communities by promoting participation in mitigation measures to further understanding of the volcanic hazards, difficulties in prediction and trust in the judgment of the authorities.

*ANSWER* *(from page 22)*

Land use planning, and some protective measures can help reduce the damage due to volcanic eruptions. It should be remembered that protective measures are often dangerous, costly, and not consistently proven effective. The best protection for human and other lif is evacuation.

***Q.*** *What are the three basic preparedness measures for volcanic eruptions?*

***A.***

## Typical post-disaster needs

Response to a volcanic eruption must be swift and efficient. Initially, local authorities must ensure that the area is evacuated and care is provided to victims. Feeding and shelter is normally required and may be assisted by donations or personnel from foreign sources.

The secondary response by local authorities involves relocating the victims and providing financial assistance for replacement of housing, agriculture and small businesses. Volcano disasters occasionally require temporary shelters but more often, large volcanoes such as Ruiz, Pinatubo, and Mt. St. Helens, continue to erupt in a manner that threatens large populations for months to years. This may necessitate permanent resettlement of residents or long term emergency settlements. Emphasis should also be placed on reestablishing infrastructure and communications that have been damaged or disrupted.

Cleanup of ash is an important step in the recovery process. Volcanic ash makes excellent foundation material for roads, runways and building sites.

### *Aquino Opens Campaign to Cash In on Ash*

*Reuters*

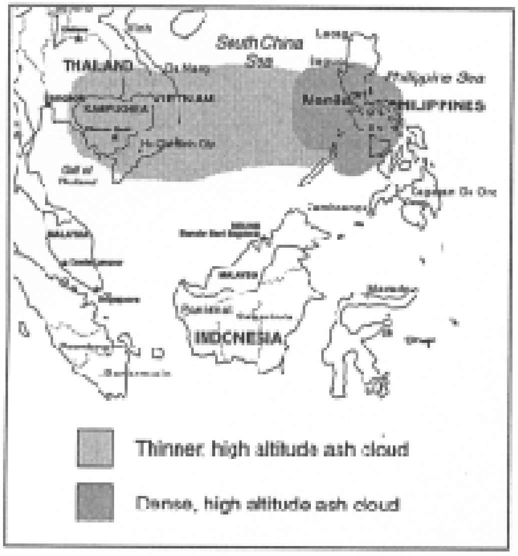
MANILA — Souvenirs made from ash spewed by Mount Pinatubo would make ideal Christmas gifts, President Corazon C. Aquino suggested on Monday.

Launching "Cash from Ash," a program to help victims of the volcano's eruptions, Mrs. Aquino urged companies to buy the souvenirs. "I know many of the corporations are already thinking of their giveaways for Christmas," she said. "I hope they will find some interesting objects here."

A group of Philippine firms has joined the government in producing ceramics and glassware as well as construction materials from ash and rocks ejected by the volcano, which has killed more than 400 people since eruptions began in June.

The volcano has continuously emitted ash since coming to life after 600 years.

## ■ CASE STUDY




*Regional map showing extent and type of ash cloud from the Mt. Pinatubo Volcano. After Punongbayan, 1991, quoted in Tayag and Punongbayan, 1994*

After Punongbayan, 1991, quoted in Tayag and Punongbayan, 1994.

### Volcanic Disaster Mitigation in the Philippines Experience from Mt. Pinatubo

Since the devastating Hibok-Hibok eruption of 1951, considerable progress has been made in volcanic disaster mitigation in the Philippines, beginning with the establishment of the Philippine Institute of Volcanology and Seismology (PHIVOLCS) in 1952. The management of the Mt. Pinatubo eruption emergency in 1991 was a high point in the application of disaster mitigation measures in the country. State of the art volcano monitoring techniques and instruments were employed and the eruption was accurately predicted. A month prior to the eruption, hazard zonation maps were prepared and disseminated. An alert and warning system was designed and implemented and the disaster response was initiated on time. The success of the response can also be attributed to the combined efforts of the scientific community, civilian officials, NGOs and the affected citizens.

While economic and property losses were considerable, loss of human lives was relatively small considering the violence of the explosions. The majority of the deaths were due to exposure to elements or diseases in evacuation centers. Analysis in the aftermath of the eruption, however, underscored the need for clearer understanding of the volcanic hazards and further preparedness measures.

The Pinatubo eruption unleashed three major destructive agents: ashfalls, pyroclastic flows and lahars. The ash not only caused local destruction and death but also affected the global climate, circling the earth in tiny water droplets called aerosols. Most of the local ashfall deposits were washed away by rain and most agricultural lands have since recovered. Pyroclastic flows buried 16,000 ha of land. Some of these flows will remain hot for 5–10 years and have made the affected areas uninhabitable. Further, some of the flow deposits are located on the headwaters of major river systems and could be eventually mobilized into lahars.

Lahars started occurring along with the major eruption on 12 June burying villages and destroying bridges. Additional lahars were triggered by the seasonal typhoons and monsoon rains of June to July. Lahars affected almost 36,000 ha.

Two major post-eruption problems are being addressed. First, the volcano continues to be active and its behavior is uncertain. Post eruption surveys were conducted by PHIVOLCS which indicated that the alert and warning systems did not always function as desired, creating overreaction in some cases and not reaching all the affected population or being delayed in other cases. Due to the possibility of another eruption and weaknesses in the warning system, it was proposed that a permanent 10 km danger zone be declared and human habitation be prohibited within it.

*ANSWER (from page 22)*

The three basic preparedness measures for volcanic eruptions are: volcano monitoring, development of volcanic emergency plans, and training and community participation

Second, the lahar danger may continue up to 20 years. Three major strategies were developed for dealing with the lahar threat and some major constraints still need to be overcome.

1. **Lahar monitoring-warning-evacuation system.** A monitoring network consists of rain gauges and flow sensors located on the upper slope of the volcano and human watchers deployed to look out for lahars and relay warnings. Constraints to the system include limited understanding of the lahar phenomenon on Pinatubo and lack of trained lahar watchers. Due to the flat terrain subject to lahars there are few places of natural refuge for inhabitants and the strategy does not offer protection for infrastructure. The lahar season lasts six months and evacuees may have to be sustained for that period.
2. **Relocation for high risk zones.** Due to the large areas at risk to lahars, the relocation of all settlements would be impractical and costly. Relocation sites are being developed for persons displaced by the eruption and related lahars but for man the solutions are not adequate. Alternative solutions include building more modest sites with community participation to complete the development and integration of evacuees into existing communities.
3. **Engineering countermeasures for moderate and low risk zones.** Check dams were constructed to stop the sediments in the upper parts of the rivers near the pyroclastic deposits. The dams have prevented significant damage and have allowed other mitigation measures to be enacted. These include channel deepening to convey the material to the sea, and strengthening dikes, channels and retention basins to control the sediment as it moves from the mountain to the alluvial plains.

Many of the engineering measures have been subject to great controversy due to their high costs, failures of some measures, and effects of the measures on the environment. For example, channel and dike construction in some areas will adversely affect rice and fish production. Ultimately, the most effective, least costly, and most socially and politically acceptable combination of measures will have to be determined.

*Source:* Tayag, Jean and Ramundo Punongbayan, Volcanic Disaster Mitigation in the Philippines: Experience form Mt. Pinatubo, in **Disasters,** Vol. 18, No. 1, March 1994, pg 1–15.

## ■ REFERENCES


Barberi, F., et al, **Reducing volcanic disaster in the 1990s,** Bulletin of the Volcanological Society of Japan, 1990.

Disaster Management Center, **Natural Hazards: Causes and Effects,** University of Wisconsin, Madison, Wisconsin, 1986.

**Earthquakes and Volcanoes,** U.S. Geological Survey, Vol. 18, No. 1, 1986.

Erikson, Jon, **Volcanoes and Earthquakes,** Tab Books, Blue Ridge Summit, PA, 1988.

Newhall, C.G. and Self, S, The Volcanic Explosivity index (VEI): an estimate of explosive magnitude for historical volcanism, *Journal of Geophysical Research,* 87: 1231–1238, 1982.

Nuhfer, E., Proctor, R. and Moser, P., **The Citizen's Guide to Geologic Hazards,** American Institute of Professional Geologists, 1993.

OAS/DRDE, **Primer on Natural Hazard Management in Integrated Regional Development Planning,** Washington, D.C., 1991.

Smith, Keith, **Environmental Hazards: Assessing Risk and Reducing Disaster,** Routledge, London, 1996.

Tilling, Robert I., "Volcanic Hazards and Their Mitigation: Progress and Problems", **Reviews of Geophysics,** 27, 2, May 1989, pages 237–269.

UNDRO, **Mitigating Natural Disasters, Phenomena, Effects and Options,** United Nations, 1990.

UNDRO, **Volcanic Emergency Management,** United Nations, New York, 1985.

Wood, Robert Muir, **Earthquakes and Volcanoes,** Weidenfeld and Nicolson, New York, 1987.


## ■ RESOURCES

Ad hoc and monthly volcanic activity bulletins may be obtained from the global volcanism network:

Museum of Natural History
MRC 129 Smithsonian Institution
Washington, DC 20560 USA
Phone: 202-357-4795
Fax: 202-786-2557

PART 1.4

# LANDSLIDES

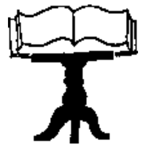
This chapter is designed to enhance your understanding of:

- *the forces that cause landslides*
- *different types of landslides and their effects*
- *methods to reduce the vulnerability of human settlements to landslides.*

## Introduction

Landslides are a major threat each year to human settlements and infrastructure. “Landslide” is a general term covering a wide variety of land forms and processes involving the movement of earth, rock or debris downslope under the influence of gravity. Although they may take place in conjunction with earthquakes, floods and volcanoes, they are much more widespread than those hazards and over time cause more property loss than any other geological event.

LANDSLIDES



**LANDSLIDE HAZARD DATA SHEET**

**Recent major landslides**

| Year | Location | Cause | Death | Damage |
|---|---|---|---|---|
| 1970 | Yungay, Peru | earthquake | 25,000 | 3 million affected |
| 1974 | Mayunmarca, Peru | | 310 | US $21 million |
| 1985 | Stava, Italy | dam collapse | 329 | |
| 1989 | Tajikistan | earthquake | 270 | |
| 1991 | Uttarkashi, India | earthquake | 2,000 | 10,000 homes destroyed |
| 1991 | Ormoc, Philippines | typhoon | 4,899 | widespread destruction |

| Average estimated damage from landslides from 1989 to 1993 in thousands US $ | |
|---|---|
| Africa | 0 |
| America | 25,400 |
| Asia | 215,400 |
| Europe | 24,100 |
| Oceania | 0 |
| Total | $264,900 |

Compiled from: **OFDA Disaster History**, 1996
IFRC, **World Disaster Report**, 1995
AIPG, **Citizen's Guide to Geologic Hazards**, 1993

## Causes

Landslides occur as a result of changes, either sudden or gradual, in the composition, structure, hydrology or vegetation on a slope. These changes may be natural or human-caused and result in disturbance of the equilibrium of the materials in the slope. A landslide occurs when the strength of the material comprising the slope is exceeded by the downslope stres. The resistance in a slope may be reduced by:

***Increase in water content*** caused by heavy rainfall or rising ground water.

***Increase in slope angle*** for new construction or by stream erosion.

***Breakdown or alteration of slope materials*** from weathering and other natural process, placement of underground piping for utilities, or use of landfill.

The downslope stress may be caused by:

***Vibrations*** from earthquakes, blasting, machinery, traffic and thunder. Some of the most disastrous landslides have been triggered by earthquakes.

***Removal of lateral support*** by previous slope failure, construction, and excavation.

***Removal of vegetation*** from fires, logging, overgrazing, and deforestation which causes loosening of soil particles and erosion.

***Loading with weight*** with rain, hail, snow, accumulation of loose rock or volcanic material, weight of buildings, or seepage from irrigation and sewage systems.

***Q.*** *From the causes of landslides given above, which are most significant to your community?*

***A.*** ______________________________

______________________________

______________________________

______________________________

______________________________

______________________________

______________________________

## General characteristics

Landslides usually occur as secondary effects of heavy storms, earthquakes and volcanic eruptions. The materials that compose landslides are divided into two classes, bedrock or soil (earth and organic matter debris). A landslide may be classified by its type of movement:

**Falls** – A fall is a mass of rock or other material that moves downward by falling or bouncing through the air. These are most common along steep road or railroad embankments, steep escarpments, or undercut cliffs especially in coastal areas. Large individual boulders can cause significant damage.

**Slides** – Resulting from shear failure (slippage) along one or several surfaces, the slide material may remain intact or may break up.

**Topples** – A topple is due to overturning forces that cause a rotation of the rock out of its original position. The rock section may have settled at a precarious angle, balancing itself on a pivotal point from which it tilts or rotates forward. A topple may not involve much movement and it does not necessarily trigger a rockfall or rock slide.

**Lateral spreads** – Large blocks of soil spread out horizontally by fracturing off the original base. Lateral spreads generally occur on gentle slopes, less than 6 percent, and typically spread 3 m to 5 m but may move from 30 m to 50 m where conditions are favorable. Lateral spreads usually break up internally and form numerous fissures and scarps. The process can be caused by liquefaction whereby saturated, loose sands or silts assume a liquefied state. It is usually triggered by ground shaking (as with an earthquake). During the 1964 Alaskan earthquake, more than 200 bridges were damaged or destroyed by lateral spreading of flood plain deposits near river channels.

**Flows** – Flows move like a viscous fluid, sometimes very rapidly, and can cover several miles. Water is not essential for flows to occur, however, most flows form after periods of heavy rainfall. A mudflow contains at least 50 percent sand, silt and clay particles. A *lahar* is a mudflow that originates on the slope of a volcano and may be triggered by rainfall, sudden melting of snow or glaciers, or water flowing from crater lakes. A *debris flow* is a slurry of soils, rocks and organic matter combined with air and water. Debris flows usually occur on steep gullies. Very slow, almost imperceptible, flow of soil and bedrock is called *creep.* Over long periods of time, creep may cause telephone poles or other objects to tilt downhill.

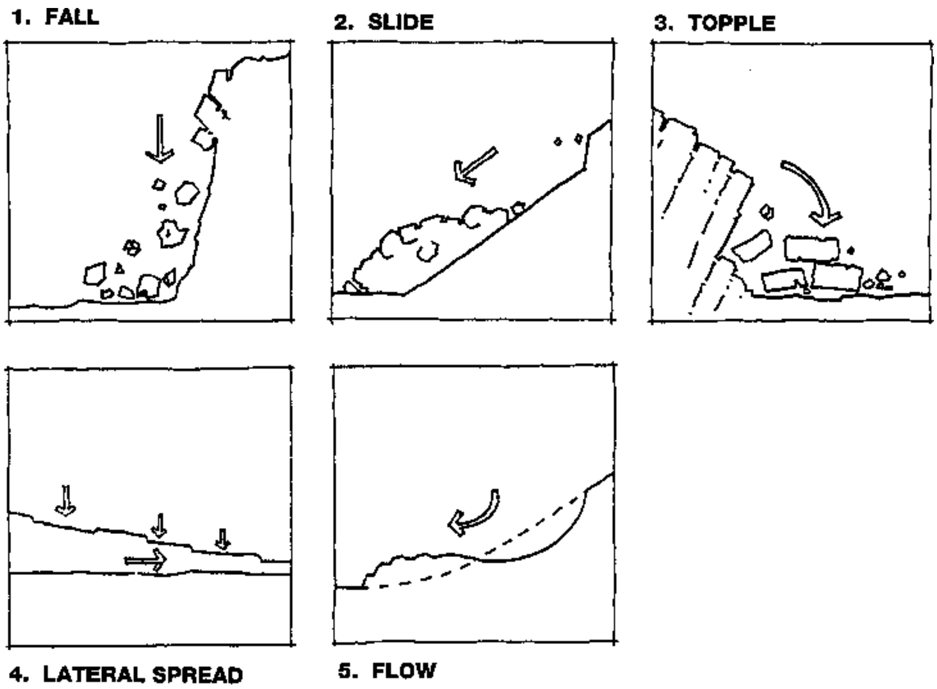



**Figure 1.4.1**
*Types of landslide movement.*

## Predictability

Landslide velocity varies from extremely slow (less than .06 meters/yr) to extremely fast (greater than 3 meters/sec.), which might imply a similar variation in predictability. In absolute terms, however, it is very difficult to predict the actual occurrence of a landslide although situations of high risk – forecasted heavy rainfall or seismic activity combined with landslide susceptibility – may lead to estimation of a time frame and possible consequences.

Estimation of landslide hazard potential includes historical information on the geology, geomorphology (study of land forms), hydrology and vegetation of a specific area. By examining the following, an evaluation may be made of the possible volume of materials susceptible to failure and the area that may be affected.

**Geology** – Two aspects of geology are important in assessing the stability of land and predicting landslides.

1) *Lithology* – the study of characteristics of rock such as the composition, texture or other features which influence its behavior. These attributes determine the strength, permeability, susceptibility to chemical and physical weathering and other factors which affect slope stability.
2) *Structure of rocks and soils* – Structural features that may affect stability include sequence and type of layering, lithologic changes, planes, joints, faults and folds.

**Geomorphology** – The most important geomorphological consideration in the prediction of landslides is the history of landslides in a given area. Other important factors are steepness of slope in relation to the strength of the slope-forming materials, and slope aspect, or the direction in which the slope faces and its curvature.

**Hydrology and climatology** – The source, movement, amount of water and water pressure must be studied. Climatic patterns combined with soil type may cause different types of landslides. For example, monsoons in tropical regions may cause large debris slides of soils, rocks and organic matter.

**Vegetation** – Plant cover on slopes may have a positive or negative stabilizing effect. Roots may decrease water runoff and increase soil cohesion, or conversely may widen-fractures in rock surfaces and promote infiltration.

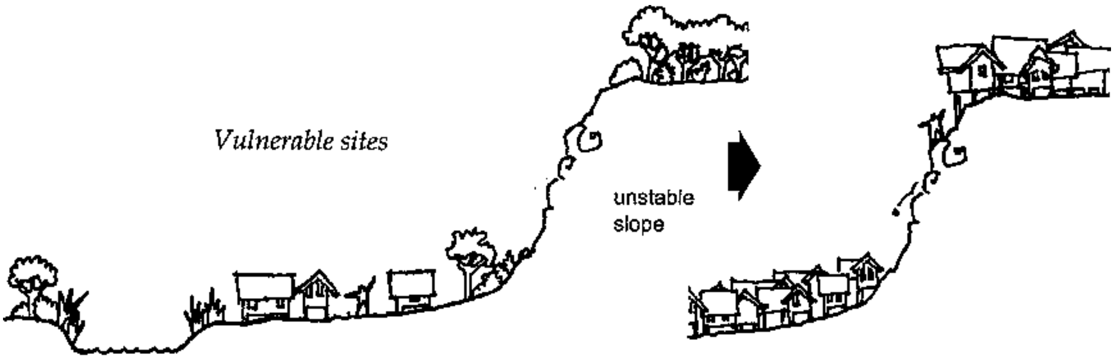
## Factors contributing to vulnerability

The greatest threat of landslide exists in:

- areas prone to earth tremors and earthquakes
- mountainous areas
- areas of severe land degradation
- areas covered with fine grained sand or tephra (material ejected by volcanic eruptions)
- areas which receive high rainfall

Human settlements built on steep slopes, weak soils, cliff tops, at the base of steep slopes, on alluvial outwash fans or at the mouth of streams emerging from mountain valleys are all vulnerable. Roads and other communication lines through mountain areas are in danger. In most types of landslides,

damage may occur to buildings even if foundations have been strengthened. Infrastructural elements such as buried utilities or brittle pipes are vulnerable.




## Typical adverse effects

### *Physical damage*

Anything on top of or in the path of a landslide will suffer severe damage or total destruction. In addition, rubble may damage lines of communication or block roadways. Water ways may be blocked creating a flood risk. Casualties may not be widespread, except in the case of massive movements due to major hazards such as earthquakes and volcanoes.

***Anything on top of or in the path of a landslide will suffer severe damage or total destruction.***

In addition to direct damage from a landslide, many indirect adverse effects occur. These include:

- loss of productivity of agricultural or forest lands (if buried)
- reduced real estate values in high risk areas and lost tax revenues from these devaluations
- adverse effects on water quality in streams and irrigation facilities
- secondary physical effects such as flooding.

### *Casualties*

Fatalities have occurred due to slope failure where population pressure has prompted settlement in areas vulnerable to landslides. Casualties may result from collapse of buildings or burial by landslide debris. Worldwide, approximately 600 deaths per year occur, mainly in the Circum Pacific region. Estimates for loss of life in the United States is 25 lives per year, greater than the average loss from earthquakes. Catastrophic landslides have killed many thousands of persons, such as the debris slide on the slopes of Huascaran in Peru triggered by an earthquake in 1970, which killed over 18,000 people.

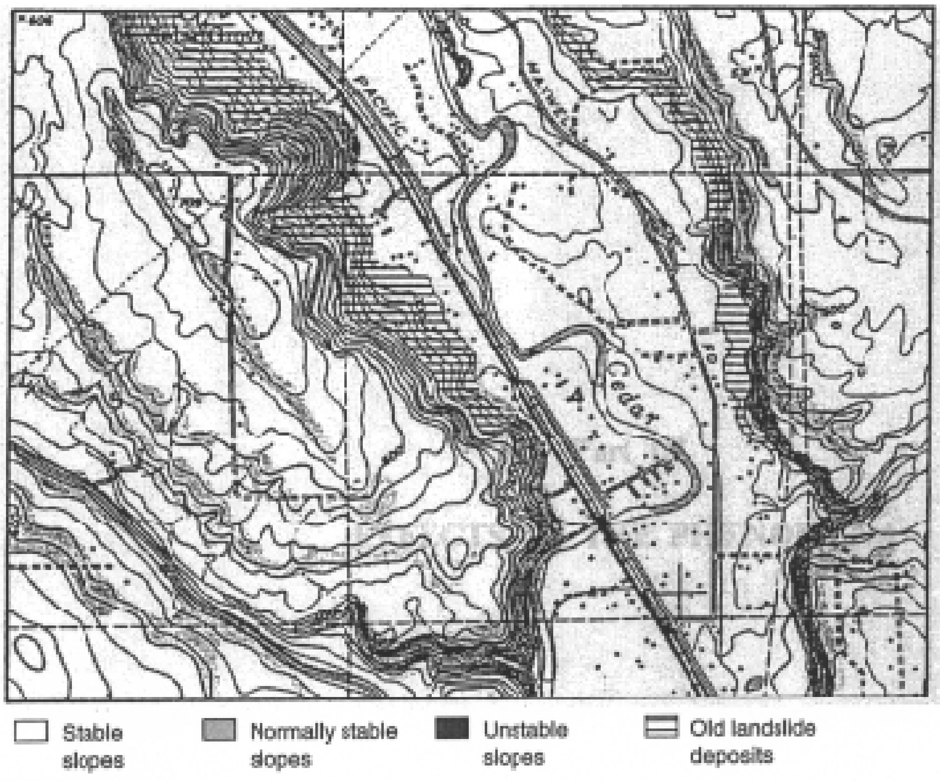



**Figure 1.4.2**

*Detail from map showing relative slope stability in part of west-central King Country, Washington, USA.*

*Mitigating Natural Disasters: Phenonema, Effects and Options,* UNDRO, Geneva, 1991.

## Possible risk reduction measures

### *Preparation of a landslide hazard map*

The implementation of risk reduction measures must be preceded by locating areas prone to slope failures. The landslide hazard map permits planners to determine the level of risk and to make decisions regarding avoidance, prevention or mitigation of existing and future landslide hazards. Reasonably accurate techniques are available to planners for mapping slope hazard areas. These techniques rely on past history, topographic maps, bedrock data and aerial photographs. Various types of mapping formats may be used. The maps can be supplemented by additional data such as proximity to earthquake zones, local undercutting by rivers or impaired drainage.

In France, the ZERMOS (Zones Exposed to Risks of Movements of the Soil and Subsoil) plan produces landslide hazard maps at scales of 1:25,000 or larger which are used as tools for mitigation planning. The maps portray degrees of risk of various types of landslides, including activity, rate and potential consequences.

***Q.*** *What information is needed for the preparation of a landslide hazard map?*

***A.*** ________________________________________

## *Land use regulation*

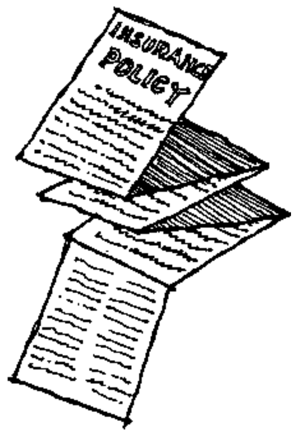
The most effective way to reduce damage caused by landslides is to locate development on stable ground and to utilize landslide susceptible areas as open space or for low intensity activities such as park land or grazing. Land use controls can be enacted to prevent hazardous areas from being used for settlements or as sites for important structures. The controls may also involve relocation away from the hazardous area particularly if alternative sites exist. Restrictions may be placed on the type and amount of building that may take place in high risk areas. Activities that might activate a landslide should be restricted. Where the need for land is critical, expensive engineering solutions for stabilization may be justified.

***The most effective way to reduce damage caused by landslides is to locate development on stable ground and to utilize landslide susceptible areas as open space or for low intensity activities such as park land or grazing.***

## *Legislation*

Governments may assume responsibility for damage repair expenses from landslides as well as efforts to prevent them. In Japan, landslide control activities were originally connected to conservation legislation for river improvement, erosion control and maintenance of agricultural and forest lands. In 1969, a comprehensive control program was legislated devoted exclusively to landslides which provides governmental assumption of expenses for recovery from natural disasters for which no individuals bear responsibilities.

## *Insurance*




Insurance programs may reduce losses to landslides by spreading the expenses over a larger base and including standards for site selection and construction techniques. In New Zealand, a national insurance program assists individuals whose homes have been damaged by landslides or other natural hazards beyond their control. A special disaster fund is accumulated by surcharge to a fire insurance program.

## *Structural changes*

Strengthening of existing buildings and infrastructure is not considered by most experts to be a viable option for mitigation of damage due to landslides, as vulnerability for structures built in the path of landslides is nearly 100 percent. The selection of mitigation options depends on:

- The value of land or structures in relation to the cost of the protective measures.
- The opportunities to enforce land use regulations and the availability of alternative locations.
- The number of people affected by the intervention.
- The predicted amount of damage.

Improvements and protective measures may be added to sites, such as improvement of soil drainage (by addition of permeable materials), slope modifications (reduction of slope angle prior to construction), and re-vegetation of slopes. Concrete retaining walls may stabilize possible sites. Large scale engineering works may also be considered.

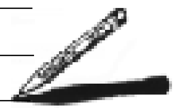
***Vulnerability for structures built in the path of landslides is nearly 100 percent.***

***Q.*** *What are the basic mitigation measures applicable to landslide hazards?*

***A.***

***Q.*** *Are any of these measures now in practice in your community?*

***A.***



## Specific preparedness measures

### *Community preparedness*

The most damaging landslides are often related to the activities of people. Construction of roads, housing, and other infrastructure frequently causes landslides. Thus the most effective preparedness measures should be taken before people occupy a vulnerable area. Public education programs will help people understand the causes and effects of landslides, identify unstable areas and avoid settling there. Some areas may be stabilized prior to settlement or subjected to strict land use regulations. For areas already built upon, ground stabilizing procedures, such as terracing and treeplanting, may be of some use in reducing damage but losses will not be completely avoided.

### *Monitoring, warning and evacuating systems*

Areas susceptible to landslides may be monitored to allow timely warning and evacuation. Monitoring methods include field observation and use of inclinometers, vibration meters, and electrical fences or tripwires. Immediate relay of information is essential in places where rockfalls or debris flows are likely to occur rapidly. In these cases, use of the media, sirens or other widely reaching information systems may be required. Monitoring and warning systems should place inhabitants on alert when heavy rains occur or if ground water levels rise.

*ANSWER* *(from page 60)*

Preparation of landslide hazard maps require information on: past landslide events, topography, bedrock data, and aerial photographs.

Public education programs may involve descriptions of climatic conditions or hazards that provoke landslides and what actions to take when such conditions exist. Evacuation plans for high risk areas should be established and practiced particularly when the risk of landslide is interconnected with threat of seismic, volcanic or flooding activity.

### Typical post-disaster assistance needs

Needs for the direct impact area of a landslide include search and rescue equipment and personnel, and possibly use of earth removal equipment. Emergency shelter may be required for those whose homes have been lost or damaged. Experts trained in landslide hazard evaluation should be consulted to determine whether slide conditions pose additional threat to rescuers or residents.

Secondary effects of landslides such as flooding may require additional assistance measures. If the landslide is related to an earthquake, volcano or a flood, assistance to the landslide-affected area will be part of the total disaster assistance effort.

## ■ *CASE STUDY*

### Adaptive resettlement for villages at high risk to landslides


In the rugged, steep mountainsides in Penjikent district, Tadjikistan, earthquakes, rockslides, rock falls and mudslides occur frequently and are largely unpredictable. There is also heavy snow accumulation in the high altitudes. By early 1996, a series of landslides had eaten up nearly half the houses in the village of Shing and the debris was stll moving downslope, posing a constant hazard to the villagers.

Altogether five villages (kishlaks) located in the same valley faced the same problems. Most of the houses were built upon 20–30 degree sllopes, which made even subsistence farming difficult. The area is also suffering from overgrazing, deforestation, soil destabilization and erosion. Seasonal flooding from rapid runoff had previously destroyed a tourist resort, one of the sources of local income. Adding to the threat of natural disaster, the economic situation of the kishlaks had deteriorated due to high unemployment. Local residents were very interested in relocation.

Extensive records kept by the State Geological Committee since 1969 indicated an increasing frequency in the occurrence of avalanches and landslides in the valley. The ability for local rescue teams to reach the sites and respond to emergencies was hampered for the kishlaks located in the steepest part of the valley, further increasing their vulnerability. All five kishlaks were therefore designated for potential resettlement due to their extreme vulnerability to landslides.

To address the crtical issues involved in mitigating the landslides and planning for relocation, representatives of the five kishlaks, government agencies, international organizations. NGOs and private enterprises wishing to offer assistance worked together. Among the most pressing problems were need for agreement with the local people on where to relocate, how to obtain materials for building, and needs for employment and basic services. Also of great concern was the need to address the present danger of landslides.

To facilitate the adaptation of the residents to the relocation, local government and kishlak leaders would plan and implement the most acceptable resettlement strategy for each kishlak, allocating scarce resources and developing a local mechanism to monitor progress and deal with problems. The “khashtar” method would be used where members of the community build houses in a collective effort, utilizing local materials and materials removed from the old houses. Step by step over a year, the needed infrastructure and housing would be constructed, the villagers moved, and the old houses demolished. National and international agencies would join forces to support the villagers’ needs during the relocation.

To address the landslide hazard, the following steps were proposed:

1. District level workshops would be held to assess the risks of natural hazards and related problems facing each kishlak and identify reasonable solutions, including identification of an emergency shelter to be used in case of injuries or homelessness due to landslides.
2. An emergency communication system would be established for all kishlaks.
3. Hazard mapping would be undertaken for the old and new locations.

*Source:* International Organization for Migration, “Adaptive Resettlement for Villages at High Risk for Environmental Hazards”, Project Proposal, Dushanbe, Tadjikistan, February, 1996.

## ■ REFERENCES

American Institute of Professional Geologists, **The Citizen’s Guide to Geologic Hazards,** 1993.

Disaster Management Center, **Natural Hazards: Causes and Effects,** University of Wisconsin 1986.

Erickson, Jon, **Volcanoes and Earthquakes,** TAB books, Blue Ridge Summit, PA., 1988.

Erley, Duncan and William J. Kockelman, **Reducing Landslide Hazards: A Guide for Planners,** American Planning Association, Chicago, 1981.

**Facing Geologic and Hydrologic Hazards,** U.S. Geological Survey Professional Paper 1240-B, U.S. Government Printing office, Washington, D.C., 1981.

International Federation of Red Cross and Red Crescent Societies, **World Disaster Report 1995,** Martinus Nijhoff, The Netherlands, 1995.

Kockelman, William J., “Some Techniques for Reducing Landslides Hazards”, **Bulletin of the Association of Engineering Geologists,** Vol. XXIII, No. 1, 1986, p 29–52.

**Landslides – Investigation and Mitigation,** Special Report 247, Transportation Research Board, National Academy Press, Washington, DC, 1996.

Office of Foreign Disaster Assistance, Disaster History: Significant Data on Major Disasters Worldwide, 1900–1995, Washington DC, June 1996.

OAS/DRDE, **Natural Hazards Primer,** Organization of American States, Washington, D.C., 1990.

Smith, Keith, **Environmental Hazards: Assessing Risk and Reducing Disaster,** Routledge, London, 1996.

UNDRO, **Mitigating Natural Disasters, Phenomena, Effects and Options,** United Nations, New York, 1991.

ANSWER *(from page 62)*

Appropriate mitigation measures include; land use planning, legislative controls or assurances, insurance, and in some cases site engineering projects.

PART 2.1

# TROPICAL CYCLONES

This chapter is designed to enhance your knowledge of:

- *the physical nature and cause of tropical cyclones*
- *hazards which can accompany a tropical cyclone such as hurricane winds, storm surges and floods*
- *the predictability of tropical cyclones and use of warning systems*
- *the impact of tropical cyclones on human settlements and infrastructure and measures that can be taken to reduce or prevent damage and casualties.*

## Introduction

TROPICAL CYCLONES

The World Meteorological Organization (WMO) uses the generic term "tropical cyclone" to cover weather systems in which winds exceed "gale-force" (minimum of 34 knots or 63 kph). Tropical cyclones are rotating, intense low-pressure systems of tropical oceanic origin. "Hurricane-force" (63 knots or 117 kph) winds mark the most severe type of tropical storm. They are called **hurricanes** in the Caribbean, the United States, Central America and parts of the Pacific; **typhoons** in the Northwest pacific and East Asia; **cyclonic storms** in the Bay of Bengal and **tropical cyclones** in the South Indian, South Pacific and Australian waters. To facilitate identification and tracking, the storms are generally given alternating masculine and feminine names, or numbers which identify the year and annual sequence.

Tropical cyclones are the most destructive of seasonally recurring rapid onset natural hazards. Between 80 and 100 tropical cyclones occur around the world each year. Devastation by violent winds, torrential rainfall and accompanying phenomena including storm surges and floods can lead to massive community disruption. In the last decade, the official death toll in individual tropical cyclones reached 140,000 (Bangladesh, 1991) and 6,000 (Ormoc, Philippines, 1991) and damages approached US$ 40 billion in Hurricane Andrew (1992) in Florida, USA.

## TROPICAL CYCLONE HAZARD DATA SHEET

**Selected cyclones of the 1990s, Losses in US$ millions**

| Year | Location | Name | Deaths | Losses |
|---|---|---|---|---|
| 1990 | Philippines | Typhoon Mike | 748 | 700 |
| 1990 | India | unnamed cyclone | 967 | 1,124 |
| 1991 | Bangladesh | unnamed cyclone | 140,000 | 2,000 |
| 1991 | Philippines | Tropical Storm Thelma | 6,000 | n/a |
| 1992 | United States | Hurricane Andrew | 40 | 40,000 |
| 1993 | Fiji | Cyclone Kina | 30 | 300 |
| 1994 | Bangladesh | unnamed cyclone | 400 | n/a |
| 1994 | China | Typhoon Fred | 1,126 | 2,093 |
| 1994 | Madagascar | Cyclone Geraldo | 300 | n/a |
| 1994 | Haiti | Hurricane Gordon | 800 | n/a |
| 1995 | Philippines | Typhoon Angela | 800 | 200 |

Number of persons affected by declared tropical cyclone disasters from 1980-89: 24,110,139

Compiled from: **OFDA, Disaster History,** 1996

## Causes

The development cycle of tropical cyclones may be divided into three stages: **formation and initial development, full maturity,** and **modification** or **decay.** Depending on their tracks over the warm tropical seas and proximity to land, they may last from less than 24 hours to more than three weeks (the average duration is about six days). Their tracks are naturally erratic, but initially move generally westward, then progressively poleward into higher latitudes where they may make landfall or into an easterly direction as they lose their cyclonic structure.

### *Formation and initial development stage*

Four atmospheric and oceanic conditions are necessary for development of a cyclonic storm:

1. **A warm sea temperature** in excess of 26° C, to a depth of 60 m, which provides abundant water vapor in the air by evaporation.
2. **High relative humidity** (degree to which the air is saturated by water vapor) of the atmosphere to a height of about 7000 m facilitates condensation of water vapor into weather droplets and clouds, releases heat energy and induces drop in pressure.
3. **Atmospheric instability** (an above average decrease of temperature with altitude) encourages considerable vertical cumuls cloud convection when condensation of rising air occurs.
4. A location of at least **4-5 latitude degrees from the Equator** allows the influence of the forces due to the earth's rotation (Coriolis force) to take effect in inducing cyclonic wind circulations around low pressure centers.

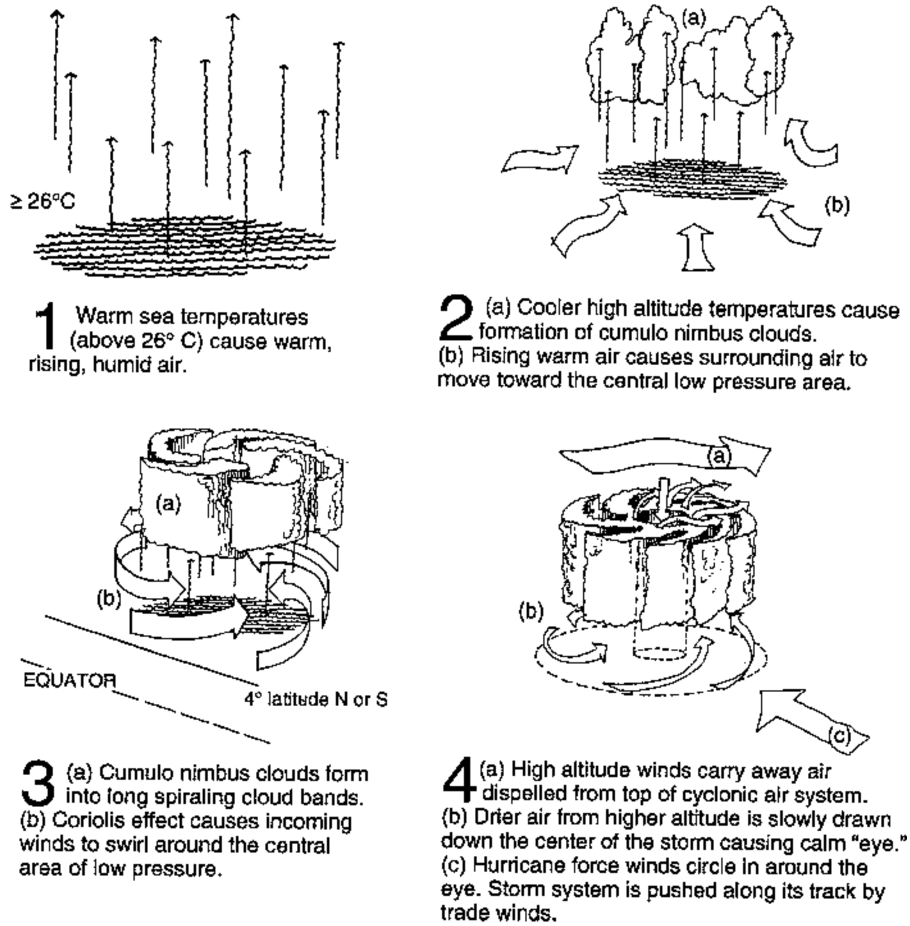



**Figure 2.1.1**

*Formation of a tropical cyclone (Northern Hemisphere rotation)*

The atmosphere can usually organize itself into a tropical cyclone in wo to four days and is characterized by increasing thunderstorms and rain squalls at sea. Meteorologists can monitor these processes with weather satellites, orbiting or in fixed position above the earth, and by radar scanning up to 400 km from the radar station. The exstence of favorable conditions for cyclone development determine the cyclone season for each monitoring center. In the Indian/South Asian region the season is divided into two periods, from April to early June and from October to early December. In the Caibbean and United States, tropical storms and hurricanes reach their peak strengths in middle to late summer. In the NW Pacific-South China Sea typhoons are most frequent in the months of July to November, but have been known to occur in each month of the year. In the Southern Hemisphere, the cyclone season extends from November to April/May but occasionally cyclones do occur in other months in lower latitudes.

***Q.*** *What are the four conditions required for the formulation of a cyclonic storm?*

***A.*** ______________________________

______________________________

______________________________

### *Mature tropical cyclones*

As viewed by weather satellites and radar imagery, the main physical feature of a mature tropical cyclone is a spiral pattern of highly turbulent giant cumulus thundercloud bands. These bands spiral inwards and form a dense highly active central cloud core which wraps around a relatively calm and cloud-free “eye”. The eye typically has a diameter of from 20-60 km of light winds and looks like a black hole or dot surrounded by white clouds.

In contrast to the light wind conditions in the eye, the turbulent cloud formations extending outwards from the eye accompany winds of up to 250 kph, sufficient to destroy or severely damage most non-engineered structures in the affected communities. These strong winds are caused by gradients which separate the much warmer low pressure core of the cyclone from the cooler air (by as much as 10° C) in the higher pressure environment outside the cyclone.

***When the cyclone hits land, especially over mountainous or hilly terrain, widespread riverine and flash flooding may last for weeks.***

### *The weakening stage of a tropical cyclone*

A tropical cyclone begins to weaken in terms of its central low pressure, internal warm core and extremely high winds as soon as its sources of warm moist air begins to ebb or are abruptly cut off. This would occur during landfall, by movement into higher latitudes, or through influence of another low pressure system. The weakening of a cyclone does not mean the danger to life and property is over. When the cyclone hits land, especially over mountainous or hilly terrain, widespread riverine and flash flooding may last for weeks. Or, the energy from a weakening tropical cyclone may be reorganized into a less concentrated but more extensive storm system causing widespread violent weather.

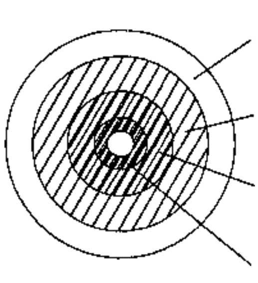
*A tropical cyclone in the Bay of Bengal on May 8, 1990 as recorded on weather radar in Madras, India. The dark “eye” of the storm can be plainly seen.*

Nature and Resources, Vol. 27, No. 1, 1991.

## General characteristics

Tropical cyclones are characterized by their destructive winds, storm surges and exceptional level of rainfall which may cause flooding.

***Destructive winds*** – The strong winds generated by a tropical cyclone circulate clockwise in the Southern Hemisphere and counter-clockwise in the Northern Hemisphere, while spiraling inwards and increasing toward the cyclone center. Wind speeds progressively increase toward the core.



- 150 to 300 km from the center of a typical mature cyclone, winds of 63-88 kph
- 100-150 km from the center, storm force winds of 89-117 kph
- 50 to 100 km from the center; winds in excess of hurricane force, 117 kph or greater
- 20 to 50 km from the center, on the edge of the inner core contains winds 250 kph or higher.

As the eye arrives, winds fall off to become almost calm but rise again just as quickly as the eye passes and are replaced by hurricane force winds from a direction nearly the reverse of those previously blowing.

A scale classifying the intensity of the storms, the **Beaufort scale,** estimates the wind velocity by observations of the effects of winds on the ocean surface and familiar objects. Both the United States **(Saffir-Simpson Potential Hurricane Damage Scale)** and Australia **(Cyclone Severity**

**Categories)** use country-specific scales which estimate potential property damage in five categories. The Philippines recently increased its typhoon warning signal numbers from 3 ranges of wind speeds to 4 in order to take into account the lower standards of building structures and regional variations.

***Storm Surges*** – The storm surge, defined as the rise in sea level above the normally predicted astronomical tide, is frequently a key or overriding factor in a tropical storm disaster. As the cyclone approaches the coast, the friction of strong on-shore winds on the sea surface, in combination with the "suction effect" of reduced atmospheric pressure, can pile up the sea water along a coastline near a cyclone's landfall well above the predicted tide level for that time. In cyclones of moderate intensity the effect is generally limited to several meters, but in the case of exceptionally intense cyclones, storm surges of up to eight meters can result. The major factors include:

a) *A fall in the atmospheric pressure over the sea surface.* In the center of a tropical storm the atmospheric pressure is much less than outside. The maximum rise in mean sea level due to this effect is about one meter.

b) *The effect of the wind.* As the winds strengthen they will exert force on the surface of the water causing waves, swells and storm surges.

c) *The influence of the sea bed.* As the storm approaches a coastline, especially if the sea bed slopes gradually, friction at the sea bottom will interfere with the return water currents and the wind will pile up water along the shore. This combination of strong winds and gently sloping sea bed can reslt in very strong storm surges, reaching as high as eight meters.

d) *A funneling effect.* A semi-enclosed bay in the path of a storm surge permits the storm's winds to trap high water there for extended periods.

e) *The angle and speed at which the storm approaches the coast.* In general, the greater the forward speed and the more nearly perpendicular the track is to the coast, the higher the surge will be, but these two conditions do not have to exist for a severe storm surge to occur.

f) *The tides.* Tides in some countries show variation in height with the seasons as well as the time of day. If a storm surge coincides with the high tide and/or the maximum seasonal tide, the effect can be devastating.

Of the countries experiencing cyclonic storms, those most vulnerable to storm surges are those with low lying land along the closed and semi-enclosed bays facing the ocean. These countries include Bangladesh, China, India, Japan, Mexico, the United States and Australia. Prevailing on shore winds and low pressures due to winter depressions in non-tropical latitudes, as in countries bordering the North Sea, are also subject to storm surges which require substantial mitigation measures, such as dikes.

**STORM SURGES**

***Exceptional rainfall occurrences*** – The world's highest rainfall totals over one or two days have occurred during tropical cyclones. The highest 12 and 24 hour totals, 114 cm and 182 cm have both occurred during cyclones at La Reunion Island in the SW Indian ocean. The very high specific humidity condenses into exceptionally large raindrops and giant cumulus clouds, resulting in high precipitation rates. When a cyclone makes landfall, the rain rapidly saturates even dry catchment areas and rapid runoff may explosively flood the usual water courses and create new ones.

*ANSWER (from page 67)*

1. Warm sea temperature
2. High relative humidity
3. Atmospheric instability
4. Location 4-5 degrees latitude from the equator

The relationship between cyclone strength and rainfall is often not proportional. For instance, if the atmosphere over land is dry, a strong cyclone may decay quickly and rainfall may be quite limited. On the other hand, if the atmosphere is already saturated and the terrain flooded over large areas, a weak to moderate strength cyclone may weaken only slowly and rainfall will persist. In recent times catastrophic cyclone riverine and flash flood events have increased due to the incidence of heavy rainfall on heavily deforested hill slopes. Landslides and small rivers jammed with floating logs and debris have quickly swamped villages and inhabited flood plains resulting in thousands of casualties. A relatively weak typhoon at Ormoc in the central Philippines drowned 6000 persons in such circumstances in 1991 in barely 30 minutes.

***Q.*** *Aside from strong winds, what other hazards are associated with cyclonic storms?*

***A.*** ____________________________________________

____________________________________________

____________________________________________

____________________________________________

## Predictability

Tropical cyclones form in all the oceans of the world except the South Atlantic and South Pacific east of 140 degrees W longitude. Nearly one quarter form between 5 and 10 degrees latitude of the equator and two thirds between 10 and 20 degrees latitude. It is are for a tropical cyclone to form

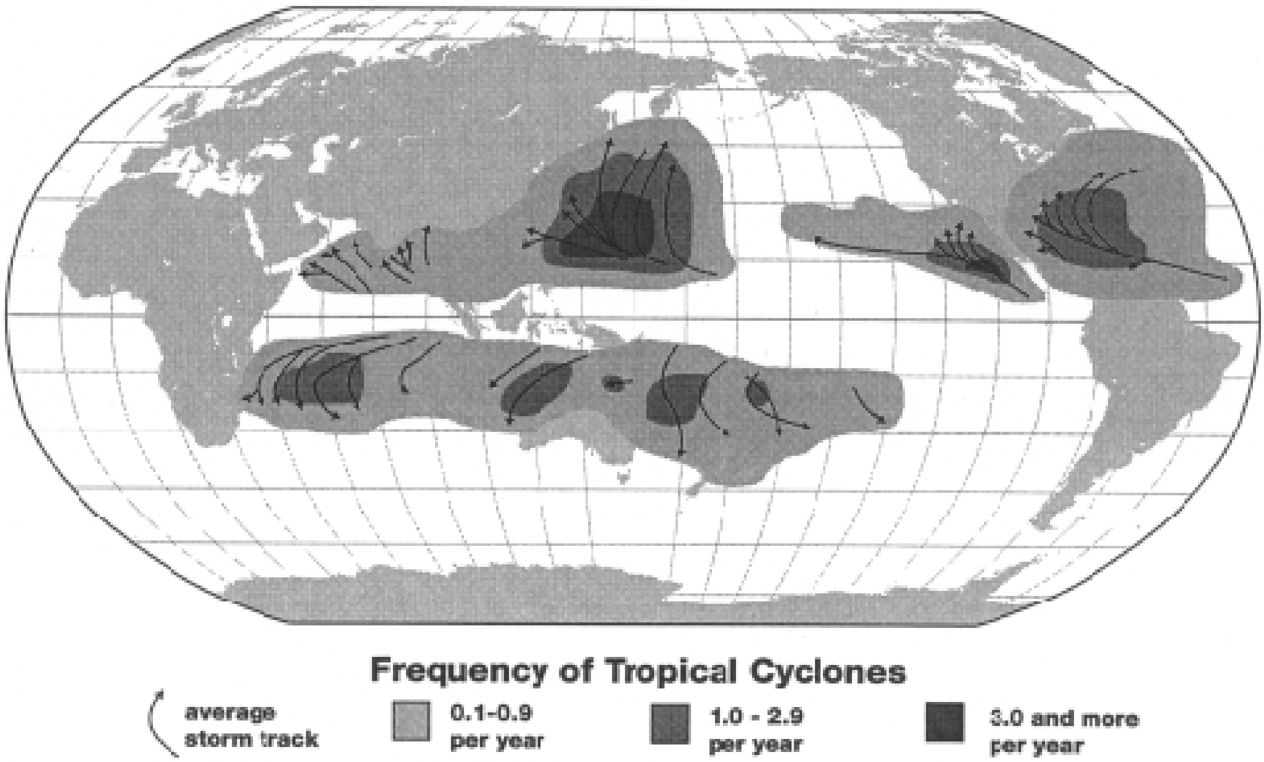


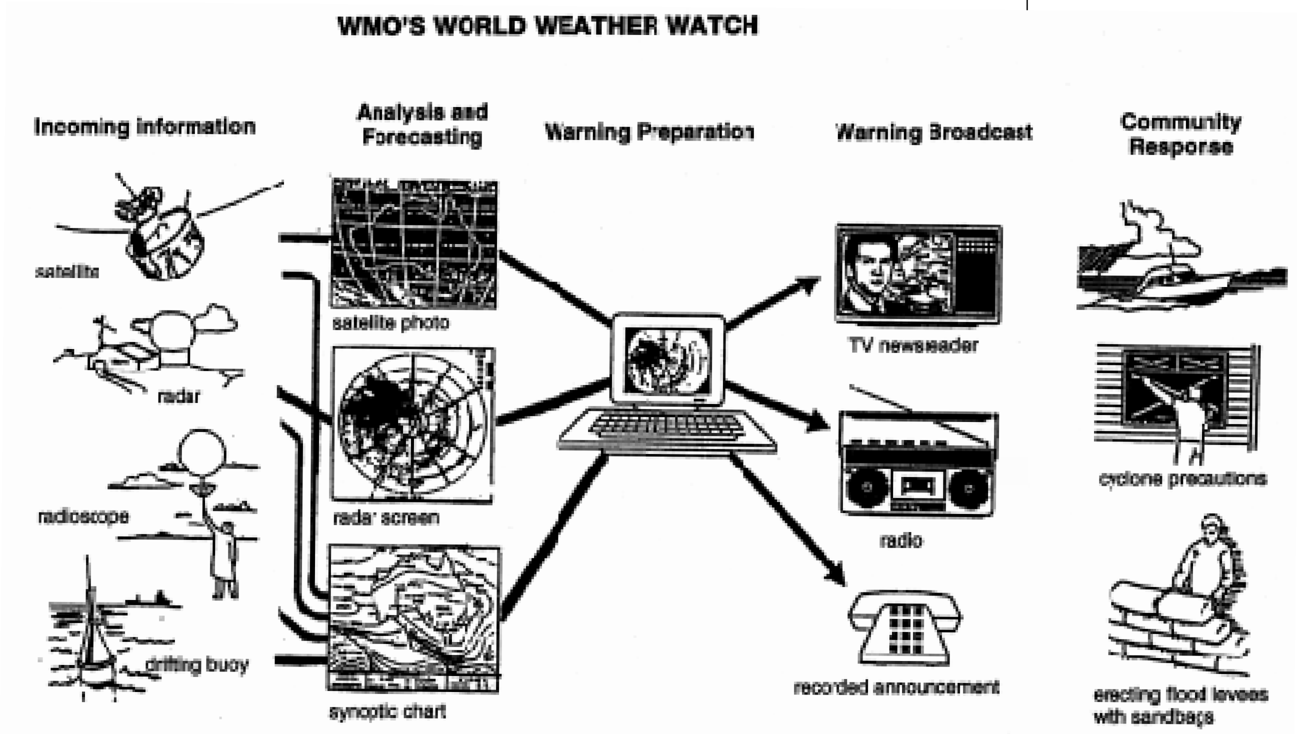

**Figure 2.1.2**

*World map showing the average annual frequency of tropical cyclones by location. After Berz, 1990.*

south of 20-22 degrees latitude in the Southern Hemisphere, however, they occasionally form as far north as 30-32 degrees in the more extensive warmer water of the Northern Hemisphere.

The locations, frequencies and intensities of tropical cyclones are well known from historical observations and, more recently, from routine satellite monitoring. Tropical cyclones do not follow the same track except coincidently over short distances. Some follow linear paths, others recurve in a symmetrical manner, others accelerate or slow down and become "quasi-stationary" for a time. For this reason it is often difficult to predict when, where and if the storm will hit land, especially islands. In general, the difficulty in forecasting increases from the low to higher latitudes while the margin of error in determining the cyclone center decreases as landfall approaches depending on the availability of radar detection.

**Figure No. 2.1.3**
*WMO's World Weather Watch*




Substantial progress has been made in the organization of warning and dissemination systems particularly through regional cooperation. The activities of national meteorological services are coordinated at the international level by the World Meteorological Organization (WMO). Forecasts and warnings are prepared within the framework of the WMO's World Weather Watch Program (WWW). Under this program, meteorological observational data provided nationally, data from satellites and information provided by the regional centers are exchanged around the world. Specialized products are being provided by centers designated under the WWW and the associated Tropical Cyclone Program (TCP) in the form of guidance material to assist in detecting, monitoring and forecasting cyclones.

The WWW system includes 8,500 land stations, 5,500 merchant ships, aircraft, special ocean weather ships, automatic weather stations and meteorological satellites. A tropical cyclone is first identified and then followed from satellite pictures. A complex Global Telecommunications System relays the observations. Ultimately, however, the responsibility for providing forecasts and warnings to the local population regarding tropical cyclones and the associated winds, rains and storm surges, falls upon the national services. Many regional and national meteorological centers are now using computerized workstations to assist them, such as the Australian Tropical Cyclone Workstation (ATCW) to improve forecasting.

***Human settlements located in exposed, low lying coastal areas will be vulnerable to the direct effects of the cyclone such as wind, rain and storm surges.***

## Factors contributing to vulnerability

Human settlements located in exposed, low lying coastal areas will be vulnerable to the direct effects of the cyclone such as wind, rain and storm surges. Settlements in adjacent areas will be vulnerable to floods and mudslides or landslides from the resultant heavy rains. The death rate is higher where communications systems are poor and warning systems are inadequate. Communities without prior experience in a cyclone or without an evacuation plan may be more vulnerable.

The quality of structures will determine resistance to the effects of the cyclone. Those most vulnerable are lightweight structures with wood frames, older buildings with weakened walls, and houses made of unreinforced concrete block. Infrastructural elements particularly at risk are telephone and telegraph poles, fishing boats and other maritime industries. Hospitals may be damaged reducing access to health care and essential drugs.

## Typical adverse effects

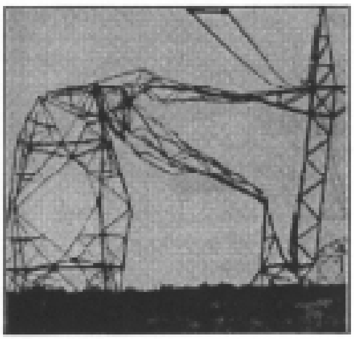
*Hurricane damage in Nicaragua, 1988.*
UNDRO NEWS, May/June 1989.

### *Physical damage*

Structures will be damaged or destroyed by wind force, through collapse from pressure differentials, by flooding, storm surge and landslides. Standing crops may be lost to floods, storm surges, and sea water salinity. Salt from storm surges may also be deposited on agricultural lands and increase ground water salinity. Fruit, nut or lumber trees may be damaged or destroyed by winds, flood or storm surges. Plantation type crops such as banana and coconut are extremely vulnerable. Erosion could occur from flooding and storm surges. Additional items subject to severe damage include overhead powerlines, bridges, culverts and drainage systems. jetties and retaining walls, embankments and coastal dikes, general lack of weatherproofing of buildings, huge losses to building work in progress, scaffolding, marinas, and roofs of most structures. Falling trees, wind-driven rain and flying debris cause considerable damage.

### *Casualties and public health*

There are relatively few fatalities but there may be numerous casualties requiring hospital treatment due to the high winds associated with cyclonic storms. Storm surges may cause many deaths but usually few injuries among the survivors. Due to flooding and possible contamination of water supplies, malaria and other viruses may be prevalent several weeks after the flooding.



*Downed power lines between South Africa and Maputo after March 26, 1985 cyclonic storm.*
UNDRO NEWS, March/April 1985.

### *Water supplies*

Open wells and other ground water supplies may be temporarily contaminated by flood waters and storm surges. They be contaminated by pathogenic (disease producing) organisms if bodies of people or animals are lying in the sources or sewage is swept in. Normal water sources may be unavailable for several days.

### *Crops and food supplies*

The combination of high winds and heavy rains, even without flooding, can ruin standing crops and tree plantations. Food stocks may be lost or contaminated if the stores/structures in which they were held have been destroyed or inundated. It is possible that food shortages will occur until the next harvest. It is also possible that tree and food crops may be blown down or damaged and must be harvested prematurely.

### *Communications and logistics*

Communications may be severely disrupted as telephone lines, radio antennas and satellite disks are brought down, usually by wind. Roads and railroad lines may be blocked by fallen trees or debris and aircraft movements will be curtailed for at least 12 to 24 hours after the storm. Modes of transportation such as trucks, carts and small boats may be damaged by wind or flooding. The cumulative effect of all damage will be to impede information gathering and transport networks.

***The cumulative effect of all damage will be to impede information gathering and transport networks.***

***Q.*** *From your own experience, what has been the greatest loss to communities caused by tropical cyclones? Do your answers agree with the typical losses described above?*

***A.*** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

## Possible risk reduction measures

### *Risk assessment*

The evaluation of risk for a tropical cyclone is a relatively straightforward process. A hazard map should be prepared which illustrates the areas vulnerable to a tropical cyclone in any given year. The following information may be used to estimate the probability of storms of cyclones of various intensities which may strike different sections of the country.

1) Analysis of climatological records to determine how often tropical cyclones have struck, their intensities and locations.
2) History of wind strengths, frequencies, height and location of storm surges, and frequencies of flooding.
3) Information about tropical cyclone occurrences in the past 50-100 years over the ocean adjoining the country.

### *Land use control*

Land use planning for disaster prevention and mitigation is designed to control land use so that least critical activities can be placed in most vulnerable areas. Sensitive issues must be addressed regarding existing conditions, such as cultural patterns of ownership, characteristics of the local economy and population pressures. Population growth and land shortages

*ANSWER* *(from page 71)*

Flooding, of all types, flash floods, riverine flooding, and storm surges.

have pushed the poor further into marginal lands. Squatters may settle in floodplains to be close to urban centers where they seek jobs and services. Land use regulations in these cases would have to be integrated with other social and economic policies.

Policies regarding future development may regulate land use and enforce building codes for areas vulnerable to the effects of tropical cyclones such as wind, flooding and storm surges. For example, in coastal areas, regulations can stipulate maximum building height, type of land use and occupant density of buildings. Another option entails purchase of vulnerable areas by government for use as parks, sports facilities, wildlife preserves, or open grazing land.

### *Flood plain management*

All three major types of flooding (flash, river and coastal floods) may result from a tropical cyclone. Therefore, a master plan for flood plain management must be enacted. (See chapter on floods for additional information.)

### *Reducing vulnerability of structures and infrastructure*

Building regulations establish minimum standards of design, construction and materials that strengthen structures to avoid collapse. The majority of homes in developing countries, however, receive no engineering input and are made of locally available materials In these cases it would be more sensible to provide performance standards, recommendations for construction or improvements to existing construction, as follows:

- Improvement of a building site by raising the ground level to protect against flood and storm surges.
- Low cost housing may be strengthened to resist wind and flood damage. Houses subjected to intense winds are literally pulled apart by the wind moving around and over the building. In preventing this effect, the construction materials are often not as important as the manner in which they are used.
- New buildings should be designed to be wind and water resistant.
- Infrastructure should be inspected prior to the cyclone season and strengthened against wind and floods. Communications lines should be located away from the coastal areas or installed underground.
- Buildings or silos used to store food supplies must be protected against the winds and water.
- Protective river embankments, levees and coastal dikes should be regularly inspected for breaches and erosion, and opportunities taken to plant mangroves to reduce breaking wave energy.

### *Improving vegetation cover*

An important concern in management of the watershed lies in improvement of the vegetation to increase the water infiltration capacity of the soil. The roots of trees and other plants keep the soil intact, preventing erosion while slowing runoff to prevent or lessen flooding. The use of trees planted in rows may also act as a windbreak near houses and compounds, or may be planted around towns. Reforestation and conservation are very cost effective in mitigation of floods and other disasters. (See chapters on deforestation and environmental degradation.)

***Q.*** *What are some mitigation measures that might lessen the loss of the type you answered as being most severe in the previous question?*

***A.*** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

## Specific preparedness measures

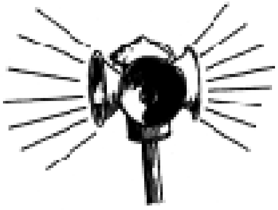
### *An integrated warning/response system*

Specific preparedness measures to counter the impact of tropical cyclones may be classified into two categories:

1. Those of a **long term or seasonal** nature which need to be planned, funded, implemented and operationally tested and coordinated by means of simulation exercises well before a seasonal threat commences. Among these are pre-season coordination meetings at headquarters, district and local levels at which operational contingency plans are reviewed and amended, training and community preparedness programs conducted and maintenance inspections made of all facilities and services which constitute community lifelines. Critical supplies may have to be stockpiled.
2. Those of a **short-term** nature which relate to a state of readiness to act once a contemporary cyclone threat is announced. Among these are domestic, vocational and animal husbandry arrangements to safeguard the survival, property assets and livelihoods of individual families and communities. Crops may have to harvested when a warning is issued to prevent their complete loss. Or boats may need to be moved to more protected shelters.

An integrated warning/response system consists of five sets of tasks:

- technical arrangements for monitoring the lifecycle of tropical cyclones, with supporting research to aid in successful tracking
- conversion of this technical information into timely weather forecasts and warnings to the public
- technical and organizational arrangements with the media and other communication networks to disseminate of warnings and recommended actions and obtain feedback or acknowledgment of messages
- public education through community awareness programs about the hazards of tropical cyclones and training for cyclone disaster management officials
- frequent evaluations to identify deficiencies in the plan



## *Public Warning system*

The three main objectives in a tropical cyclone warning are:

1. To **ALERT** the people to the danger by announcing the existence of a threat due to a cyclone.
2. To **IDENTIFY THE AREAS** where people will be actively threatened by the cyclone and where communities should monitor further warning announcements, and
3. To **CALL THE PEOPLE TO ACTION** by recommending specific preparedness activities which may be part of an integrated warning/ response plan to protect vulnerable resources.

## *Warning phases*

It is the responsibility of each country to determine its public warning procedures, although generally WMO has assisted in coordinating regional arrangements. A suggested warning schedule is as follows:

1. **12 hour media announcements** of the existence and expected motion of a tropical cyclone which has possibly already been named but is unlikely to be a threat for 48-72 hours. This will encourage preliminary community readiness.
2. **6 hour "Alert" or "Watch"** bulletins when a threat is expected but wind strengths of gale force will not commence before 36-48 hours The exact landfall location is not yet available. At this stage, counter-disaster emergency offices will begin to implement plans with a long lead time. Cautionary advice should be offered to distant fishing fleets concerning coastal areas coming under increasing threat (Note: the speed of approach of a cyclone is likely to equal or exceed the return speed of fishing craft).
3. **3 hourly or 6 hourly full "warnings"** are issued when gales are likely and landfall may occur within 24-36 hours. The strength of the cyclone and weather details are available. Depending on the expected angle of approach of a cyclone to the shoreline the locations warned of destructive impact may be narrowed down to coastal sectors within about 300-400 km on either side of expected landfall. Advice should be issued to communities regarding evacuation to shelters or emergency camps, closure of public facilities, or use of them for services. Small craft and fisherman operating in near-coastal waters are warned to return to harbor as roughening of seas occur 12-18 hours ahead of landfall.
4. **Hourly warnings.** If the cyclone comes within radar range, frequently about 18 hours ahead of landfall, warnings may be issued on an hourly basis. Important decisions must occur earlier than 12-18 hours. Attention is given to the eye of the cyclone to determine the velocity of the winds and the likely location of storm surges, heavy rain and flash flooding. General flooding warnings should be issued. All preparedness measures should be finalized six to eight hours before forecasted landfall.
5. **Post landfall forecasts and warnings.** The warning decrease in frequency as the cyclone moves inland and weakens. Winds will usually moderate within 6-12 hours to a low danger level. Flooding may be promoted by heavy rain which may continue for several days and possible rise in river systems due to storm surges and onshore winds. Evacuation may be necessary upon very short notice.

***Q.*** *What are the three main objectives of a cyclone warning system?*

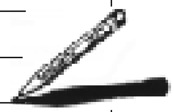
***A.*** ______________________________________________

______________________________________________

______________________________________________

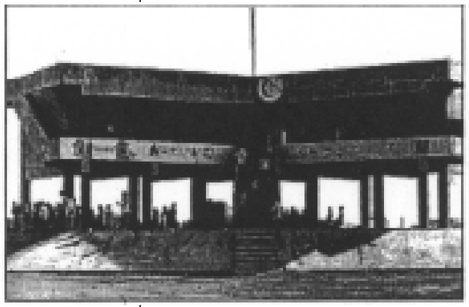
______________________________________________

______________________________________________



### *Evacuation plan*

An essential component of disaster preparedness is an evacuation plan. The plan would specify: a) areas to be evacuated and time required for the operation; b) areas/buildings to be used as shelters; c) assembly points to be used in transferring people to places of safety; d) transport arrangements; e) locations for storage of goods and animals; f) location of first aid clinics. The plan must be tested prior to a real event.



*East Sonadia Cyclone Shelter, Cox's Bazaar, Bangladesh.*

### *Community preparedness*

Systematic methods must be employed to inform people about the threat of a disaster. Public awareness programs must explain some of the very basic issues to clarify the causes of the hazard, the disaster impact, and the ways in which the local population is vulnerable. Explanations of the warning system and evacuation plans must be publicized. There are several methods of promoting public information and education:

1) **Public dissemination of information** through mass media, poster campaigns, town councils and village meetings. These campaigns should intensify as the tropical cyclone storm season approaches, and should encourage the public to share responsibility for preparedness measures with the government officials.
2) **Education programs,** designed for different age levels may be offered in schools and universities, perhaps as part of a science curriculum.
3) **Training programs** should be offered for officials who will play a part in disaster mitigation, preparedness and post disaster assistance. Training programs are also essential for medical personnel to deal with the specific types of casualties brought on by a tropical cyclone.
4) **Community based training** which emphasizes post disaster activities such as practicing the evacuation plan, team efforts to search and rescue, flood fighting measures such as filling and stacking sandbags.

### *Post-cyclone audits*

A post-cyclone audit should be initiated immediately after a cyclone event to facilitate longer term relief and recovery processes, record successes and identify problems. The audit should be prepared by the principal disaster coordinating authority for presentation to the government. It should include total impact, assistance sought, storm parameters, warnings issued, response procedures used and recommendations for future response.

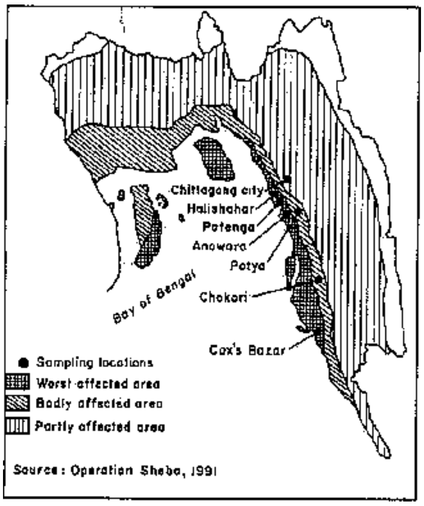
### Typical post-disaster assistance needs

The initial response by local authorities includes:

- ✓ evacuation
- ✓ emergency shelter
- ✓ medical assistance
- ✓ provision of short term food and water
- ✓ water purification
- ✓ epidemiological surveillance
- ✓ provision of temporary lodging
- ✓reopening roads
- ✓ reestablishing communications networks and contact with remote areas
- ✓ brush and debris clearance
- ✓ disaster assessment
- ✓ provision of seeds for replanting.

## ■ *CASE STUDY*

### Cyclone Disaster Vulnerability in Bangladesh




*This map shows the areas affected by the 1991 cyclone and tidal surge, Chittagong Division, Bangladesh.*

After Hoque, et. al., 1993

The climatic conditions required for cyclone formation are common in the Bay of Bengal and 16% of cyclones reach the coast of Bangladesh, usually during May to October. An early cyclone formed in late April of 191, with lower pressures than other recorded cyclones, resulting in stronger winds and greater increases in sea level, due to its prematurity. Warnings were issued to the village level but only 350,000 moved to safety.

The cyclone hit with great destructive force, with gusts up to 223 kph, able to lift a 100 mm concrete roof slab. The cyclone bought torrential rains for five hours, and then a storm surge struck the coast and islands both north and south of Chittagong. On the morning of 30 April, the storm surge submerged parts of the mainland and seven densely populated islands, where it remained standing for another 24-48 hours. Wind and rain continued for five days, constraining rescue efforts, particularly for the island populations.

The cyclone affected more than 4.5 million people in 16 districts, killing about 140,000. Casualties were mostly attributable to the storm surge and 40-50% of the population died in the unprotected islands. On islands protected by embankments, 30-40% died and on the mainland, 20-30%. Considerable damage was inflicted on infrastructure and production and eventually a severe negative impact on domestic growth. Immediately after the cyclone, UNDP/ UNDRO undertook a study of actual disaster management activities for use in the Disaster Management Training Programme (DMTP). The following conclusions were reached regarding the vulnerability of the Bangladesh coastal areas:

1. The entire coast of Bangladesh is vulnerable to cyclone disasters. Protective embankments may have saved some lives but many are minimally effective. Because of population pressures, farmers plant

*ANSWER (from page 77)*

1. **Alert** the population to the hazard threat.
2. Define the **Area** that is threatened.
3. Call those in the warning area to **Action** by explaining preparedness measures that should be taken by the public.

them with root crops and need river pools to grow rice which conflicts with objectives of shrimp producers who require sea pools.

2. The women are very vulnerable to disaster in a male-dominated society where they are dependent on men for disaster preparedness and recovery resources. (80% of the fatalities were women and children.)
3. Infrastructure such as communications, health and service facilities were very vulnerable and had not been assessed for disaster preparedness in recent years. Interruptions in communications severely disrupted relief operations.
4. The number of cyclone shelters were totally inadequate and poorly maintained.
5. The possible severity and effect of the cyclone were not understood either by the urban or the rural population. Some did not prioritize saving their lives against protecting their possessions and livelihood from robbery or squatting. Secondly, past false alarms and no means to compensate the possible loss of possessions increased the possibility that warnings went unheeded.

After the 1991 cyclone, many agencies took action to address some of the problems. The number of cyclone shelters rose in Cox's Bazar from 24 to 229. The Cyclone Preparedness Programme (GPP), a partnership between the government and the Bangladesh Red Cross Society, continued to develop a sophisticated early warning system for seven million people in the vulnerable areas. CPP maintains a 24 hour control room which transmits storm warning by radio to five centers where it is relayed by public broadcast, flags, sirens and word of mouth. The program has a core staff but relies on 27,000 trained community volunteers who often risk their lives to facilitate evacuation.

In 1994, another cyclone of the same intensity struck in May, but luckily its impact was limited to less densely populated areas. Only 400 lost their lives, mainly from flying debris. Evacuation warnings were issued almost 18 hours before landfall. And, perhaps due to memories of the 1991 event but also to efforts of community awareness building, twice as many people moved to safety. Some additional problems, however, identified in the aftermath require further action.

- The national warning signal system, a remnant of the colonial era, is confusing. A simplified system is under consideration.
- Women are reluctant to take responsibility for cyclone preparedness without male family members. It is thought that adding females to the volunteer force may help to mobilize women.
- Volunteers require better equipment to carry out their duties and need to coordinate with volunteers from NGOs at the field level to cover all areas. There are still not enough cyclone shelters (over 200,000 were unable to reach a safe area) and the shelters still pose problems especially for women due to lack of toilets and privacy, and inadequate water supplies.

**Source:** Sevenhuysen, G.P., "Report of Cyclone Disaster Response in Bangladesh." Disaster Research Unit, The University of Manitoba, June 25, 1991.

International Federation of the Red Cross and Red Crescent Societies, "Bangladesh: How to survive a cyclone", **World Disasters Report 1995,** Geneva, 1995.

***Q.*** *1) What particular features of the Bangladesh coast increase the vulnerability of the population?*

*2) What socioeconomic factors increase the vulnerability of the population?*

***A.***

## ■ REFERENCES


Berz, G., "Natural disasters and insurance/reinsurance", *UNDRO News,* Jan./Feb., p. 18-19.

Disaster Management Center, **Natural Hazards: Causes and Effects,** University of Wisconsin Board of Regents, 1986.

**Global Guide to Tropical Cyclone Forecasting,** WMO Technical Document – No. 560, TCP Report TCP-31, Geneva 1993.

**Global Perspectives on Tropical Cyclones,** WMO Technical Document – No. 693, TCP Report TCP-38, Geneva 1995.

**Tropical Cyclone Warning Systems,** WMO Technical Document – No. 394, Tropical Cyclone Programmed Report, No. TCP-26, Geneva 1990.

**Typhoon Commitee Operational Manual,** WMO Technical Document, No. 196, TCP Report, No. TCP-23, Geneva, 1987.

UNDRO, **Mitigating Natural Disasters, Phenomena, Effects and Options,** United Nations, New York, 1990.

UNDRO News, "Toward More Effective Early Warning Systems", July/August, 1990, p. 14-15.

Vickers, Donat O., "Tropical Cyclones", **Nature and Resources,** Vol. 27, No. 1, 1991, p. 31-36.

Wernly, Donald, **The Roles of Meteorologists and Hydrologists in Disaster Preparedness,** WMO/TD–No. 698, Report No. TCP 34, Geneva, 1994.


## ■ RESOURCES

Tropical cyclone advisories and warnings are available from:

Tropical Cyclone Programme (TCP)
Regional Specialised Meteorological Service (RSMS) Tokyo-Typhoon Center c/o Japanese Meteorological Agency, 1-3-4 Ote-Machi
Chiyoda-ku
Tokyo 100, Japan
Phone (24 hours): 81 3 3211 7617
Fax: 81 3 3213 2453

For weather analyses, forecasts and warnings, hydrological products and research:

World Weather Watch (WWW) Programme
41 Avenue Giuseppe-Motta
1211 Geneva 2, Switzerland
Phone: 41 22 730 8216
Fax: 41 22 733 0242

*ANSWER* *(from page 80)*

1. The probability of occurrence of tropical cyclones is very high. Many islands support very large populations who must travel some distance to reach higher ground. The storm surge accompanying the 1991 cyclone inundated the islands making rescue attempts difficult or impossible.
2. The extreme insecurity brought on by population pressure and poverty makes people willing to risk their lives to save their property and livelihoods. Population pressures on land force mitigation measures, such as embankments, to be used for other purposes and thus reduces their effectiveness. Education was lacking regarding the risks accompanying a cyclone, such as storm surges and torrential rains. Women and thus children, are at great risk, if they are not able or willing to protect themselves. There is still not adequate shelter or enough resources for evacuation.

# NOTES

PART 2.2

# FLOODS

This chapter of the module aims to improve your understanding of:

- *the causes of floods and factors which intensify their effects*
- *impacts of floods on human settlements*
- *flood control, prevention and preparedness measures*
- *flood forecasting and warning systems*

## Introduction

FLOODS

Flood occurs when surface water coves land that is normally dry or when water overflows normal confinements. The most widespread of any hazard, floods can arise from abnormally high precipitation, storm surges from tropical storms, dam bursts, rapid snow melts or even burst water mains. The majority of floods are harmful to human settlements and yearly flooding, on average, may claim 20,000 lives and affect 75 million people. However, floods can provide benefits without creating disaster and are necessary to maintain most river ecosystems. Floods replenish soil fertility, provide water for crop irrigation and fisheries, and contribute seasonal water supplies to support life in arid lands.

**FLOOD HAZARD DATA SHEET**

Number killed by declared flood disasters, 1980-89: 16,108

Number affected: 279,330,901 *(OFDA, 1990)*

**Selected severe flood disasters of the 1990's**

| Year | Location | Deaths | Losses in US$ million |
|---|---|---|---|
| 1991 | China (Anhui, Jiangsu, Henan, 100 yr. flood) | 2,470 | 12,500 |
| 1991 | Bangladesh (cyclone storm surge) | 140,000 | 3,000 |
| 1993 | USA (Mississippi-Missouri) | 50 | 17,000 |
| 1993 | Nepal, India, Bangladesh | 2,500 | n/a |
| 1993 | China (Quighai, dam burst) | 290 | 27 |
| 1994 | Italy (Po and Tanaro valleys) | 59 | 3,600 |
| 1995 | China (22 of 30 provinces) | 1,473 | 14,000 |
| 1995 | India, Bangladesh (monsoon) | 700 | 175 |
| 1995 | South Africa (Kwazulu-Natal) | 130 | n/a |

## Causes

The most important cause of floods is excessive rainfall. Rain may be seasonal occurring over wide areas, or may form localized storms which produce the highest intensity rainfall. Some floods are attributed to atmospheric and oceanic processes such as the El Niño Southern Oscillation (ENSO) or strong jet streams. Melting snow is another major contributor to floods.

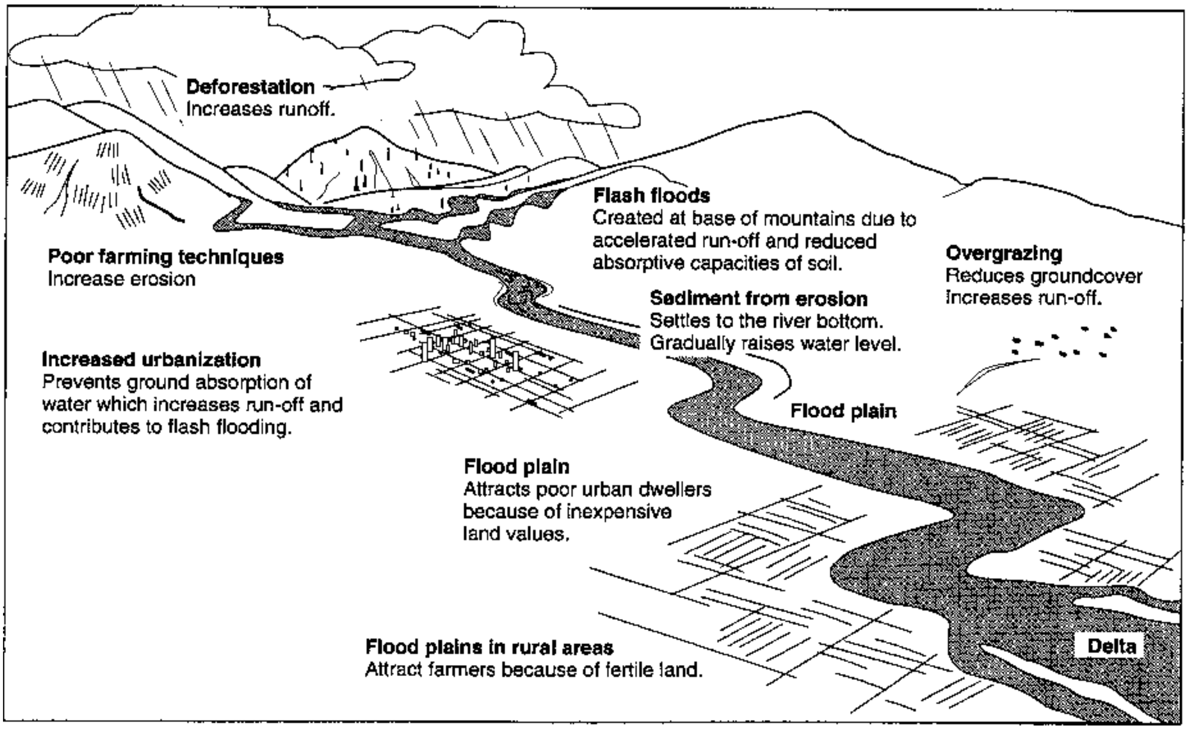
### *Types of floods*

*Truck carried away by flooding*
Mass Media Production Centre, Manila, *UNDRO News,* Sep/Oct 1984

**Flash floods** – These are usually defined as floods which occur within six hours of the beginning of heavy rainfall, and are usually associated with towering cumulus clouds, severe thunderstorms, tropical cyclones or the passage of cold water fronts. This type of flooding requires rapid localized warnings and immediate response by affected communities if damage is to be mitigated. Flash floods are normally a result of runoff from a torrential downpour, particularly if the catchment slope is able to absorb and hold a significant part of the water. Other causes of flash floods include dam failure or sudden breakup of ice jams or other river obstructions. Flash floods are potential threats particularly where the terrain is steep, surface runoff is high, water flows through narrow canyons and where severe rainstorms are likely.

**River floods** – River floods are usually cased by precipitation over large catchment areas or by melting of the winter's accumulation of snow or sometimes by both. The floods take place in river systems with tributaries that may drain large geographic areas and encompass many independent river basins. In contrast to flash floods, river floods normally build up slowly, are often seasonal and may continue for days or weeks. In some semi-arid countries, such as Australia, flooding of dry or stagnant rivers may

**Figure 2.2.1**
*Flooding and its causes*
*Natural Hazards,* Disaster Management Center, 1989.



occur many weeks after the onset of heavy rain, hundreds of kilometers away. Historical records of flooding of towns on the main river can be unreliable for flood protection purposes due to the many contributing river tributaries.

**Coastal floods** – Some flooding is associated with tropical cyclones (also called hurricanes and typhoons). Catastrophic flooding from rainwater is often aggravated by wind-induced storm surges along the coast. Salt water may flood the land by one or a combination of effects from high tides, storm surges or tsunamis. (See the chapter on tsunamis and tropical cyclones for more information.) As in river floods, intense rain falling over a large geographic area will produce extreme flooding in coastal river basins.

### *How do humans contribute to flooding?*

Floods are naturally occurring hazards. They become disasters when they affect human settlements. The magnitude and frequency of floods is often increased due to the following human actions.

**Settlement on floodplains** contributes to flooding disasters by endangering humans and their assets. However, the economic benefits of living on the floodplain outweigh the dangers for some societies. Pressures from population growth and shortages of land also promote settlement on floodplains. Floodplain development can also alter water channels which if not well planned can contribute to floods.

**Urbanization** contributes to urban flooding in four major ways. Roads and buildings cover the land preventing infiltration so that runoff forms artificial streams. The network of drains in urban areas may deliver water and fill natural channels more rapidly than naturally occurring drainage, or, may be insufficient and overflow. Or, the natural or artificial channels become constricted due to debris, or obstructed by river facilities, impeding drainage and overflowing the catchment areas.

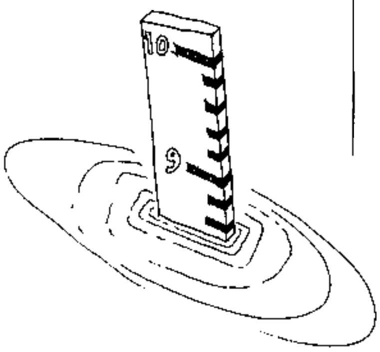
**Deforestation** and removal of root systems increases runoff. Subsequent erosion causes sedimentation in river channels which decreases their capacity.

**Failure to maintain or manage drainage systems, dams and levee bank protection** in vulnerable area also contributes to flooding.

***Floods are naturally occurring hazards. They become disasters when they affect human settlements.***

***Q.*** *Is your community or country susceptible to flooding? What types? How do humans contribute?*

***A.*** ______________________________




## General characteristics

The damage potential of floods is dependent on many factors which determine the key characteristics of the flood event, such as the magnitude of the flood, speed of onset, and the duration of the event. The main considerations are:

**Nature of the precipitation or water source** – Seasonal rains may be intense with multiple storms, causing monsoon floods. Rains associated with seasonal cyclonic depressions may be long in duration and extensive in coverage. High intensity locals storms, usually occurring in summer seasons, and melting snow, usually in the spring, also produce high volumes of water. Other sources of water may be dam bursts or damaged water mains.

**The characteristics of the drainage basin** – The size of the drainage area is important for estimating the depth of water and duration of inundation by water which relate to the degree of damage to structures and vegetation during a flood. Estimates of the rate of rise and discharge of a river form the basis for warnings and zoning regulations. Small catchment areas may have steep slopes, causing rapid runoff and flash floods. The ground conditions are also important to the rate of infiltration such as the moisture in the soil, vegetation cove, depth of snow, or extent of cover by impervious surfaces.

**The velocity of the water flow** – High velocities of flow may be strong enough to undermine the foundations of buildings and are even more dangerous when the water contains debris, such as rock, sediment or ice. The tremendous physical forces are a threat to life and property and may damage sewage and chemical storage facilities causing widespread environmental pollution.

## Benefits of floods

Positive effects of floods include preserving of the wetlands, recharging groundwater, and maintaining the river ecosystems by providing breeding, nesting and feeding areas for fish, birds and wildlife. In Bangladesh, floods replenish the inland fish supply which supports a major industry for dwellers of the delta regions. Generally, floods flush out the pollutants in the waterways. Where dams prevent resulting of downstream areas, reduced fertility and improper drainage may affect agricultural productivity.

Flooding may be almost entirely beneficial to some populations dependent on seasonal rains such as in the arid tropics. In these areas, rain replenishes soil moisture and promotes growth of grasses for animal grazing as well as short term crops. Flooding in semi-arid areas of West Africa is of great economic importance to support large agricultural outputs.

## Predictability

Flood forecasting and warning has become highly developed in the past 20 years and flooding from precipitation or snowmelt is often predictable. Global and regional meteorological centers provide global weather charts several times daily compiled from information from weather satellites, computer models and national maps. Longer range forecasts may be available three to four days ahead while more specific probabilities can be assigned from 24 to 36 hours ahead.

Most river and flash floods depend on observations made by national weather services for activation of flood alert warnings. Weather information is combined with knowledge of the local runoff conditions and flood monitoring measurements to issue warnings. Real-time data communication is possible where technology is available such as satellite, radar and remote sensing equipment, which can track flood waves as they move downriver.

An effective means of monitoring the floodplains is through use of a world-wide satellite communications network such as INMARSAT, an intergovernmental organization, which can provide information to and from remote areas. These systems are strategic when flood conditions exist over international boundaries and they could greatly promote early warning for countries like Bangladesh where 90% of river flow originates in another country. Many countries, however, still rely on wireless networks and telephone connections to monitor flood conditions. Even state-of the art equipment is not always able to deliver flash flood warnings for timely evacuation.

## Vulnerability

Persons living in low lying parts of floodplains, small drainage basins, areas below unsafe dams, low-lying shorelines, or river delta areas, are particularly vulnerable to flood hazards. At notable risk in flood plain settlements are buildings made of earth or with soluble mortar, buildings with shallow foundations or non-resistant to water force and inundation. Infrastructural elements at particular risk include utilities such as sewer systems, power and water supplies, machinery and electronics belonging to industry and communications. Of great concern are flood stocks and standing crops, confined livestock, irreplaceable cultural artifacts, and fishing boats and other maritime industries.

Other factors affecting vulnerability are lack of adequate refuge sites above flood levels and accessible routes for reaching those sites. Similarly, lack of public information about escape routes and other appropriate response activities renders communities more vulnerable.

## Typical adverse effects

### *Physical damage*

Structures are damaged by a) force of impact of flood waters on structures b) floating away on rising waters c) becoming inundated d) collapsing due to undercutting by scouring or erosion and e) damage by water-borne debris.

Damage is likely to be much greater in valleys than in open, low-lying areas. Flash floods often sweep away everything in their paths. In coastal areas, storm surges are destructive both on their inward travel and again on the outward return to the sea. Mud, oil and other pollutants carried by the water are deposited and ruin crops and building contents. Saturation of soils may cause landslides or ground failure.

**Use of a high resolution, GIS-based system for integrated storm hazard modeling**

In the last decade, the science of mapping has dramatically advanced through use of Geographic Information Systems (GIS) and remote sensing (see inset in drought chapter). GIS combines the graphics capability of Computer Aided Design (CAD) software with a data base management system and map processing abilities such as the creation of digital terrain models from a set of contours. Models such as The Arbiter of Storms (TAOS), which use the many available GIS data bases worldwide, can readily access a large library of data. Satellite images from low-earth observation satellites such as LANDSAT and SPOT are also excellent sources of information on surface characteristics. This allows the rapid development of a model to show the potential impact of storms or engineering plans. A storm hazard model generates huge amounts of data and GIS provides a mechanism to make this information accessible to variety of users.

The TAOS system was selected by the Caribbean Disaster Mitigation Project (CDMP) to estimate storm surge, wave action and flooding potential for coastal areas of the Caribbean region. Maps produced by the model are used to identify hazardous areas and to plan evacuation routes for residents. In response to requests from users, a Real Time Forecast System was developed to generate storm surge forecasts every 6 hours.

### *Casualties and public health*

Currets of moving or turbulent water can knock down and drown people and animals in relatively shallow depths. Major floods may result in large numbers of deaths from drowning, particularly among the young and weak but generally inflict few serious but non-fatal injuries requiring hospital treatment. Slow flooding causes relatively few direct deaths or injuries, but often increases occurrences of snake bites.

Endemic disease will continue in flooded areas, but there is little evidence of floods directly causing any large scale additional health problems apart from diarrhea, malaria and other viral outbreaks eight to ten weeks following the flood.

### *Water supplies*

Open wells and other groundwater supplies may be contaminated temporarily by debris carried by flood waters or salt water brought in by storm surges. They will, however, only be contaminated by pathogenic organisms if bodies of people or animals are caught in the sources or if sewage is swept in. Normal sources of water may not be available for several days.

### *Crops and food supplies*

An entire harvest may be lost together with animal fodder resulting in long-term flood shortages. Food stocks may be lost by submersion of crop storage facilities resulting in immediate flood shortages. Grains will quickly spoil if saturated with water even for a short time.

***The majority of deaths and much of the destruction created by floods can be prevented by mitigation and preparedness measures.***

Most agricultural losses result from the inundation of crops. Susceptibility to inundation depends on the type of crop and duration of flooding. Some crops, such as taro are quickly killed by relatively small amounts of flood water. Others may be able to resist submersion but may die eventually if large amounts of standing water stagnate as in the disastrous 100 year 1988 Bangladesh flood.

Large numbers of animals, including draught animals, may be lost if they are not moved to safety. This may reduce the availability of milk and other animal products and services, such as preparation of the land for planting. These losses, in addition to possible loss of farm implements and seed stocks, may hinder future planting efforts.

Floods bring mixed results in terms of their effects on the soil. In some cases, land may be rendered infertile for several years following a flood due to erosion of the topsoil or by salt permeation in the case of coastal floods. Heavy silting may either have adverse effects or may significantly increase the fertility of the soil.

In coastal areas where fish provide a source of protein, boats and fishing equipment may be lost or damaged.

## Possible risk reduction measures

The majority of deaths and much of the destruction created by floods can be prevented by mitigation and preparedness measures. The first step involves identifying vulnerable elements by preparation of a flood hazard map and then integrating that information into a plan for preparedness and development. A strategy might combine regulation of land in the floodplains with flood control measures. Planners may seek contribution from a variety of disciplines to assess risk, the level of acceptable risk, and viability of proposed activities. Information and assistance may be obtained from different sources ranging from international agencies to the community level.

**Mapping of the floodplain** – Floods are normally described in terms of statistical frequency using the 100 year flood plain event parameters for flood mitigation programs. The 100 year flood plain describes an area subject to a 1% probability of a certain size flood in a given year. Depending on the degree of acceptable risk that is selected for an evaluation, other frequencies may be chosen such as 5, 20, 50, or 500 year floodplains.

The basic map is combined with other maps and data to form a complete picture of the floodplain. Other inputs include frequency analysis, inundation maps, flood frequency and damage reports, slope maps and other related maps such as land use, vegetation, population density and infrastructural maps. In some developing countries, obtaining extensive long term information may be difficult. Remote sensing techniques provide an alternative to traditional techniques of floodplain mapping and can be equally or more cost effective as they allow estimates of data otherwise requiring labor intensive collection methods, as in hydrology studies over extensive areas.

**Multiple hazard mapping** – Floods often cause, occur in conjunction with, or result from other hazards. A multiple hazard map, known as a composite, synthesized or overlay map, serves to highlight areas vulnerable to more than one hazard. It is an excellent tool for designing a multiple hazard

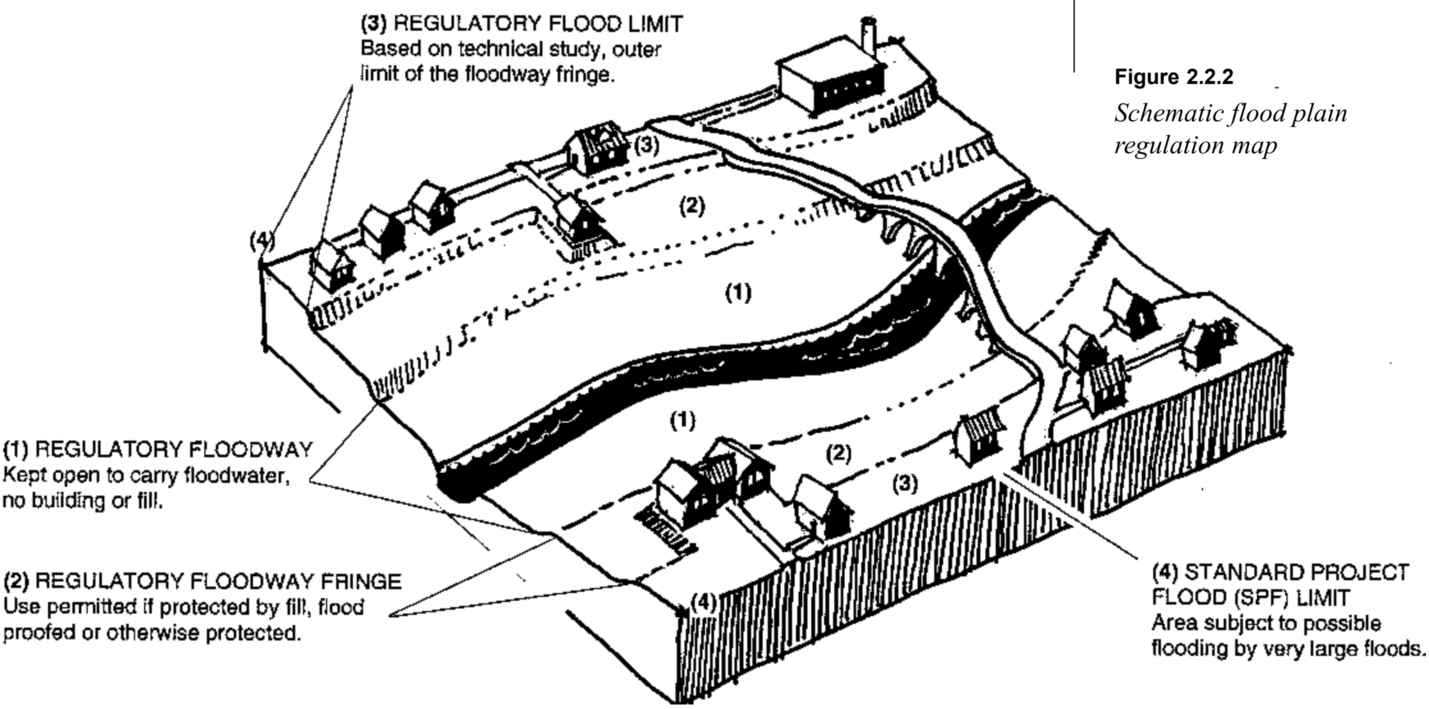



**Figure 2.2.2**
*Schematic flood plain regulation map*

mitigation and emergency plan. It may, however, not be adequate for site-specific, hazard specific engineered activities.

*Land use regulations ensure that flood risks are not made worse by ill-conceived new land uses.*

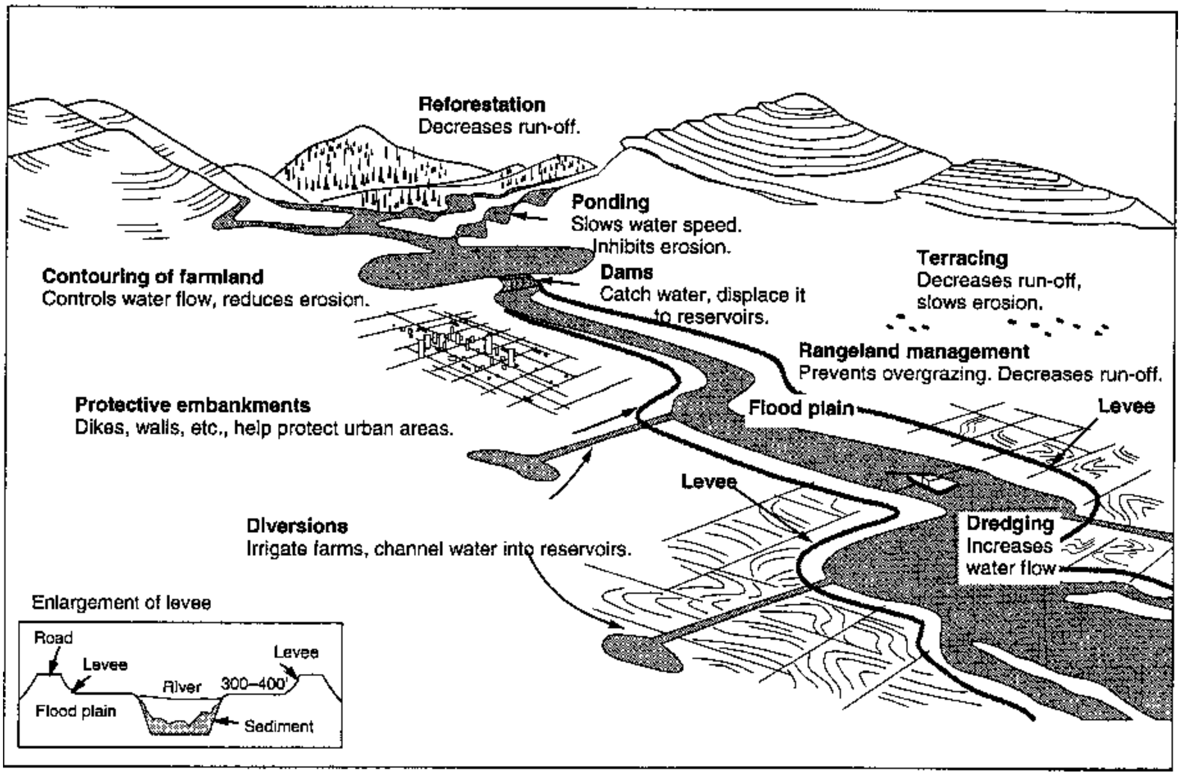
**Land use control** – The purpose of land use regulations is to reduce danger to life, property and development when high waters inundate the floodplains or the coastal areas. Land use regulations ensure that flood risks are not made worse by ill-conceived new land uses. Of particular concern are regions of urban expansion. The following elements should be addressed.

1. **Reduction of densities:** In flood prone areas, the number of casualties is directly related to the population densities of the neighborhood at risk. If an area is still in the planning stages, regulation of densities may be built into the plan. For areas already settled, especially squatter settlements, regulation of density can be a sensitive issue and would have to address the socioeconomic implications of resettlement. Unfortunately, many situations exist where dense unplanned settlements are located on floodplains. Planners must incorporate measures to improve sites and reduce vulnerability.
2. **Prohibiting specific functions:** No major development should be permitted in areas found to be subject to flooding once every 10 years on average. Areas of high risk can be used for functions with a lower risk potential such as nature reserves, sports facilities and parks. Functions with high damage potential such as a hospital are permitted in safe areas only.
3. **Relocation of elements that block the floodway:** In addition to the obvious danger of being washed away, buildings blocking the floodway may cause damage by trapping floodwaters which then oerflow into formerly flood free zones.

Figure 2.2.3

*Flood Plain Management*

*Natural Hazards,* Disaster Management Center, 1989.



4. **Regulation of building materials:** In certain zones wooden buildings and other light structures should be avoided. In some cases, mud houses are permitted only if flood protection measures have been taken.
5. **Provision of escape route:** Neighborhoods should have clear escape routes and provision of refuge areas on higher ground.

Other preventative strategies include:

- the acquisition of floodplain land by developmental agencies, perhaps by swaps that provide alternatives for building sites
- establishment of incentives (loans or subsidies, tax breaks) to encourage future development on safer sites using safer methods of construction
- diversification of agricultural production such as planting flood resistant crops or adjusting the planting season; establishing cash and flood reserves
- reforestation, range management and animal grazing controls to increase absorption (see chapters on deforestation, desertification)
- construction of raised areas or buildings for use as refuge if evacuation is not possible.

## *Flood control*

As mentioned above, land use controls will be of limited use in already developed floodplains. Yet, changes must be implemented to reduce a community's vulnerability to flood damage. The most commonly used options involve measures for flood reduction and diversion and flood-proofing and may be used in combination with land use controls.

***Flood reduction*** aims to decrease the amount of runoff, usually by altering the watershed, and is most effective when employed over most of the drainage basin. Typical treatments include reforestation or reseeding, contour plowing or terracing, and protection of vegetation from fire, overgrazing and clear cutting. Other approaches involve clearing sediment and debris from streams and constructing or preserving farm ponds and other water holding areas. In urban areas, water holding areas can be created in parks and ponds.

***Flood diversion*** includes levee and dam construction and channel improvements. Levees, embankments and dikes restrict flood waters to low value and on the floodplain and are relatively cheap to construct. Dams are capable of storing water so that it can be released at a manageable rate. Levees and dams are subject to failure and also can be damaged by earthquakes. They must be carefully engineered to anticipate maximum water levels, for failures may cause much more damage than if the facility had not been built.

Existing channels can be improved by deepening and widening the riverbed and thus reducing the area of the floodplain. New channel construction may be a feasible alternative to the cost of moving a settlement but, again, great care must be exercised in the design and construction of diversion channels which tend to be costly. Such channels may pose negative consequences for the natural river channel and dependent ecosystem.

***Flood-proofing*** helps reduce the risk of damage. Temporary measures include blocking or sealing entrances or windows, and the use of sandbags to keep flood waters away. Permanent measures include use of hazard resistant design such as raising living or working spaces high above the possible flood level. Houses may be elevated by structural means (stilts) or by raising the land using landfill. Buildings should be set back from water bodies. Land surrounding buildings and infrastructure should be protected against erosion. Streambeds should be stabilized with stone masonry or vegetation especially near bridges.

***Q.*** *What are some possible risk reduction measures which may be used in regard to flood hazards?*

***A.*** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

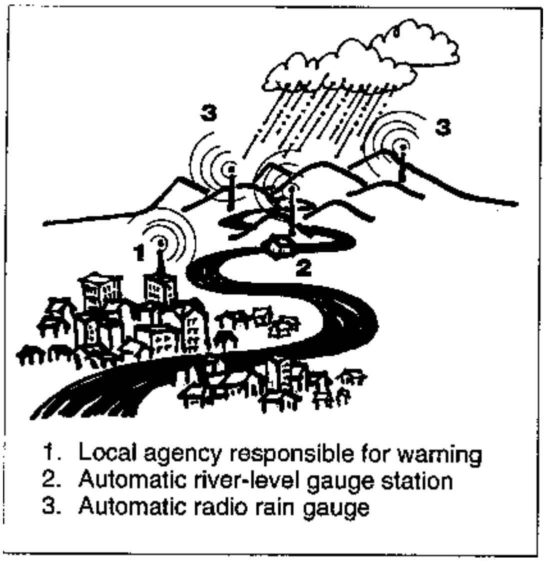
______________________________________________

______________________________________________

## Specific preparedness measures

### *Flood forecasting and warning systems*

Case studies in some countries have shown that flood forecasts and warnings can reduce damage between 6 and 40 percent (WMO). Flood detection systems which provide the basis for flood forecasts, warning and preparedness systems range from inexpensive networks involving volunteers who observe rainfall and stream stages to sophisticated networks of gauges and computerized models. A system known as ALERT (Automated Local Evaluation in Real Time) has demonstrated a cost effective capability to protect life and property through participation by local level agencies. Field stations designed as complete modules are maintained locally.




*Schematic drawing of a radio-based flood warning network*

Whatever the method for warning the public, communication systems must be must be well planned. Evacuation procedures should be practiced on a regular basis. Ways to disseminate warnings include radio, television, warning sirens or bells, public address systems, and at village level by bicycle and on foot. National warning systems are more vulnerable to failure because of problems disseminating warnings locally in a clear manner which reach the target community in time for action to take place. National warning systems are more effective in warning urban populations. Rural systems require respected local leaders to issue clear instruction and prior arrangements for protecting assets and reaching evacuation sites.

### *Community preparedness – Living with Floods*

Inhabitants of flood prone areas usually have a number of traditional methods at their disposal for coping with floods. In countries such as Bangladesh where a great number of people and area of land is vulnerable to flooding, governments would be hard pressed to provide complete coverage with even simply engineered mitigation measures. Some aspects of flood planning and response can be managed at the village level and upgraded with outside assistance. These are:

- issuing warnings at the local level
- participating in flood fighting by organizing work parties to repair embankments or clear debris from drainage areas, pile sandbags and stockpile needed materials
- facilitating agricultural recovery
- planning emergency supplies of flood and clean drinking water
- identifying traditional mitigation and preparedness measures and determining their effectiveness.

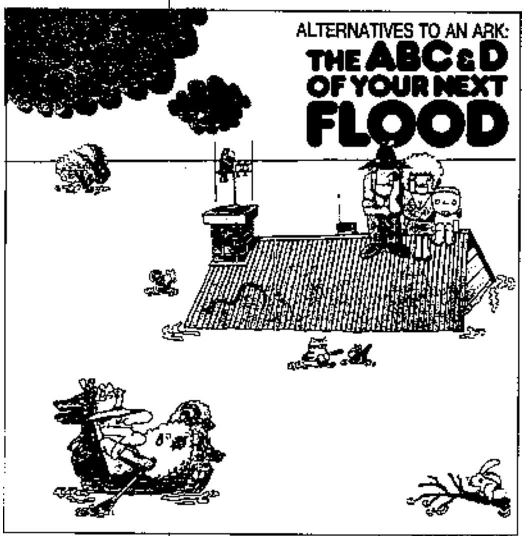
Programs to promote public awareness of the flood hazard may contain the following components:

- Explanations of the function of floodplains, location of local floodplains and drainage patterns
- Identification of flood hazards and warning signs
- Encouraging individuals to floodproof their possessions and develop personal escape plans
- Explanation of community evacuation plans and warning systems, and appropriate post-disaster activities
- Encouraging personal responsibility for flood prevention/mitigation in day to day living practices. This would include use of proper farming practices, prevention of deforestation and maintenance of drainageways.

### *Master plan*

The basic guide that provides local officials and developers or landowners with information about the floodplain is called the master plan. The master plan should contain land use control regulations and a public information program. Steps to be taken in developing a master plan are as follows:

1) Obtain an accurate mapping of the area.
2) Develop the hydrology for several frequencies of flood occurrence including the 100 year.
3) Delineate the floodplains for the flood frequencies using existing channel and floodplain conditions.
4) Estimate flood damages for various frequencies and develop flood damage frequency curves and average annual damages.
5) Conduct a review of all possible flood damage reduction alternatives such as dams, channels etc.
6) Prepare preliminary designs and cost estimates for the remaining alternatives and delineate residual floodplains for the frequencies being used.




*The ABC&D of Your Next Flood* – A public information publication of the Australian Bureau of Meteorology.

7) Determine residual flood damages for each alternative.
8) Complete a cost benefit analysis for each alternative.
9) Review each alternative for other factors such as political considerations, multiple use opportunities and environmental factors.
10) Select an alternative or combination acceptable to each affected jurisdiction.
11) Publish a master plan report with documentation of the above process.

*ANSWER (from page 22)*

Some of the possible risk reduction measures which can be used in relation to flood hazards are: preparation of floodplain mapping, multiple hazard mapping and associated land use controls, physical flood control structures (existing river channel improvement, diversion channels, and dikes and dams), individual site improvements, and individual structural modifications.

## Typical post disaster needs

The initial response to flooding by local authorities should include:

- search and rescue
- medical assistance
- disaster assessment
- short term flood and water provision
- water purification
- epidemiological surveillance
- temporary shelter

The secondary response should include:

- repair or reconstruction
- reestablish or create employment
- assist with recovery of agriculture through loans, distribution of farm equipment and tools and animals
- assist with recovery of small businesses and fisheries

# ■ CASE STUDY


## Flood Mitigation in Vietnam

Every year in Vietnam, floods cause enormous damage to human lives and the economy. The annual rainfall ranges between 1,800-2,500 mm and 70-80% falls in monsoon rains between July and October. Vietnam is vulnerable to flooding disasters from typhoons, severe storms, and rapid runoff in hilly areas. Each year country loses about 300,000 MT of food due to floods and farmers living in flood-prone areas only grow about one crop per year compared to two or three crops in protected areas. Due to salt water incursion, farmers near the sea grow less productive saline resistant rice varieties.

### Measures for flood mitigation

Structured or engineered mitigation measures in Vietnam include dikes, groynes (a structure built at an angle to shore to protect against erosion), reservoirs, channel improvement, canals, pumping systems and sluices. Dikes provide the most effective mitigation and there are 5,000 km of river dikes and 2,000 km of sea dikes, some constructed a thousand years ago. Dike management and control is extremely important and is performed by a large number of brigades and working groups. Dike inspectors monitor the dikes and are rewarded for

detecting weaknesses. The Department of Dike Management and Flood Control under the Ministry of Water Resources, is devoted to day-to-day management of flood control facilities.

Non-structural measures include flood forecasting and warning systems, flood and storm control planning, institution building, and educating, training and mobilizing people. Emergency supplies and repair materials are stockpiled close to weakened dikes. The Vietnamese people participate in flood and disaster management through contribution of 10 days of free labor to repair dikes and other disaster related work.

**Problems encountered**

There are a number of problems with maintenance and management of flood control measures.

- Due to age and poor construction materials in some dikes, there are frequent slides and seepage and many hidden termite nests all of which can lead to dike failure.
- Changes in the river channel during floods can cause bank erosion, but erosion protection such as groynes are expensive and difficult to engineer.
- Many sluices, which allow water to pass through dikes, are damaged and do not operate during floods.
- Some sea dikes are too low and fail during strong typhoons and storm surges.
- Resources and equipment for dike monitoring and repair are inadequate.
- Despite legislation to protect dikes, violations are increasing particularly in densely populated areas.
- Dikes create other problems such as raising the sediment level of the river bed inside the dikes, causing higher water levels and blocking the mouth of the river. The dikes also keep the sediment from depositing on crop land and adding to the fertility of soils, causing farmers to rely on fertilizer, a practice that may eventually harm the environment.

In terms of flood forecasting, there is sufficient time for flood warning due to water flowing upstream into the Mekong River. The Mekong passes through five other countries before reaching Vietnam, and data collection is coordinated by a central agency in Bangkok. However, coverage of the Mekong is hampered by a shortage of facilities, insufficient coverage by hydrological data collection equipment, and inadequate network of radiophones to transmit data.

The Red River flows through China and Laos and steep mountains in Vietnam.

There is no organization to monitor the Red River and water levels can rise very rapidly so that forecasting is more difficult than for the Mekong. Relying on data gathered within Vietnam, flood warnings can be given only 24 hours in advance. If timely data could be obtained from the China catchment area, warnings might be issued up to 72 hours ahead, but present communications systems cannot provide it.

**Possible solutions**

Vietnam has established an organizational structure and culture for flood control which has been successful in the past. In order to strengthen the program and reduce damage from floods, Vietnam needs to invest in equipment to detect unseen weaknesses in dikes, monitor storms using radar, satellite and computer technology, and to forecast floods with hydrometeorological instruments. Communication should be improved for transmitting data from other countries and within the country. To better live with floods, Vietnam will require external assistance to acquire new technology and experience.

Source: Wickramanayake, Ebel, “Flood Mitigation Problems in Vietnam”, **Disasters,** Vol., 18, No., 1, 1994.

## ■ REFERENCES

"Automated Local Evaluation in Real Time (ALERT): A Cooperative Flood Warning Service for Your Community", National Weather Service, Western Region, Box 11188 Federal Building, Salt Lake City, utah 84147, USA.

Askew, Arthur, "Learning to Live With Floods", in **Nature and Resources, Vol. 27, No. 1, 1991, p. 4-8.**

Cuny, Frederick C., "Living with Floods: Alternatives for Riverine Flood Mitigation", in **Development: from vulnerability to resilience,** p. 62-73, 1989.

Disaster Management Center, **Natural Hazards: Causes and Effects,** University of Wisconsin Board of Regents, 1986.

Khan, H.R., "Floods and Flood Preparedness", Disaster Management Course, Asian Disaster Preparedness Center, Asian Institute of Technology, Bangkok, Thailand.

**Natural Disaster Reduction: How Meteorological and Hydrological Services Can Help,** WMO – No. 722, Geneva, 1989.

Smith, Keith, **Environmental Hazards: Assessing risk and Reducing disaster,** Routledge, London, 1996.

Staffa, E., "The Use of INMARSAT in Disaster Mitigation and Emergency Operations", in **STOP Disasters** (No. 18) March-April 1994.

UNDRO, **Mitigating Natural Disasters, Phenomena, Effects and Options,** United Nations, New York, 1991.

**UNDRO NEWS,** "Unprecedented Floods Devastate Bangladesh", Sept/Oct. 1988.

Watson, Charles C., "The Arbiter of Storms: A High Resolution, GIS Based System for Integrated Storm hazard Modeling", **National Weather Digest,** Vol., 20, No. 2, December 1995, pp. 2-9.

Wernly, Donald, The Roles of Meteorologists and Hydrologists in Disaster Preparedness, WMO/TD–No. 698, Report no TCP 34, Geneva, 1994.

## ■ RESOURCES

For more information on the Caribbean Disaster Mitigation Project, contact:
Department of Regional Development
Department of Regional Development and Environment
Organization of American States
1889 F Street
Washington DC 20006 USA
Fax: 202 458 3560
E-mail: vermeirenjan@oas.org
or
CDMP Regional Coordinator
Organization of American States
12 Camp Road
Kingston 4, Jamaica
Phone: 809 960 0639/0640
Fax: 809 928 1921
E-mail: kfordcdmp@uwimona.edu.jm

PART 2.3

# DROUGHT

The chapter of the module will enhance your understanding of:

- *the meaning of drought*
- *the causes of drought*
- *the effects of drought on communities*
- *the factors affecting vulnerability to drought*
- *drought preparedness and mitigation measures*
- *typical assistance needs*

## Introduction

Of all the natural disasters, droughts can have the greatest potential impact and affect the largest number of people. They invariably have a direct and significant impact on flood production and the overall economy. Droughts, however, differ from other natural hazards. Because of their slow onset, their effects may accumulate over time and may linger for many years. Their impacts are less obvious than for events such as earthquakes or cyclones but may be spread over a larger geographic area. Because of the pervasive effects of droughts, assessing their impact and planning assistance becomes more difficult than with other natural hazards.

**DROUGHT HAZARD DATA SHEET**

| | Africa | America | Asia | Europe | Oceania | Total[1] |
|---|---|---|---|---|---|---|
| Number of events, 1969-93 | 277 | 49 | 83 | 15 | 14 | 438 |

**Recent drought disasters[2]**

| Year | Country | Deaths | Affected |
|---|---|---|---|
| 1984 | Ethiopia[3] | Estimates range from 250,000 to one million | 7,750,000 |
| 1987 | India | | 300,000,000 |
| 1988 | Sudan[3] | 250,000 | 3,750,000 |
| 1989 | Angola[3] | 10,000 | 1,900,000 |
| 1990 | Bolivia | | 283,160 |
| 1990 | Burkina Faso | | 2,600,000 |
| 1992 | Mozambique[3] | Reports of tens of thousands | 3,300,000 |
| 1993 | Peru | | 1,100,000 |
| 1993 | Mauritania | Some deaths reported | 446,507 |
| 1995 | Kenya | | 1,000,000 |
| 1995 | Zimbabwe | | 5,000,000 |

1 IFRC, World Disasters Report, 1995

2 OFDA, Disaster History, 1996

3 (also civil strife)

## What is Drought?

There is no universally agreed upon definition of drought. It may be generally defined as a temporary reduction in water or moisture availability significantly below the normal or expected amount for a specified period. However, because droughts occur in nearly all regions of the world and have varying characteristics, working definitions must be regionally specific and focus on the impacts. The impact of drought results from the shortage of water, or the discrepancies between supply and demand for water.

DROUGHT

While droughts are most often associated with low rainfall and semi-arid climate, they also occur in areas with normally abundant rainfall. Humans tend to stabilize their activities around the expected moisture environment, thus, after many years with above average rainfall, humans may perceive the first year of average rainfall as a drought. Further, a rainfall level which meets the needs of a pastoralist may constitute a serious drought for a farmer growing corn. In order to define drought in a region, it is necessary to understand both the meteorological characteristics as well as the human perception of the conditions of drought.

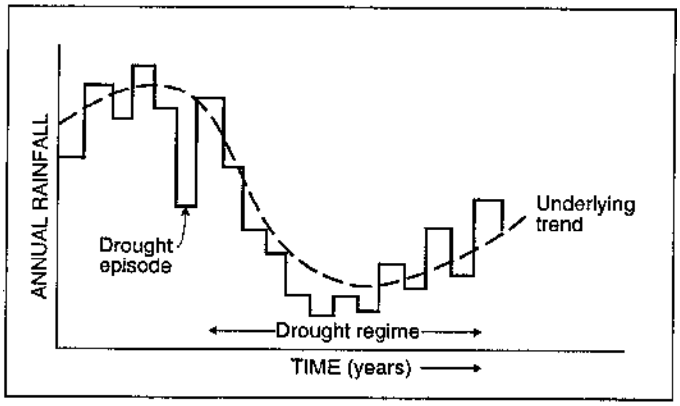


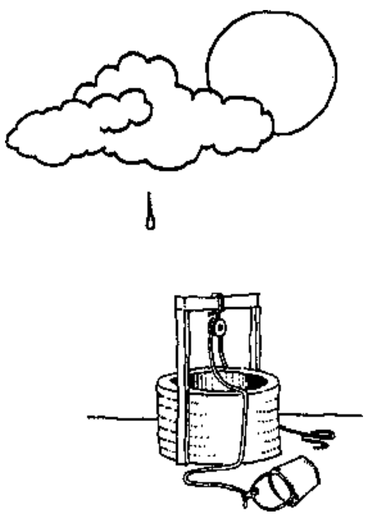

**Figure 2.3.1**
*Schematic presentation of fluctuations occurring on different time scales*

## Types of Drought

Droughts may be grouped by type. **Meteorological drought** results from a shortfall in precipitation and is based on the degree of dryness relative to the normal or average amount and the duration of the dry period. This comparison must be region specific and may be measured against daily, monthly seasonal, or annual timescales of rainfall amounts. Rainfall deficiency on its own, however, does not always create a drought hazard.

**Hydrological drought** involves a reduction of water resources such as streams, groundwater, lakes and reservoirs. Its definition involves data on availability and offtake rates in relation to the normal operations of the system (domestic, industrial, irrigated agricultural) being supplied. One impact is competition between users for water in these storage systems.

**Agricultural drought** is the impact of meteorological and hydrological droughts on crop and livestock production. It occurs when soil moisture is insufficient to maintain average plant growth and yields. A plant's demand for water, however, is dependent on the type of plant, its stage of growth and the properties of the soil. The impact of agricultural drought is difficult to measure due to the complexity of plant growth and the possible presence of other factors which may reduce yields such as pests, weeds, low soil fertility and low crop prices.



Famine drought can be regarded as an extreme form of agricultural drought, where flood shortages are so severe that large numbers of people become unhealthy or die. Famine disasters usually have complex causes often including war and conflict. Although scarcity of flood is the main factor in a famine, death can result from other complicating influences such as disease or lack of access to water and other services.

**Socioeconomic drought** correlates the supply and demand of goods and services with the three above mentioned types of drought. When the supply of some goods or services such as water, hay or electric power is weather dependent, drought may cause shortages. The concept of socioeconomic drought recognizes the relationship between drought and human activities. For example, poor land use practices exacerbate the impacts and vulnerability to future droughts.

***Q.*** *What are the differences between meteorological, hydrological, and agricultral drought and socioeconomic drought?*

***A.***

## Causes

The reasons for lack of rain are not well understood. Displacement of the normal path of the jet stream may steer rainbearing storms elsewhere. Recent research has focused on “teleconnections” or linkages to global scale interactions between the atmosphere and the oceans. Sea surface temperature anomalies (SSTAs) influence heat and moisture such that warm surface water may create air conditions favorable for a cyclone formation. A large scale SSTA is linked to the El Niño Southern Oscillation (ENSO) events in the Pacific. These involve the periodic (every 2-7 years) invasion of warm surface waters into the normally colder waters off the coast of South America. Droughts of 1982-83 in Africa. Australia, India, Brazil and the United States coincided with a major El Niño.

*Parched agricultural land*
FAO, *UNDRO NEWS,* May/June, 1989.

**Human causes of drought** – Land use practices which give rise to desertification such as deforestation, overcultivation, overgrazing, and mismanagement of irrigation are thought to result in greater persistence of drought. Traditional drought coping systems in Africa such as pastoralists’ use of seasonal grazing lands and farmers’ use of fallow periods have been reduced due to population pressures and economic policies. (See chapter on desertification.)

Droughts vary in terms of intensity, duration and coverage. Droughts tend to be more severe in drier areas of the world due to low mean annual rainfall and also longer duration of dry periods. In dry areas, drought builds up slowly over a number of poor rainfally years. Dry conditions in the African Sahel over a 16 year period led to widespread famine in 1984-85. In fact, a quarter of a century of drought conditions had largely existed in the Sahel, interrupted by heavy rains in 1994. The area affected by drought in a country has important implications for food security. Larger countries such as India or Brazil are rarely completely affected by drought but smaller countries may be totally affected. Worldwide food availability may be adversely affected by drought in grain exporting nations.

***Although it may be possible to indicate the immediate cause of a meteorological drought occurring in any particular location, it is often not possible to indicate the underlying cause.***

## Predictability

Through use of modern meteorological monitoring and telecommunications systems, it is possible to prevent casualties from drought-induced food shortages. The slow onset of drought allows a warning time between the first indications, usually several months, to the point where the population will be affected. In 1987, satellite imagery and rainfall reports indicated areas within Ethiopia with below normal moisture and allowed timely intervention to avert a major food shortage. Longer term prediction requires analysis of a century of rainfall data which isn't available for some parts of the world.

*The slow onset of drought allows a warning time between the first indications, usually several months, to the point where the population will be affected.*

Many drought prone countries have developed systems to collect information on which to base warnings and have created Early Warning Units in relevant government ministries. Information is compiled on meteorology, agriculture, crop marketing and nutritional status in order to promptly detect failing food supplies and initiate remedial action. However, better early warning systems are needed which are capable of using sophisticated technology, but also support highly trained field workers to initiate warnings at the community level.

The importance of regional factors in drought management prompted WMO to create AGRHYMET, a regional program headquartered in Niamey, Niger. The aim is to train local staff to improve agricultural production, water availability and drought response. Other regional organizations in Africa, such as CILSS (Permanent Inter-state Committee for Drought Control in the Sahel) and IGAD (Intergovernmental Authority on Development) have promoted regional early warning systems which combine the output of national systems with information from other sources, such as satellite remote sensing outputs. FAO GIEWS (Global Information Early Warning System) is an important source of information worldwide.

**The role of NOAA satellite data in drought early warning and monitoring**

Satellite remote sensing is a powerful tool for detecting the characteristics of drought from a distance. In addition to the unique vantage point and condensed view, remote sensing provides a permanent and historical record. The National Oceanic and Atmospheric Administration (NOAA) satellites using Advanced Very High Resolution Radiometer (AVHRR) provide twice-daily coverage of the planet's surface and the data is available at many receiving stations around the world. Other satellites such as SPOT and LANDSAT also monitor vegetation and are frequently use for mapping and inventory.

NOAA has developed crop monitoring technology for monitoring large areas of the Sahel in Africa and this has been adapted for other areas. The twice-daily coverage plus the reasonable cost make it useful for drought early warning and monitoring. The Normalized Difference Vegetation Index (NDVI) uses the satellite data to indicate areas of stressed vegetation, which when combined with local weather data and crop information can help make predictions of food shortages.

## Factors contributing to vulnerability

Drought is more likely in dry areas with limited rainfall. Physical factors such as the moisture retention of soil and timing of the rains influence the degree of crop loss in droughts. Dependency on rain-fed agriculture increases vulnerability. Farmers unable to adapt to drought conditions with repeated plantings may experience crop failure. Livestock-dependent populations without adequate grazing territory are also at risk. Those dependent on stored water resources or irrigation will be more vulnerable to water shortages and may face competition for water.

Drought related effects will be more severe in countries with overall yearly food deficits and for largely subsistence level farming and pastoralist systems. In these areas, drought can more easily lead to famine and deaths. Food shortages will have the greatest impact where malnutrition already exists. Most famine related deaths occur in the semi-arid countries of sub-Saharan Africa, including the Sahel region. In more developed countries, the consequences of drought are largely economic.

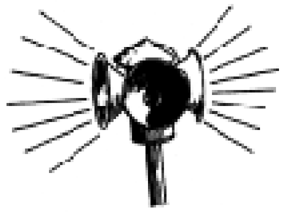
Where drought response has not been adequately planned by governments and assistance agencies, assistance measures may be poorly targeted or ineffective. Vulnerability to death may increase when coping mechanisms have been exhausted and abnormal migration takes place. Situations in relief camps such as overcrowding and poor sanitation may cause death from disease.

## Typical adverse effects

Adverse effects can be grouped into sectors; economic, environmental and social.

### *Economic:*

- Losses in production of crops, dairy and livestock, timber and fisheries
- Loss of national economic growth and development
- Income loss for farmers and others directly affected
- Losses from tourism and recreational businesses
- Loss of hydroelectric power and increased energy costs
- Losses to industries related to agricultural production
- Decline in food production and increased food prices
- Unemployment from drought related production declines
- Revenue losses to government and increased strain on financial institutions



*Early warning systems*

### *Environmental:*

- Damage to animal and fish species and habitat
- Wind and water erosion of soils
- Damage to plant species
- Effects on water quality (salination)
- Effects on air quality (dust, pollutants, reduced visibility)

### *Social:*

- Food shortage effects (malnutrition, famine)
- Loss of human life from food shortage or drought related conditions
- Conflicts between water users
- Health problems due to decreased water flow
- Inequity in the distribution of drought impacts and relief assistance
- Decline in living conditions in rural areas
- Increased poverty, reduced quality of life
- Social unrest, civil strife
- Population migration for employment or relief assistance

(Adapted from Wilhite, 1992)

***Q.*** *What are some factors contributing to vulnerability from drought?*

***A.*** ______________________________

*ANSWER (from page 22)*

Meteorological drought is a reduction in rainfall. Hydrological drought is a reduction of water resources including lakes, streams, underground aquifers, and groundwater. Agricultural drought is the result of both hydrological and meteorological drought on agricultural practices. Socioeconomic drought correlates supply of weather dependent goods with demand.

*The effects of drought*
L. Anström, *UNDRO News,* Jan/Feb. 1985

## Possible risk reduction measures

### *Drought planning*

Although the call to develop national drought plans may result from external agencies such as the WMO, support must spring from internal consensus of relevant agencies for the plan to be successfully initiated and implemented. The plan may be incorporated into an already existing plan, for example, on water resources management, or overall disaster management. Constraints to planning include lack of understanding of the drought hazard, low priority for droughts and inadequate financial resources or capacity to implement the plan.

The plan should address the inevitability of drought and incorporate resource management to prevent and reduce impacts, rather than focus on relief assistance. This pro-active approach is likely to produce significant saving on future relief costs. Drought planning efforts should use existing political and institutional structures to the extent possible. The initial step in planning is the appointment of a "National Drought Commission" to oversee the development of the plan and to formulate a general drought policy.

The plan itself should have three main components.

1. The monitoring component will assess current and future water availability and moisture conditions.
2. The impact component will determine the economic sectors most likely to be affected by drought and how assistance can be targeted.
3. The mitigation and response component will design long term programs to reduce vulnerability to drought.

Other steps in the process involve supporting research and institutional capacity building, enhancing the connections between scientific and policy issues, implementing the drought plan, developing education programs, and evaluating the drought plan.

### *Land use planing*

As drought places pressure on land, better agricultural practices may help withstand the effects of drought. These include erosion control by planting grass or legume ground covers and protecting against wind. Animal stocking rates should be appropriate relative to available pasture and water supplies. Use and development of drought resistant crops should be encouraged. Development of water reservoirs may also be helpful.

### *Risk mapping*

Maps which depict levels of population vulnerability as determined through measurements of risk ascertained by NDVI indicators (see inset above), and assessment of coping ability as measured through income and assets, are extremely valuable tools for targeting food assistance, development planning and preparedness for emergencies. The Zambia vulnerability, assessment and mapping project (VAM) sponsored by the World Food Programme, utilizes geographical information systems (GIS – for further explanation, see chapter on foods) to produce a straight forward analysis for decision makers. Variables measured include food and livestock production, wages, nutrition indicators and access to markets.

## Preparedness and response measures

### *Community preparedness*

Most rural societies have developed strategies which anticipate food shortages and facilitate survival in drought. Livestock dependent societies diversify their herds and build up animal numbers in good years as insurance against drought. Others diversify their income sources so they are less dependent on rain for subsistence. In times of drought, people may eat less and rely on foods not normally consumed. Assets are often sold and family members sent away for work or better conditions. Those with previous experience in coping with drought may not need to migrate.

While appropriate drought coping mechanisms should be strengthened, a state of preparedness needs to include planning for warning and implementation of mitigation measures at the community level. Following the drought-famines of 1984-5 and 1987, Ethiopia developed a national disaster plan which links disaster preparedness to sustainable development through capacity building of the nationwide network. Committees for early warning are established at central, regional and village levels for data collection and information dissemination. Relief plans are initiated at the community level and contain measures for addressing needs for income, water and food as well as expected roles for all involved agencies. Employment generation schemes help provide income or food by implementing various disaster reduction projects.

*Water pumped from the Niger River for irrigation.*
UNDP/Ruth Massey, *World Development,* Sept. 1989.

### *Drought response*

Food shortages may be addressed through price stabilization, food subsidies, employment creation, general food distributions or supplementary feeding programs. Water shortages may be addressed by rationing water or curbing usage for non-drinking purposes.

**Disaster assistance** – In severe droughts or famine droughts, government intervention may be required to save lives. International agencies such as the UN (UN-DHA, UNHCR, UNICEF or WFP) and NGOs may assist in the response. Effective drought response involves the following:

1. Collection and dissemination of reliable and timely information on drought conditions and impacts, particularly current weather data for drought assessment.
2. Impact assessment tools are needed to supply decision makers with information to plan mitigation actions.
3. Operational procedures for relief should be coordinated under one agency and criteria established ahead of time.
4. To avoid delays, assistance programs should be established ahead of time.

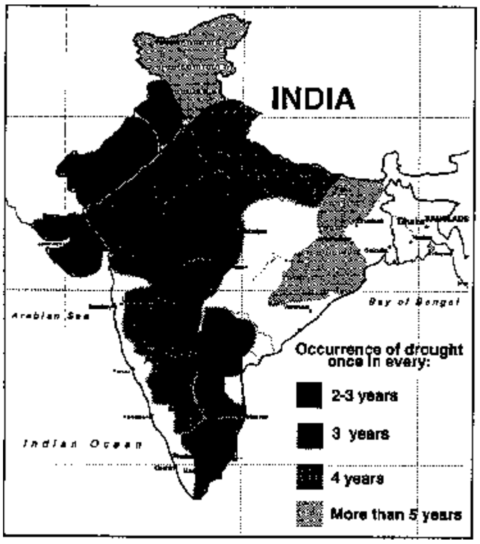
Studies of recent drought relief programs have illustrated the need to target food assistance wisely as large scale distribution of food does not always help those at greatest risk. Many deaths of children and the elderly may be due to disease and poor sanitation from water shortages. Donated food supplies may undermine local markets and result in dependency on food aid.

***While appropriate drought coping mechanisms should be strengthened, a state of preparedness needs to include planning for warning and implementation of mitigation measures at the community level.***

### Typical post disaster assistance needs

The affected population must be assisted to replace assets lost during the period of temporary food insecurity and, where this is realistic, to re-establish their livelihoods. The severity of this food insecurity episode will determine the nature and scale of the rehabilitation requirements. Thus, if migration to camps and significantly increased mortality has occurred, then a comprehensive rehabilitation program will be required. This may involve health care, counseling, assisting the migrants back to their homes and material support to re-establish their homes and productive activities. Such provisions may include seeds, tools, cooking utensils, blankets, and support until households are capable of supporting themselves. If the impact of the temporary food insecurity episode has not been severe and most households have not been obliged to sell productive assets (e.g. consume seed stocks and breeding livestock) then a rehabilitation program may not be required. Rehabilitation needs should therefore be carefully assessed and interventions tailored to the particular situation.

## ■ *CASE STUDY*




*Map of India showing frequency of drought by area.*

After Subbiah, quoted in Wilhite, 1993.

### Drought Management in India

India is regularly affected by drought and has suffered some of the most disastrous famine droughts in history. Dry regions in India include about 94 million ha and about 300 million people, or one-third of India's population live in these areas. More than 50% of the dry region is affected by droughts once every four years.

India has sought to achieve food self-sufficiency in order to withstand drought, but has also evolved numerous strategies to cope with droughts. These strategies changed over the past 20 years from a purely relief focus to the present drought management approach. In the drought of 1965-67 India had to import more 10 million tons of grain and rely on significant outside assistance. However, the country met the needs of the 1987-88 drought without food imports and with its own resources. Although the 1987-88 drought was more severe in terms of rainfall deficiency and affected twice as many people, mitigation efforts were more successful in reducing impact.

The improvement in drought response can be attributed to an increased resilience and improved level of drought preparedness. India's response to the need for enhanced drought management has, in fact, contributed to overall development which subsequently has reduced vulnerability to drought. Each major drought brought on new challenges. The drought of 1965-67 encouraged the "Green Revolution" which made the country self-sufficient in grain production. After the 1972 drought, employment generation programs were developed for the rural poor The 1987-88 drought relief effort focused on preserving quality of life by not only providing food but also clean drinking water and health care.

Current drought management practices in India include the following:

1. **Operation of an early warning system** – Meteorological conditions, particularly the monsoon rains from June to September, are closely monitored. Hydrological conditions such as reservoir and groundwater levels, and agricultural production are also monitored. Early warning enables response to drought well before famine indicators occur.
2. **Drought preparedness measures** – Communities contribute to planning for drought management and relief. Institutions for health care, veterinary care, water resources and disaster assistance are ready to expand services in times of drought.
3. **Conservation of water** – Water is budgeting during droughts. Additional water supplies were developed for drought affected areas and those with chronic shortages.
4. **Stabilizing crop production** – Contingency crop planning involves trying to save crops from drying out, planting alternative crops, use of seed reserves, and measures to improve production in irrigated areas and in nontraditional seasons.
5. **Assurance of access to food** – A national food security system makes grain available at a reasonable cost and stabilizes market prices. Food is distributed from surplus to deficit areas. Additional food supplies are provided to families with caloric deficiencies during drought based on nutritional surveys.
6. **Preservation of farmers assets** – Employment generation schemes are offered to the rural work force to stabilize incomes. To enable farmers to keep livestock, fodder is transferred from surplus to deficit areas.

Since seasonal vulnerability to drought is a reality in India, the country will continue to tackle problems of drought management. The transfer of food, fodder and water resources to vulnerable areas is costly and is thought to increase dependency and undermine the ability of local systems to cope. What is needed is greater understanding of traditional household response systems in order to strengthen useful components.

Source: Subbiah, A.R., "Indian Drought Management: From Vulnerability to Resilience", in Wilhite, D.A. (ed) **Drought Assessment, Management, and Planning; Theories and Case Studies,** Klewer Acad. Publ. Boston, 1993.

ANSWER *(from page 101)*

Some factors contributing to the vulnerability to drought are:

– the proportion of agricultural production which is irrigated
– the moisture retention capacity of the soil
– the timeliness of the rain
– the adaptive behavior of the farmers

## ■ REFERENCES


Borton, J. and Clay E., "The African food crisis of 1982-86". **Disasters** 10 (4), 258-273, 1986.

Corbett, J., "Famine and Household Coping Strategies" **World Development** Vol. 16 (9), 1099-1112, 1988.

de Waal, A., **Famine That Kills: Darfur, Sudan 1984-85,** Oxford: Oxford University Press, 1989.

Disaster Prevention and Preparedness Commission, "General Guidelines for the Implementation of the National Policy on Disaster Prevention and Management", Addis Ababa, Ethiopia, July 1995.

Dréze, J. and Sen, A., **Hunger and Public Action.** Oxford: Oxford University Press, 1989.

Johnson, G.E., Achutuni, VR, Thiuvengadachari, S., and Kogan, F., "The Role of NOAA Satellite Data in Drought Early Warning and Monitoring Selected Case Studies", in Wilhite, D.A. (ed) **Drought Assessment, Management, and Planning: Theory and Case Studies,** Klewer Acad. Publ, Boston, 1993.

Minear, L. et al., **Humanitarianism Under Siege: A Critical Review of Operation Lifeline Sudan** Red Sea Press, New Jersey/Bread for the World, Washington, 1991.

Nicholls, N., "The El Niño/Southern Oscillation Phenomenon" in M. Glantz et al. (eds.) **The Societal Impacts Associated with the 1982-83 World-wide Climate Anomalies.** Boulder, Colorado: UNEP/NCAR, 1987.

Rahmato, D., **Famine and Survival Strategies: A Case Study from Northeast Ethiopia.** Uppsala: Scandinavian Institute for African Studies, 1991.

Smith, Keith, **Environmental Hazards: Assessing Risk and Reducing Disaster,** Routledge, London, l1996.

Wilhite, Donald A. A Methodology for Drought Preparedness, **Natural Hazards,** 13: 229-252, 1996.

Wilhite, Donald A., **Preparing for Drought: A guidebook for developing countries,** UNEP, Earthwatch Climate Unit, 1992.

WFP, "GIS as a tool in disaster preparedness – the Zambia vulnerability assessment and mapping (VAM) project", presented at "Using GIS for disaster management" workshop, Madison, Wisconsin, Dec. 4-6, 1996.


## ■ RESOURCES

For monthly food outlooks and special reports, contact:

Global Information and Early Warning System on Food and Agriculture (GIEWS)
Office of the Chief, ESCG
FAO
viale delle Terme di Caracalla
00100 Rome, Italy
Phone: 39 6 522 53737
Fax: 39 6 522 54495
E-mail: GIEWS1@fao.org

PART 3.1

# ENVIRONMENTAL POLLUTION

This chapter of the module should enhance your understanding of:

- *the causes of air and water pollution, ozone depletion, and possible global warming*
- *the relationship of these degrading processes to other hazards*
- *the characteristics of degrading processes and their impact on the global ecosystem*
- *options for action to prevent further degradation of the environment.*

## Introduction

The world population is expected to be 8.3 billion by 2050, increasing by 86 million people annually. Despite the pressures placed on natural resources by the expanding population, many poor countries still desperately need the benefits accompanying industrialization and economic growth. In general, people in developing countries are much more vulnerable to the effects of environmental degradation because they are poorer and often more directly dependent on the land.

The world's environmental dilemma requires urgent action and international cooperation. This chapter is devoted to heightening your awareness of three aspects of the environmental pollution hazard: air and water pollution, ozone depletion, and possible global warming.

### ENVIRONMENTAL POLLUTION HAZARD DATA SHEET

**Greenhouse Gas Emissions, 1991–1992 in thousands of metric tons**

| | Carbon Dioxide | Industrial $CO_2$ from Land Use Change | Methane Sources Solid Waste | Coal Mining | Oil and Gas Prod. | Rice Prod. | Livestock |
|---|---|---|---|---|---|---|---|
| Africa | 715,773 | 730,000 | 1,700 | 1,700 | 6,000 | 2,400 | 9,000 |
| Europe | 6,866,494 | 11,000 | 17,000 | 6,600 | 15,000 | 420 | 14,000 |
| North and Central America | 5,715,466 | 190,000 | 11,000 | 6,100 | 8,200 | 590 | 9,200 |
| South America | 605,029 | 1,800,000 | 2,200 | 280 | 2,200 | 870 | 15,000 |
| Asia | 7,118,317 | 1,300,000 | 9,900 | 20,000 | 12,000 | 65,000 | 30,000 |
| Oceania | 297,246 | 38,000 | 690 | 1,400 | 310 | 75 | 3,300 |

More than 70% of the global population does not have clean water. One fifth of fresh water fish species is endangered or extinct partly due to water pollution.

Source: **World Resources,** 1992-93 and 1996-97.

## Causes

### *Air and water pollution*

Varous parts of the environment are subjected to the effects of toxic (poisonous) chemicals produced in manufacturing, such as paint and metal production, and the burning of fossil fuels including gasoline, coal, and oil. Some of these chemicals are heavy metals such as lead which are essentially non-degradable. Other toxic compounds are purposely introduced into the environment, such as pesticides. The toxic chemicals may accumulate and affect the quality of the air and water. Other pollutants of importance are from biological sources such as human wastes, soil sediments and decaying organic matter.

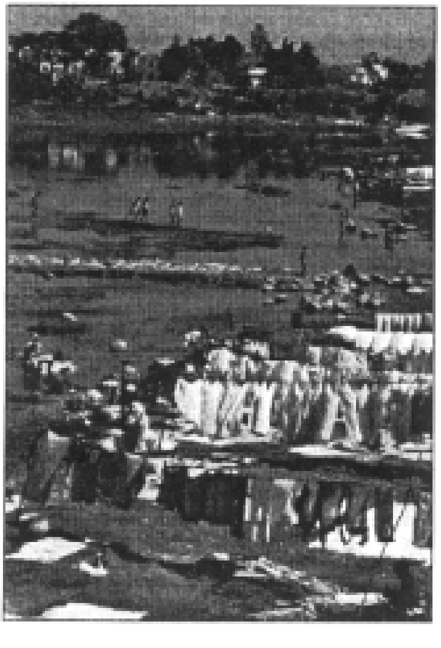
**Air pollution** – Much of the world's urban population breathes polluted air at least part of the time. Sulfur dioxide ($SO_2$), a major pollutant, is a corrosive gas harmful to humans and the environment. Electricity generation using fossil fuels s the key source of this compound in industrialized countries. In developed countries, the burning of fossil fuels such as coal contribute. Other air pollutants include nitrogen oxides, carbon dioxide, and lead, mainly from vehicle exhaust.

**Marine pollution** – Sewage is the major cause of ocean pollution. Raw sewage, containing human excreta and domestic wastes, is disposed of in large quantities directly into the ocean. Often industrial effluents are also piped into the ocean. Other pollutants include marine litter, spills of petroleum or other chemical compounds such as those containing mercury and dumped radioactive substances.

**Fresh water pollution** – Human waste and other domestic wastewaters are often discharged directly into nearby bodies of water, particularly in urban areas. In developing countries this waste may be completely untreated. Industrial effluents from paper making industries, chemicals, metalworking, textile and food processing industries reach bodies of water by direct discharge or by leaching from dumps.

*River in Madras, India is polluted with domestic and human waste.*

UNDP/Robson, *Source*, June 1990.



The clearing of land for agricultural uses and agricultural practices such as irrigation and use of fertilizers and pesticides have seriously affected water quality in many countries. Deforestation on an unprecedented scale has lead to soil erosion, causing accelerated runoff and sediment deposits in riverbeds. The sediment level in rivers may increase 100-fold in deforested areas during rainy seasons.

Runoff of nitrogen from fertilizers, particularly in industrialized nations, renders some water unfit to drink without treatment. Use of irrigation systems may lead to increased salinity of water sources and salt water intrusion on coastal areas where water is withdrawn. Approximately 25% of the world's pesticide market is used in developing countries mainly on cash crops. Accumulations of pesticide toxins are found in food, soil and water. Although data on Africa is lacking, studies in Asia indicate that rivers and lakes in Indonesia and Malaysia have very high levels of PCBs (poly-chlorinated by-phenols) and some pesticides.

***Q.*** *What is the main cause of marine pollution worldwide? Is this true in your country or community?*

***A.*** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

## *Ozone depletion*


Ozone is a rare form of oxygen which is composed of three (normal oxygen gas has two) atoms of oxygen. Most of the atmospheric ozone is concentrated in the upper atmosphere, or stratosphere, forming the ozonosphere or the ozone layer and is located 11 to 24 km above the earth. Ozone screens out harmful wavelengths of ultraviolet radiation from the sun, protecting life on earth. Ultraviolet light is associated with skin cancer and cataracts, and reduced phytoplankton in the oceans. Thinning of the ozone layer is caused by released chlorofluorocarbons (CFCs), a chemical used in refrigeration, foam products and aerosol propellants.

The CFCs that damage the ozone layer may also contribute to global warming. They compose a fraction of greenhouse gases yet they account for 20% of the warming trend due to their radiative trapping potential (10,000 times greater than carbon dioxide).

## *Global warming*

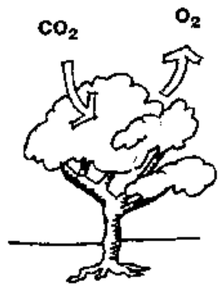
Global temperatures appear to be higher today than they have been since 1862, when temperatures were first recorded by instrumentation. The last 15 years include some of the hottest temperatures ever recorded. One explanation for this increase is a global warming caused by the "greenhouse effect".

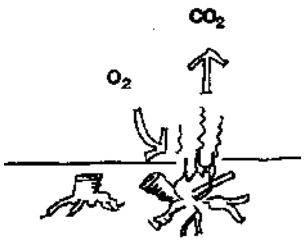
The term "greenhouse effect" is used to describe the role of certain atmospheric gases such as carbon dioxide ($CO_2$), methane and water vapor in trapping radiations which would otherwise leave the atmosphere. Without this canopy of gases and clouds, the earth's temperature would be very cold. The atmospheric gases, therefore, behave similarly to a greenhouse.

***Since the beginning of the Industrial Revolution in the late 18th century, $CO_2$ in the atmosphere has increased by nearly 25 percent, mostly due to combustion of coal, oil, natural gas and gasoline.***

Since the beginning of the Industrial Revolution in the late 18th century, $CO_2$ in the atmosphere has increased by nearly 25%, mostly due to combustion of coal, oil, natural gas and gasoline. Currently there is strong scientific consensus that buildup of greenhouse gases should lead to a warming of global atmosphere. Computer models, used to examine the climatic effects of increasing $CO_2$, suggest that if $CO_2$ doubles, global temperatures would increase on average by 3-5 degrees C.

Trees play a vital role in recycling carbon dioxide by taking in carbon dioxide, transforming it chemically, storing the carbon and releasing the oxygen into the air. When trees are cut down, left to decay or burned, they release stored carbon to the air as carbon dioxide. Recently, in Central Africa, the virgin rainforests were found to have air pollution levels comparable to




***The greenhouse effect is still a subject of controversy in the scientific community in that both the magnitude and the timing of the warming and future climatic changes are uncertain.***

industrial areas. A major cause of this pollution is the fires which rage for months across hug stretches of land to clear shrubs and trees for the production of crops and grasses. It has been estimated that deforestation accounts for 20% of total atmospheric content of $CO_2$. The effects of acid rain (pollutants which are held in the clouds and fall back to earth in rainwater) and air pollution in Europe, Canada and the United States also contribute to the increase of $CO_2$.

Another "greenhouse gas" is methane. Methane is generated by bacteria as they break down organic matter and is emitted largely by landfills, cattle and fermenting rice paddies. The concentration of methane gas in the atmosphere has doubled in the past two hundred years mainly with the expansion of animal husbandry and rice cultivation, the increased number of landfills and leaking natural gas pipelines.

The greenhouse effect is still a subject of controversy in the scientific community in that both the magnitude and the timing of the warming and future climatic changes are uncertain. The status is as follows:

✓ FACT: Greenhouse gases are responsible for keeping the planet warmer than it would be otherwise.
✓ FACT: Concentrations of greenhouse gases are increasing at unprecedented rates.
? THEORY: Continued greenhouse gas emissions will lead to global warming.

## General characteristics and adverse effects

### *Air pollution*

The pollution of the troposphere (lower atmosphere) is damaging to agricultural crops, forests, aquatic systems, buildings and human health. Primary pollutants often react to form secondary pollutants (acidic compounds), a frequent cause of environmental damage. The following effects are possible:

- Crop and vegetation damage by injury to plant tissue, increasing susceptibility to disease and drought.
- Decline in forests due to leaf damage by acidic compounds, acidic soils and stresses of multiple pollutants.
- Damage to aquatic ecosystems so they no longer support life.
- Degradation of building materials, such as metals, stone and brick.
- Damage to respiratory tracts, impacting human health.

### *Marine pollution*

The major effects of marine pollution are:

- Spread of pathogens from human wastes, such as viruses, protozoans, which cause hepatitis, cholera, typhoid and other contagious diseases.
- Release of undegradable materials such as plastics and netting which may injure marine mammals.
- Oil pollution from oil spills.
- Spread of hazardous chemicals and radioactive substances in the marine ecosystem where they may accumulate in seafood.

*ANSWER (from page 107)*

The main source of marine pollution is sewage.

### *Freshwater pollution*

Freshwater pollution in the following adverse effects:

- Untreated wastewater carries viruses and bacteria from human feces into human drinking water which can result in illness or even in infant mortality.
- Eutrophication, or decay of organic matter, occurs decreasing oxygen levels in water and upsetting the balance of the aquatic ecosystem.
- Industrial effluents negatively affect health of those drinking untreated water from the tainted source and cause the water to become acidified, reducing its ability to support aquatic life.
- Sediment is carried by runoff from eroded soil deposits in drainage basins, reducing the capacity and exacerbating flooding.
- Salinization from irrigation may have harmful effects on downstream agriculture.
- Pesticides and fertilizer chemicals accumulate in water and affect tissues in living organisms.

***Q.*** *Are any of the pollution effects listed above now apparent in your country or community? If so, are the causes known?*

***A.*** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

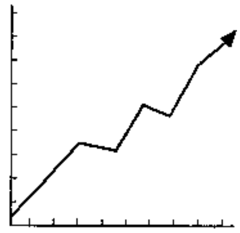
### *Ozone depletion*

**Health effects** – As the ozone layer thins, more medium wave ultraviolet light (UV-B) will reach the earth. Non-melanoma skin cancer will certainly increase in light-skinned individuals and people living near the equator. UV-B also reduces the ability of the body's immune system to fight foreign substances entering through the skin. Diseases of the eye such as cataracts and deterioration of the cornea and retina are also associated with UV light.

**Effects on marine life** – UV-B radiation can penetrate the ocean's surface, damaging fish larvae and juveniles and the phytoplankton base of the food chain, affecting growth and reproduction. As fish provide an average of 14% of the animal protein in the world (60% in Japan), the impact could be significant.

### *Global Warming*

The impacts of global warming are still uncertain. Computer models are unable to make reliable predictions of regional changes. The following changes *may* occur:



Temperature

**Sea level rise** – Melting of the arctic ice sheets and alpine glaciers could cause the seas to expand and sea levels to rise. Depending on the degree of global warming, the seas will rise 30 cm to 2 meters by the year 2075, jeopardizing coastal settlements and marine ecosystems. A rise of one meter in sea level could food 15% of arable land in Egypt's Nile Delta; would food 12% of Bangladesh and displace 11 million people. The tiny island of the Maldives, inhabited by 200,000, would be submerged.

**Climate change** – Natural disasters such as superhurricanes could become common. A temperature increase of a few degrees in tropical seas can intensify hurricane production. Warmer oceans may increase the occurrence of the El Niño phenomenon near the coast of Peru. El Niño is the incursion of warm surface water to the coast which occurs every three to seven years with disastrous effects. This phenomena inhibits phytoplankton growth, causes fish and shell fish to migrate or die forcing higher forms of life (birds and human beings) that depend on sealife to migrate or die.

Other climatic changes that could occur would lead to warmer and drier conditions in middle latitudes, higher temperatures in semi and tropical area and higher rates of evaporation. Increased temperatures may cause more rain globally but the distribution effects are uncertain. The combined effects of the increased $CO_2$ and climate changes may alter plant and animal productivity. Plants may actually grow faster and larger but may have reduced nutritive value.

**Changes in ecosystems** – In warmer climates, grasslands, savannas and deserts may be expected to expand, rendering them vulnerable to increased degradation through erosion and fire. Animal species which could not adapt to the temperature increases would have to relocate to survive, a difficult task, given population pressures on land. Plant species unable to adapt would perish.

**Public health impact** – Global warming might affect mortality due to heat stress and increase the incidence of respiratory diseases, allergies and reproductive illnesses. Expansion of geographic ranges of vector-induced diseases such mosquito-borne malaria and yellow fever is possible. Higher temperatures in high latitudes would result in fewer cold-related deaths.

## Prediction and measurement

***Pollution production is related to the per capita consumption. As countries develop, pollution also tends to increase.***

**Air and water pollution** – Pollutants are measured all over the world but to a much lesser degree in developing countries. The most comprehensive data collection system is UNEP's Global Environment Monitoring System (GEMS) which provides data on sulfur dioxide and particulate matter in urban air and contaminants in water resources. Pollution production is related to the per capita consumption. As countries develop, pollution also tends to increase.

**Ozone depletion** – Ozone levels are regularly monitored each year especially in the Southern Hemisphere where a seasonal ozone hole opens over Antarctica every year. Twenty million tons of CFC have been manufactured and have either escaped to the atmosphere or eventually will.

**Greenhouse effect** – Greenhouse gas emissions are regularly measured all over the world. But even if the exact levels of future greenhouse emissions were available, difficulties would arise in predicting the effects on global climate. Climatic models are used to study climate change, but the models differ in their interpretation of all the various interactions in the earth's systems. This is partly because information being put in the system for analysis is not complete or is poorly understood.

## Possible risk reduction measures

### *Air and water pollution*

Most nations are acting individually to control air pollution. Certain basic requirements are as follows.

- Air quality standards must be set which measure pollutants at a distance from the source and set limits on acceptable levels.
- Every source of an air pollutant should be required to meet certain emission limits and may have to acquire the technologies to do so.

Pollution control of coastal areas in the past have proved that recovery to some extent is possible. The banned pesticide DDT which was present in many forms of marine life, is now decreasing in concentration. Most strategies for protecting the oceans must address broader ranges of pollutants from sewage to industrial effluents. More effort should be focused on establishing policy for protection of coastal areas on national and international levels.

Improvement of soils can decrease the possibility of water contamination by toxic chemicals and decrease runoff, thereby lessening silting and sedimentation of waterways. Establishing terraces and contour bunds, stabilizing sand dunes, building check dams and planting trees and shrubs can help to stabilize soil. Watershed mapping, management and protection are also of vital importance in ensuring a safe and plentiful drinking water supply. Proper systems to dispose of human waste should be promoted.

Regulations must be established and enforced by government agencies to protect citizens against the toxic effects of pesticides and other chemicals. Improvement of soils will also help to absorb and degrade toxins. Further studies must be made of the effects of pesticide residues. Farmers may use crop types resistant to pests or use an integrated approach to pest management, requiring less pesticide. (See chapter on pest infestitations.)

### *Ozone depletion*

International cooperation to limit CFC emissions through an international treaty called the Montreal Protocol intends to reduce production and use of CFCs by 50% from 1986 levels before the year 2000 in industrialized nations, but developing countries are allowed to increase their use slightly. Meanwhile research is attempting to address the need for CFC substitutes, minimizing loss to the atmosphere, and recycling. Countries can regulate import and use of aerosols and disposal of refrigeration units.

***Scientists, however, estimate that 20% of greenhouse gases (mainly $CO_2$) results from deforestation, a trend occurring at a devastating rate in developing countries, particularly in tropical rainforests.***

### *Global warming*

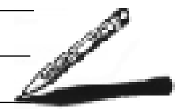
Developed countries account for more than half of greenhouse gas emissions but emissions of developing nations are increasing. Scientists estimate that 20% of greenhouse gases (mainly $CO_2$) results from deforestation, a trend occurring at a devastating rate in developing countries, particularly in tropical rainforests. In any case, global warming could affect the entire planet and steps can be taken to prepare for its effects and to prevent its acceleration. Successful strategies would include:

1) Reducing the rate of deforestation (see chapter on deforestation). Plant trees to solve community needs for wood, such as fuelwood, or to provide profits for individual farmers with agroforestry.

2) Increase the efficiency of energy production and use. Promote energy efficiency in urban areas and support renewable energy sources such as windpower, water power, geothermal, and solar. These maybe of great use in areas where no electricity sources exist.
3) Develop regulations to curb pollution from traffic emissions and industry in urban areas.

**Q.** *International measures have been instituted to limit the production of CFCs. Is your country affected by these agreements? Does your country have other pollution problems which would require international efforts to solve them?*

**A.** ____________________________________________



## Specific preparedness measures

### *A national environmental safety and protection plan*

Government ministries can demonstrate vision and provide a basis for environmental protection by establishing a plan, perhaps integrated with other disaster preparedness and mitigation plants. This should include strategies for regulating air and water pollutants, CFCs, promoting lead-free fuel and alternate fuel sources for fossil fuels and establishing programs for land use, conservation of soil, water and species, and control of hazardous substances that may harm the environment.

### *Education*

Education is a vital tool for environmental awareness. It is only through understanding the relationships of ecosystems and long term effects of degradation that people will be motivated to act. Women's groups in India have established a tree protection lobby. Their motto is "trees are not wood" a concept which promotes trees as a vital part of the ecosystem involving carbon dioxide exchange to the air and a root system to hold down the soil.

Education regarding the environment should begin in the early years. Education for adults may take place in farmers cooperatives, women's cooperatives and in village settings or may accompany programs to distribute seeds and tools. Use of the media, such as television, radio and posters or newspapers, is an effective method to reach many people in a short time.

**Worldwide Movement to Protect the Environment through Computer Networking**

The report of the World Commission on Environment and Development, "Our Common Future", gave rise to the 1992 UN Conference on Environment and Development, also known as the Earth Summit. The Summit produced a prescription for planetary survival called Agenda 21 and conventions on biodiversity and climate change. The Summit promoted the activities of the more than 100,000 community environmental organization and the many thousands of NGOS working for sustainable development.

The use of computers plays a vital part in linking the environmentally concerned network. Some key tools are found on the Internet, a global "network of networks" which includes millions of data bases and discussion forums where people meet through their computers and exchange information. Ways to access the information includes electronic mail (email), a gopher, which enables direct access, and the World Wide Web, which is interactive and is the fastest growing sector of the Internet.

For example, information on the climate change convention may be obtained at the climate change secretariat in Geneva through email address "secretariat.unfcc@unep.ch". Information on UNEP Industry and Environment OzonAction Programme is found on web site "http://www.unepie.org/ozat/ozatfly.hmtl whyd". A listserv is an automated mailing feature which brings people together on the Internet. UNEP listserv INFOTERRA helps to answer your questions on environmental matters. To subscribe to this list, send a message to "listproc@pan.cedar.univie.ac.at".

### *Institutional development*

Ongoing training of personnel in vital government institutions is important to keep pace with everchanging environmental concerns. Training should be an integral part of development programs. Institutions involved in implementing government policies on environmental protection must keep current with the latest scientific discoveries. This may be accomplished by allocation of government resources or by collaboration with UN or other agencies.

### *Impact assessment tools*

Air and ground surveys will indicate where areas of deforestation, desertification and soil erosion exist and are progressing. Socioeconomic surveys will help determine the effects of environmental degradation on the income and health of the population. Waters and soils may be tested for purity and content of toxins. Comparison of data on temperature and climate from year to year may indicate global warming trends.

## ■ CASE STUDY


### Trying to save the Black Sea

The Black Sea, named for the dark clouds and fierce storms that affect its shores each autumn, faces an even darker future. The residues of modern agriculture and industry now threaten its marine life and the air quality for its bordering countries of Bulgaria, Romania, Turkey and parts of the new Commonwealth.

The Black Sea is particularly vulnerable to pollution as it collects ten times more water per square meter of surface area than any other sea or ocean. It is fed by several major rivers carrying in a large portion of the pollutants. The most important is the Danube which flows through eight highly industrialized countries all utilizing chemically intensive agricultural practices.

In addition, the Black Sea has natural pollutants: organic matter collected over thousands of years, now decaying and diminishing the supply of oxygen in the water vital to life. In the unique two strata structure of the sea, where salt water from the Mediterranean forms a bottom layer and fresh water forms a top layer, toxic hydrogen sulfide, produced from decomposing matter, remains in the bottom layer where oxygen is not present. Construction of irrigation works and dams have reduced the flow of fresh water into the sea, so that the toxic layer which was previously 200 m below the surface has now risen to a depth of only 80 to 100 meters.

Further deterioration of the Black Sea and the air pollution from industries around it, could be economically disastrous to the surrounding countries which depend on it to draw tourists. The resource-poor country of Bulgaria has developed a 20 year plan to save the sea and to bolster tourism. The plan calls for:

- A total ban on discharge of any pollutants into the sea.
- Regulation of development of concentrated industrialization in the coastal zone.
- Environmental monitoring by 20 different institutions in coordination with UNDP.
- Restricting the inflow of fertilizer and the building of dams.

- Proliferation of blue mollusks to eat plankton which use the precious oxygen. Shellfish cultivation is also a possibility.
- Holding a convention to assess the sea's environmental problems and draw up a blueprint to attack them. This plan would be closely linked to the international effort to address the pollution problems of Europe's major rivers.

*Source:* Hanley, Mary Lynn, "Can the Black Sea be Saved?", in **World Development,** Vol. 3, No. 2, March 1990, p. 6.

## ■ REFERENCES


Hynes, Patricia, **Earth Right,** Prima Publishing and Communications, Rocklin, CA, 1990.

Lean, Geoffrey, **Atlas of the Environment,** World Wildlife Fund, Prentice Hall Press, New York, 1990.

Liverman, Diana M., "Global Warming and Mexican Agriculture: Some Preliminary Results", draft publication, Pennsylvania State University, 1991.

Moore, James, **The Changing Environment,** Springer-Verlag, New York, 1986.

Sand, Peter H., **Lessons Learned in Global Environmental Governance,** World Resources Institute, 1990.

Taking Action, An Environmental Guide for You and Your Community, UNEP, 1995.

**World Resources 1988-89,** World Resources Institute, Basic Books, New York, 1988.

**World Resources 1990-91,** World Resources Institute, Oxford University Press, 1990.

**World Resources 1992-93,** The World Resources Institute, UNEP and UNDP, Oxford University Perss, 1992.

**World Resources 1996-97,** The World Resources Institute, UNEP, UNDP and The World Bank, Oxford University Press, 1996.


## ■ RESOURCES

For additional information on environmental pollution contact:

UNEP Headquarters
P.O. Box 30552
Nairobi, Kenya
Phone: (254 2) 621234
Telex: 22068 UNEP KE
Fax: (254 2) 226886 or 226890
UNEP Internet home page: http://www.unep.ch

PART 3.2

# DEFORESTATION

This chapter of the module aims to increase your knowledge about:

- *extent and rate of deforestation and its contribution to other disasters*
- *causes and effects of deforestation*
- *measures that control or prevent deforestation*

## Introduction

DEFORESTATION

Deforestation is the removal or damage of vegetation in a region that is predominantly tree covered. Deforestation is a slow onset hazard that may contribute to disasters caused by flooding, landslides, drought and desertification. Deforestation reaches critical proportions when large areas of vegetation are removed or damaged, harming the land's protective ad regenerative properties. The rapid rate of deforestation in some parts of the world is a driving force in the yearly increase of food disasters in these areas.

Approximately 17 million hectares of tropical forests and woodlands are converted into agriculture, pasture lands or other uses every year (FAO, 1990). This includes 7.3 million hectares of tropical forest (6.1 million ha of moist forest) and 3.8 million hectares of open and savanna woodland. Less than 10% of the land being deforested is replanted every year. Although the amount of forest land coming under protection or conservation is growing, the future still poses problems due to rapidly increasing pressures of population, development and exploitation.

**DEFORESTATION HAZARD DATA SHEET**

**Estimated 1981–90 in thousands of hectares**

| | Extent of Forest and Woodland | Average Annual Deforestation | Average Annual Reforestation | Managed Forest | Protected Forest |
|---|---|---|---|---|---|
| Africa | 1,136,676 | 5,000 | 296 | 2,327 | 9,635 |
| N/Cent. America | 934,480 | 1,759 | 2,540 | 102,884 | 37,404 |
| South America | 1,082,587 | 6,950 | 608 | 0 | 16,169 |
| Asia | 668,415 | 3,600 | 1,408 | 48,705 | 25,050 |
| Europe | 178,340 | NA | 1,031 | 74,628 | 1,752 |
| USSR (formerly) | 929,600 | NA | 4,540 | 739,900 | 20,000 |
| Oceania | 156,073 | 26 | 115 | 0 | 8,009 |
| **Total** | **5,288,555** | **17,309** | **10,538** | **968,444** | **118,019** |

Source: United Nations Economic Commission for Europe and FAO in **World Resources,** 1992-93.

## Causes

The spread of agriculture, forewood collection, and unregulated timber harvesting are the principal and immediate reasons for deforestation. Beneath these obvious causes are fundamental problems in development such as inefficient agricultural practices, insecure land tenure, rising unemployment, rapid population growth and environmental pollution. In addition, some governments fail to regulate and preserve forestlands or adopt policies that undervalue forest resources and promote rapid depletion.

### *Farming*

The major cause of forest loss is the spread of farming. Agricultural land may be cleared for commercial ventures such as sugarcane, coffee or rubber plantations, a principle cause of deforestation in Central America. In the tropical rainforests, both legal and illegal colonists are trying to farm the former jungle lands, where soil conditions are very fragile. Up to 90% of the nutrients are in the vegetation rather than in the soil. When the forest is cut and burned, a nutrient surge occurs in the soil, lending initial fertility. After cropping and exposure to sun and rain, however, soil fertility rapidly declines and the area becomes unproductive, in many cases prompting the farmer to slash and burn new forest areas.

Many people in the Amazon Basin, Central Africa and Southeast Asia still practice shifting cultivation techniques, allowing fallow periods between cropping for soils to regenerate. This practice becomes unsustainable if populations increase to the extent of forcing people into smaller areas. Insecure land tenure or fixed land titles may also force overuse of the land.

Because of crowded conditions in cities and farm areas, many people migrate to areas of marginal fertility where they must keep moving their fields to produce sufficient food. Where this occurs, the migrant farmer may damage timber, wildlife and human resources. In Venezuela, which has a high rate of unemployment and rising numbers of landless peasants, 30,000 families live and farm in national parks, forest reserves and other legally protected areas. An influx of shifting cultivators who settled on the watershed above the Panama Canal has caused increased silting of a major reservoir which supplies Panama City.

### *Grazing*

In Central and South America, large areas of tropical forest have been cleared to create grazing lands. A major proportion of this can be attributed to economic enterprises designed for meat production. The Brazilian government has granted large land concessions to both domestic and foreign corporations wanting to raise cattle in the Amazon area. In Central America, virgin forest is being destroyed by ranchers who intend to export beef to the United States.

### *Firewood collection*

Firewood collection can contribute to the depletion of tree cover, particularly in lightly wooded areas. Due to lack of alternative fuels and fuel efficient stoves, this is especially a problem in Africa and highland countries in Asia such as Nepal. In areas of dense woods, dead material may fill local

requirements for fuel. The outright destruction of trees for fuel occurs most commonly around cities and towns, where commercial markets for firewood and charcoal exist. Well organized groups and individuals bring fuelwood by vehicle, pack animals and carts into many cities, hastening local deforestation.

**The fuelwood crisis** – Today 100 million people in developing countries cannot meet their minimum needs for energy, and close to 1.3 billion consume fuelwood resources faster than they are being replenished. In parts of West Africa today, some urban families spend one fourth of their income on wood or charcoal for cooking. In India, firewood is subsidized for the poorest of the poor to prevent starvation.

UN/Milton Grant: *UNDRO NEWS,* Sep/Oct 1991.

## *Logging*

Extensive logging in humid tropical forests, particularly in Asia and in temperate and mountainous forests, is conducted by large multinational corporations for export or to fill building needs in cities. The procedure seldom involves “clear cutting”. However, in the cases of unmanaged forests, logging tends to “dream” the forest; that is, a relatively limited number of valued or well known species is logged, leaving aside an important part of the resources and occasionally disrupting the whole system. Creaming (although a less radical alternative to clear cutting) still causes significant damage to vegetation and wildlife, a fact which is not apparent from the statistics. A study in Indonesia revealed that logging operations damaged or destroyed about 40% of trees left behind. The roads created by logging operations may encourage settlers to enter the forest and begin slash and burn agriculture, so that eventually even more of the forest is lost.

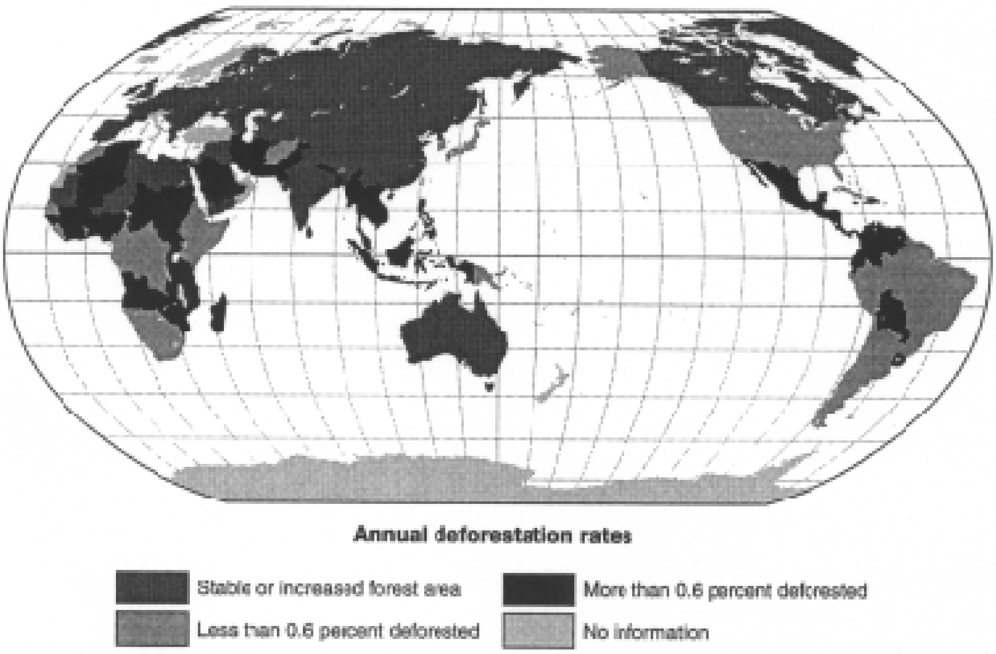



**Figure 3.2.1**

*World map showing estimated annual deforestation rates by country, 1980-1990. After Food and Agriculture Organization of the United Nations (FAO), “Forest Resources Assessment 1990: Global Synthetis”, FAO Forestry Paper 124 (FAO, Rome, 1995), Annex 1.*

***Q.*** *What are the major activities which lead to deforestation?*

***A.***

## General characteristics

Trees play a vital role in regulating our atmosphere, ecosystems and weather systems. They recycle carbon dioxide, a gas now increasing in the atmosphere and thought to contribute to global warming. They release moisture to the air thus contributing to rainfall and moderating local and global climate. Their roots trap nutrients, improve soil fertility, and also trap pollutants keeping them from the water supply. They provide habitats for species, engendering diversity. They nurture traditional cultures by giving shelter, wood, food and medicinal products. These benefits are lost as trees are destroyed.

The root systems of vegetation help retain water in the soil, anchor the soil particles and provide aeration to keep soil from compacting. When vegetation dies, the nutrients go back to the soil. when root systems are removed, soil becomes destabilized. Water tends to flow off the top of the soil instead of percolating in, and carries valuable topsoil along with it. This silt eventually forms sediment in the drainage basins.

Deforestation poses the most immediate danger by its contribution to other disasters. For example:

- Destabilized soils are more susceptible to *landslides* and may increase the landslide risk in areas vulnerable to earthquakes and volcanoes.
- Loss of moisture from deforestation may contribute to *drought* conditions which in turn may trigger *famines.* Soil nutrients may also be lost through erosion of topsoil resulting in decreased food production and possible chronic food shortages.
- Erosion and dry conditions combined with loss of vegetation and soil compaction result in *desertification* and unproductive lands.
- Dryness may accelerate the spread of *fires.*
- Research has conclusively proven that deforestation of watersheds, especially around smaller rivers and streams, can increase the severity of *flooding,* reduce streamflows, dry up springs in dry seasons and increase the amount of sediment entering waterways.

Of all the hazards listed above, flooding is perhaps the most serious side effect of deforestation. Usually, curative measures rather than preventative, such as dredging and dam building, are taken to solve flooding problems. As flooding worsens in developing countries, more attention is being given to protection of watersheds. In India, food damages between 1953-78 averaged US$ 250 million per year. Today, evenmore people live in food prone areas. It is possible that the food problems will not be lessened without reforestation of the increasingly denuded hills of northern India and Nepal.

***Q.*** *What are the secondary hazard which may be caused by deforestation?*

***A.***

## Predictability

Measurement and monitoring of forested areas may be conducted through ground level sampling, and aerial or satellite surveys. Each method has drawbacks. Ground sampling is tedious and hard to extrapolate; aerial surveys are expensive, and satellite imagery poses difficulty in distinguishing forest from other vegetation. Combinations of methods usually produce the best results.

Three different prediction methods are given below:

1) One type of study predicts future deforestation rates by **extrapolating present rates of deforestation into the future.** If the present rate of deforestation at 6.1 million hectares per year continues, the tropical moist forests will be completely cleared in 177 years. Where deforestation is more acute the losses will be more serious. Cote d'Ivoire and Nigeria annually lose about 5.2% of their forests, while Costa Rica, Sri Lanka and El Salvador lose between 3.2 and 3.6%. Each of these countries could lose all forests between 2007 and 2017. (WRI, 1988-89)
2) Another forecast for 43 tropical countries was made using a **mathematical model** which assumed that when forests in a country fell to a critical level, governments would take action to prevent further deforestation. Considerably more optimistic, the results predicted deforestation rates to decrease to between 0.9 and 3.7 million hectares per year beginning in 2020.
3) One **theoretical** forecast incorporates the effects of population growth and increasing consumption which might be assumed to increase the rate of deforestation worldwide. However, growth of economies and technologies at the sae time may assist to curtail the deforestation process if governments take appropriate action.

***Q.*** *What are three methods for prediction of rates of deforestation?*

***A.***

## Typical adverse effects

The specific impacts of deforestation include:

- loss of soil fertility in the tropics and loss of productive capacity
- soil erosion and deposition of sediment
- increased runoff
- reduction in rainfall and increase in temperature
- destruction of biodiversity and traditional cultures
- loss of "free" goods such as fuels, food and medicines
- exacerbation of other disasters.

### *Impact on economy*

Most developing countries are already importers of forest products, especially paper. The fact that the amount of wood and products available per person in the world is falling (thus, increasing in price) combined with shortages of foreign currencies suggests that import of forest products will be increasingly prohibitive for these countries. Commercially marketed firewood is becoming more scarce and prices are growing higher. Wood for construction is also scarce in many countries and adversely affects the availability of housing.

*Saplings for new houses.*
S. Reed

## Possible risk reduction measures

### *Forest management*

Most governments now recognize the vital importance of national forestry programs. Foresters help people to meet their basic needs for forest products, and not always from the traditional forest or concentrated woodlot. For instance, forestry practiced by many farmers on their own land has been shown in some cases to be more a efficient and less disruptive use of environmental resources. Reforestation has become intrinsically interwoven with other government policies that affect the population. Forestry, therefore, should be considered an integral part of land use and natural resource planning sectors of government.

***Forests should be viewed by governments as capital resources to be managed.***

Forests should be viewed by governments as capital resources to be managed. Management of the system should discourage concessionaires or other land users from practices that are not sustainable. Good management encourages highly selective harvesting without undue waste of remaining trees, especially in tropical forests. Any country that wants to address its loss of forests and ensure economic benefit from forests in the future, must take certain steps:

1) Write forest law or basic forest policy that clearly states the objective of long-term sustainable management of the forest.
2) Write and follow forest regulations or management guidelines.
3) Allocate sufficient financial and human resources to do the job.

Many rural people live in environmentally degraded areas where development projects have been unable to solve their problems. Some have fled to the urban areas and others, pushed further into the wilderness by development itself, have deforested new areas to create agricultural land. Forest management must be considered in the broadest sense of land use planning to include solutions for the people as well as the trees.

*ANSWER (from page 120)*

Farming, grazing, fuelwood collection and logging may all lead to deforestation

Compromises between complete destruction of the forests and complete conservation might entail:

- regulated clearing of forests for shifting cultivation, habitation or hunting
- voluntary and intentional protection of forests or individual species by designating areas for reserves or national parks
- the enrichment of the forest with species from other places. This option may be considered risky as pests and other species-specific problems may accompany the species.

## *Reforestation*

Many questions must be asked before beginning a reforestation program. For instance, what type of trees are needed and whom should they benefit? Some reforestation programs in West Africa have entailed clearing of rich and diverse woodlands for plantations, a process which unfortunately eliminates many non-wood products used by local people. Some of the reforestation projects have not been as productive as expected. Reforestation is not an instant panacea. Some forests and trees take many years to regrow and commitment to maintenance or protection during that period can be costly.

Social or community forestry, in which trees are planted outside of regular forested areas, is one viable long term strategy to meet forestation targets. True community forestry involves participation by a large number of people, ensuring that trees are protected, and improving the livelihoods of the local people by increasing productivity of the land. Forms of social forestry are:

**Agroforestry** – Agroforestry combines agriculture and forestry practices in the same location, increasing yields and reducing soil erosion. An important component of dryland agroforestry schemes are **multi-purpose trees,** some of which grow quickly on lower grade soils and produce food, fodder, fuelwood, building timber or other products. An example is *Acacia albida,* a multi-purpose tree that is cropped with sorghum, millet and other field crops in semi-arid regions of Africa. It comes into leaf in the dry season, providing shade for plants and fodder for animals. The tree also fertilizes the soil by increasing nitrogen and phosphorus. In Senegal, yields of millet near *Acacia albida* trees were 2 ½ times higher than in open fields.

**Farm forestry** – This is a type of social forestry where woodlots are established by farmers on their own land for personal use and for profit.

**Silvopasture** – Trees and pastures are integrated to make livestock raising more productive. Grazing is regulated to prevent damage to trees.

Other alternatives for reforestation are:

**Plantations** – Large scale plantations to meet fuelwood needs near the Sahel have not met with complete success due to slow growth of trees under harsh local conditions Tree crop plantations for lumber or wood products have been promoted by some governments by the use of economic incentives.

**Management of natural woodlands** – Recent data suggests that potential yields from natural woodlands have been underestimated and it should be possible to increase yields at a much lower cost than establishing new plantations. An advantage of natural woodlands is the natural production of a wide variety of harvestable products compared to single crop plantations.

**Forest Policy Instruments**

Discussions at the 1992 United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro and often called the Earth Summit, resulted in “Forest Principles” the first global consensus on forest policy. This non-binding document recognizes the importance of all types of forests for the conservation of all forms of life, as well as the multiple and complementary use of forests. It also emphasizes the need for national action and international cooperation to implement forest policies. Associated documents include Agenda 21 (an action plan), Convention on Biodiversity, Framework Convention on Climate Changes, and the Convention to Combat Desertification. All recognize the importance of forests in relation to global ecosystems. The impact of UNCED on the world’s forests will fall to the Commission on Sustainable Development which will evaluate the implementation of Agenda 21.

Other forest instruments include the International Tropical Timber Agreement of 1994 where timber producing countries agreed to Target 2000, the year by which all forest products should come from sustainably managed forests. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) has 128 members and helps protect tree species threatened with extinction. The Forest Stewardship Council is an assembly of NGOs that has developed guidelines to promote trade for products from well managed forests.

***Q.*** *What is social or community forestry? List five forms of social forestry as presented here. Are there others?*

***A.*** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

## Community participation in reforestation

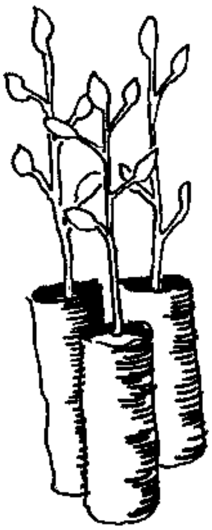
It may seem a simple task to tell people to grow trees but experience has shown that attitudes must change both on the part of government and developmental agencies and on the part of the local population. If local people have no say in the planning of their forests or do not understand the importance of them, it is possible that they will not maintain them. New saplings, if unprotected, can be quickly consumed by domestic animals. Further, the labor input of the people is usually vital to the project.

Specific steps that can be taken at the community level include:

- Establishing community based education programs as part of school curricula and at village councils and the use of media such as radio, television and newspapers.
- Encouraging non-governmental organizations to foster grassroots programs involving small farmers and landless people who depend on forests and trees for survival.
- Encouraging programs at the village or farm level for reforestation, and mitigation procedures for already deforested land with terraces and catch dams.
- Introducing alternative cook stoves that reduce fuel needs and alternative sources of fuel.
- Promoting means to increase agricultural production such as use of fertilizer and improved varieties of seed.

Many unresolved scientific issues in forest management remain. Some of the questions are:

- How can the ever-expanding areas of secondary vegetation and degraded soils be managed to be more productive to the local people?
- Since most primary forests have disappeared, what sort of forest can we establish that would be stable, productive and which would assure the conservation of biological diversity?
- What types of further basic ecological research do we need in order to manage natural forests?



*ANSWER (from page 121)*

*(Top)* Deforestation can lead to several secondary hazards including: landslides, drought and famine, desertification, fires, flooding, and possibly global warming.

*(Bottom)* Three methods for the prediction of deforestation rates presented here are:

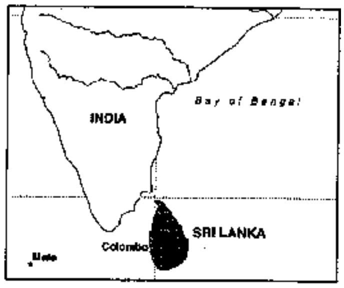
1) extrapolation from recorded trends
2) mathematical models
3) complex theoretical forecasts

### Impact assessment tools

Initial mapping of existing forests and comparison to subsequent surveys can demonstrate the extent and rate of deforestation. Areas of reforestation and the number of trees planted should be kept on record and success rates should be followed up over time (such as yearly intervals) to determine effectiveness of reforestation programs. Socioeconomic surveys can help to assess whether or not the community's needs for forest products is being met or is changing. Simple indicators could be used such as time required to gather firewood each day.

## ■ CASESTUDY

### Agroforestry in Sri Lanka and Peru




Sri Lanka


Peru

In the middle zones of the central highlands of Sri Lanka, the se of agroforestry by women has offered some hope and solutions for survival in a deteriorated environment. Due to widespread deforestation and soil erosion, sources of water especially springs have disappeared and women must spend more time collecting fuel and water. Although the mainstay of the villages is subsistence farming, due to private ownership of large tracts of land for tea and tobacco cultivation, only 20% of land is available for rice paddies. Men seek seasonal employment and women cultivate home gardens to make up the shortfall in food.

Women have prioritized forest and tree borne fruit to supplement their families needs, however, forest clearance for commercial purposes has limited accessibility, therefore focus on home gardens has increased. In recent years, women have increased the variety in their home gardens tremendously, integrating more trees. The trees help some of the ground crops to survive longer and contribute residues of leaf biomass. Some gardens may have more than 60 species of perennial plants. Tree species might include jack, breadfruit, coconut, guava, pepper and coffee. Women's priorities for selecting trees are food, fodder, fuelwood and mulch. The use of agroforestry offers great prospects for enriching soils and moisture capacities and efforts should be made to enable women to design and maintain systems appropriate for their lands.

In Peru, the HIFCO (Huerto Integral Familiar Comunal or Family/Community Integrated Garden) Project is located amidst abandoned farms and degraded pastures in Peru's Amazon. It provides a good example of how sustainable forest practices can contribute to both ecological restoration and cultural preservation. As forests disappeared through conversion to croplands, the indigenous people lost access to their traditional lands. The HIFCO project responded in 1985 to the need for dependable food production on the deleted sites and the desire of the Shipco Indians to restore their homeland.

An 11 hectare plot was used as a model and a sustainable farming system was established using intercropping, including more than 40 species of annuals and perennials surrounded by a variety of tree species which support vines and produce fruit and timber. The area around the garden is planted with more than 60 tree species. Other features include extensive use of leguminous plants and green mulches as sources of nitrogen, raised beds and infiltration ditches, which act as reservoirs for raising fish. Part of the holistic approach to agroforestry includes raising small stock animals, integrated pest control and a crop improvement program.

As a strategy to preserve the rainforest while providing livelihoods, a modified version of the "slash and burn" system is employed in the remaining forest canopy, where one hectare is cleared in the center of a six hectare plot. The burned plot is then planted in concentric rings with the lowest growing plants in the center and the tallest on the periphery. Mulch is collected from the surrounding forest when productivity begins to decline. The HIFCO farm, managed by indigenous people, serves as a training center for 28 member federations of the AIDESEP (the Interethnic Association for Development of the Peruvian Jungle). HIFCO has experienced considerable success but faces formidable challenges for outreach and support to promote the model.

*Sources:* Cabarle, Bruce, "Ecofarming in the Peruvian Amazon: An Indigenous Response" World Resources Institute trip report, 1991.

Wickremasinghe, Anoja, **Deforestation, Women and Forestry, The case of Sri Lanka,** Institute for Development Research Amsterdam, International Books, Utrecht, The Netherlands, September 1994.

## ■ REFERENCES


Disaster Management Center, **Natural Hazards: Causes and Effects,** University of Wisconsin, 1986.

FAO, **Forest Resources Assessment 1990: Global Synthesis,** FAO Forestry Paper 124, Rome, 1995.

Gomez-Pompa, A., T.C. Whitmore and M. Hadley, editors, **Rain Forest Regeneration and Management,** UNESCO, Parthenon Publishing, Paris, 1991.

Grainger, Alan, **The Threatening Desert: Controlling Desertification,** Earthscan Publications, London, 1990.

Raiford, William N., "Social Forestry: An Answer to Deforestation?" in **World Development,** UNDP, November 1988.

Shane, Douglas R., **Hoofprints on the Forest,** Institute for the Study of Human Issues, Philadelphia, PA, 1986.

**World Resources 1992-93,** The World Resources Institute, UNEP and UNDP, Oxford University Press, 1992.

**World Resources 1988-89,** World Resources Institute, Baxic Books, Inc. New York, 1988.

**World Resources 1996-97,** World Resources Institute, Oxford University Press, 1996.

**World Resources 1996-97,** The World Resources Institute, UNEP, UNDP and The World Bank, Oxford University Press, 1996.


*ANSWER* *(from page 124)*

Community forestry is simply the planting of trees outside of normally forested areas and the involvement of the community as a whole in this activity. Five forms of community forestry preserved in the text are:

1. Agro-forestry
2. Farm forestry
3. Silvopasture
4. Plantations
5. Management of natural woodlands

PART 3.3

# DESERTIFICATION

This chapter discusses:

- *the relationship of desertification to drought and other disasters*
- *the role of humans in the process of desertification*
- *the extent of desertification, its effects and the rate at which it is progressing*
- *measures to prevent, control and reverse the degradation of soil and vegetation.*

## Introduction

Desertification is defined as land degradation in arid, semi-arid and dry subhumid areas resulting mainly from adverse human impact. Poor land use by humans is a significant contributing factor, but desertification can also be caused by natural cycles of climate change. It affects both developed and developing regions such as Africa, the Middle East, India, Pakistan, China, Australia, the Commonwealth of Independent States, the central and Southwestern United States and many Mediterranean countries. A slow onset disaster, desertification worsens conditions of poverty, brings malnutrition and disease, and destabilizes the social and economic bases of affected countries.

DESERTIFICATION

**DESERTIFICATION HAZARD DATA SHEET**

**Global status of desertification/land degradation in agriculturally used drylands[1]**

| Continent | (Percentage degraded) Irrigated Lands | Rainfed Cropland | Rangeland | Total Degraded Million Hectares | % |
|---|---|---|---|---|---|
| Africa | 18% | 61% | 74% | 1,045.84 | 73% |
| Asia | 35% | 56% | 76% | 1,331.70 | 69.7% |
| Australia | 13% | 34% | 55% | 375.92 | 53.6% |
| Europe | 16% | 54% | 72% | 94.28 | 64.8 |
| N. America | 28% | 16% | 85% | 428.62 | 74.1% |
| S. America | 17% | 31% | 76% | 305.81 | 72.7% |
| World Total | 30% | 47% | 73% | 3,562.17 | 69.0% |

The annual global income lost due to desertification is estimated to be US $42 billion.

Source: Dregne, 1991

## Causes

### *The role of climate*

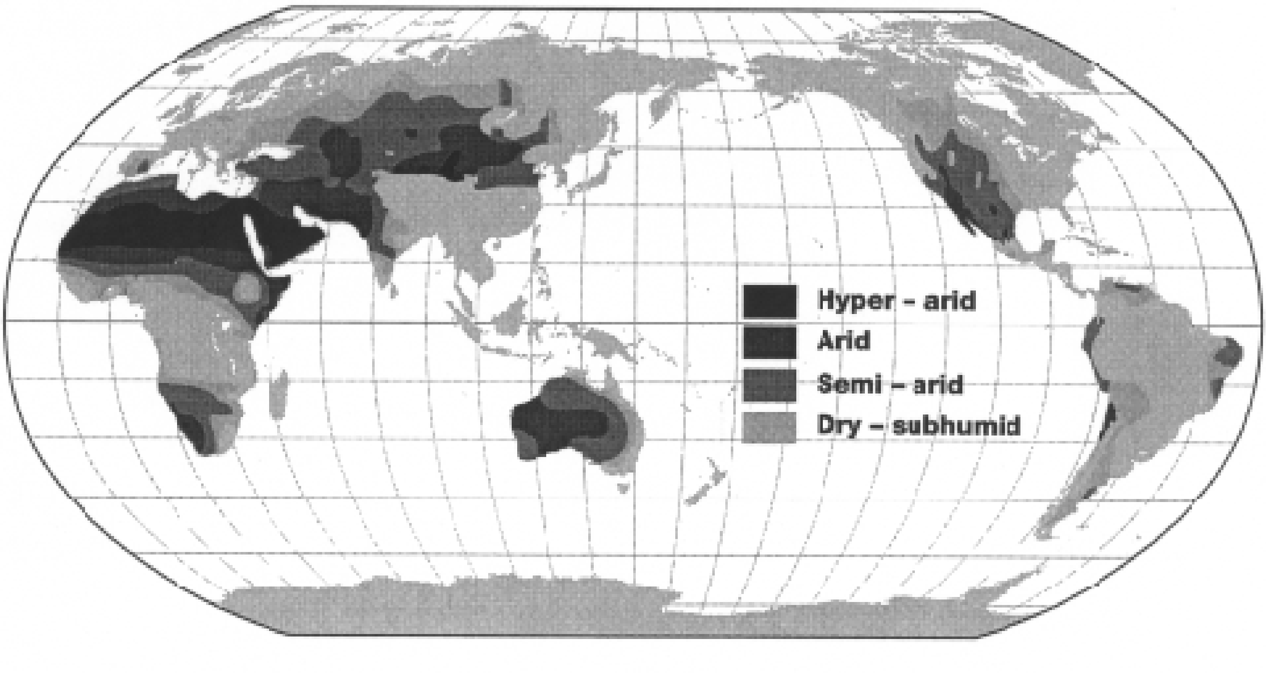
Vulnerability to desertification and the severity of its impact are partially governed by climatic conditions of an area. The lower and more variable the rainfall, the greater potential for desertification. Other influencing factors are the seasonal patterns of rainfall, high temperatures (which increase evaporation), land use and the type of the vegetation cover.

The world's drylands are found on two belts approximately centered on the Tropics of Cancer and Capricorn (23.5 degrees north and south of the Equator respectively) and cover one third of the earth's surface. More than 80% of the total area of drylands is found on just three continents, Africa (37%), Asia (33%) and Australia (14%) but significant areas are found in North and South America. The drylands can be further classified into hyper-arid, arid and semi-arid zones depending on the average amount of rainfall received per year. other factors such as temperature and soil conditions must be factored in when determining the classification.

Both natural and human caused climatic changes may contribute to desertification. Natural effects such as long term climatic variations and the basic earth-sun geometry have resulted in drier conditions in the Sahara Desert. Human influence is associated with the predicted global warming trend and local climatic changes where deforestation has reduced the moisture holding capacity of soil and has decreased cloud formation. The result is less rainfall and higher temperatures.

**Figure 3.3.1**

*World map showing global pattern of the world's drylands. After UNEP, 1992.*



**The relationship of the desert and drought to desertification**

A common misconception about desertification is that it is caused by the desert advancing itself and taking over vegetated areas. The truth is that land degradation can and does occur at great distances from deserts and the presence of the desert may have no direct relation to desertification. Desertification usually begins as a spot on the land, such as a watering hole or in a cultivated field, where land abuse has been excessive. From that spot, land degradation can spread outward if there is continued abuse. Ultimately, the spots may merge but that is unusual on a large scale.

While desertification does not cause drought, it may result in greater persistence of or susceptibility to drought. Drought, on the other hand, does contribute to desertification and increases the likelihood that the rate of degradation will increase. However, well managed lands will recover from droughts with minimal adverse effects if the rains return. Land abuse during periods of good rains and its continuation during periods of deficient rainfall is the combination that contributies to desertification.

*Desertified are around water hole.*

U.N./D. Lovejoy, *UNDRO News,* May/June 1986.

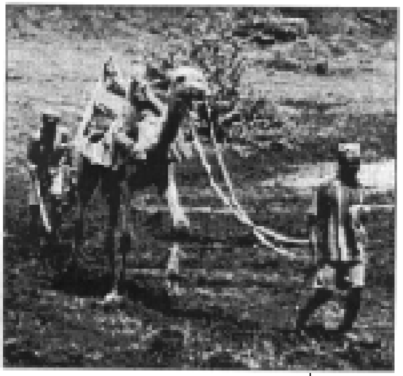
## *The role of land use management*

Desertification can be caused by five main types of poor land use: overcultivation, cash cropping, overgrazing, deforestation and poor irrigation practices.

**Overcultivation** – Overcultivation damages the structure of the soil or removes vegetation cover leaving the soil vulnerable to erosion. There are many reasons why overcultivation occurs. These include presence of drought, increasing demand for food due to population growth, cropping on marginal rangelands unsuitable for long term production, land tenure restrictions confining sectors of the population to marginal lands, mechanized farming, and expansion of cash cropping.

**Cash cropping** – Although a large part of agricultural production in developing countries fills subsistence needs, some cash crops are grown to add to foreign exchange. A feature of most cash crops, however, is their extreme demand for nutrients and optimum site conditions. Degradation of land occurs directly through improper management of such crops, and indirectly by displacing subsistence crops and pastoralism to marginal lands. For example, these conditions occurred in the 1950s and 60s when cultivation of groundnuts expanded in West Africa and Sudan. One reason was the attempt by France to combat the US domination of the vegetable oils market. According to some experts, this enterprise was a contributing factor in some areas to the Sahelian drought/disaster, which persisted from 1968 to 1974, because grazing lands had been taken over for groundnut production.

**Overgrazing** – Overgrazing is a major cause of desertification and rangelands account for 90% of desertified lands. Overgrazing results when too many animals are pastured, leading to removal of vegetation, destruction of soil structures and erosion.



*Former nomads plowing areas of marginal fertility.*
S. Reed

Nomadic herdsman were initially blamed for the Sahel drought because they had acquired more animals than could be supported by natural vegetation on grazing lands. The number of cattle in Niger, for example, increased an estimated 4 1/2 times between 1938 and 1961 and an additional 29% by 1970, when the majority were killed by starvation. The problem, however, is more complex because many outside influences have changed nomadic behavior.

Livestock density can increase in three main ways:

1) *Herd sizes have grown too large in wet years and cannot be sustained by limited vegetation growth in dry years.* Herd sizes are increased primarily because of a greater demand for meat and dairy products. Secondly, nomadic people are becoming increasingly impoverished due to decreased trading which formerly helped them to accumulate monetary wealth; thus wealth is now stored in animals. The total number of herds also increase as children and former servants of nomads start their own herds.

Economic development plays a large part in the increase in the number of animals. Inhabitants of urban areas in Africa often depend on animals raised in dry areas for meat, as humid zones are often prohibitive for animals due to trypanosomiasis and other diseases. Lucrative markets for meat in Nigeria and Cote d'Ivoire have led to the establishment of cattle ranches where concentrated activity threatens land. The introduction of better veterinary care has also decreased mortality rates.

***Due to decreasing land availability, traditional controls on rangeland grazing are breaking down.***

2) *The areas available for grazing are shrinking as nomads become farmers or are displaced by farmers.* Marginal rangelands or dry season pastures may be cultivated. Deforestation occurs and fodder decreases on the existing rangelands when trees are taken or branches cut off for fuel. Reduction of vegetation then increases vulnerability to erosion by wind and water.

Because of decreasing land availability, traditional controls on rangeland grazing are breaking down. Nomads have historically exercised rigid controls over the movements of their animals, making the extensive grazing system workable. Now, farming compares with grazing and farmers and nomads clash over rights to newly developed water wells. Merchants exporting livestock to the Middle East have broken down traditional links between nomadic pastoralists. Commercial cattle ranches have taken over nomadic areas and closed off land to nomads.

3) *Concentrations of livestock* appear around nomad resettlement villages and along popular herding routes that pass water holes. Nomads who have become sedentary, either voluntarily or at a government's insistence, often take up cattle breeding, and these animals tend to graze in close proximity to the villages. In a study of several African water holes, some were attracting more than four times the number of animals for which they had been designed. The animals tended to congregate in the water hole area and degrade the vegetation and soil.

**Deforestation** – Land is cleared for agriculture, livestock and fuelwood production among other purposes. (See chapter on deforestation.) Deforestation is the first step toward desertification, removing vegetative barriers and exposing land to sun, wind and rain. In Africa, demands for fuelwood and charcoal exert considerable stress on wood resources.

**Poor irrigation management** – The concept of using irrigation to ward off the threat of crop failure during drought seems logical and has thus been promoted by many development agencies. Ironically, poor management of irrigation projects has been a cause of desertification. In some cases productivity falls and soils become salinized, alkalized or waterlogged. The main problem is usually inadequate drainage. Damage may be irreversible. A key example is the Greater Mussayeb irrigation project in Iraq begun in 1953. By 1969, waterlogging was widespread and 2/3 of the soil was saline. In 1970, a project to reclaim the salinized land was begun but by 1976, because of technical and organizational limitations, the project still had not been successful. Egypt, Iraq, and Pakistan have lost more than 25% of their irrigated areas to salinization and waterlogging.

***Ironically, poor management of irrigation projects has been a cause of desertification.***

## *The role of policy in desertification*

Population growth and economic expansion contribute to desertification. As populations grow, government and multilateral policies must promote increased food production through appropriate technologies which prevent soil degradation and erosion. Government policy should also address the causes of poverty or the poor place more stress on the land to obtain needed resource. In some cases, governments choose to expand cash crop cultivation to improve foreign currency holdings rather than promote food security for the poor. In other cases, government shortcomings in conflict resolution contributes to the unregulated exploitation of resources. Exploitation may also result if government policies unilaterally mandate land uses which are difficult to enforce and result in breakdown of customary land tenure or natural resource management institutions.

***As populations grow, government and multilateral policies must promote increased food production through appropriate technologies which prevent soil degradation and erosion. Government policy should also address the causes of poverty or the poor place more stress on the land to obtain needed resources.***

## General characteristics

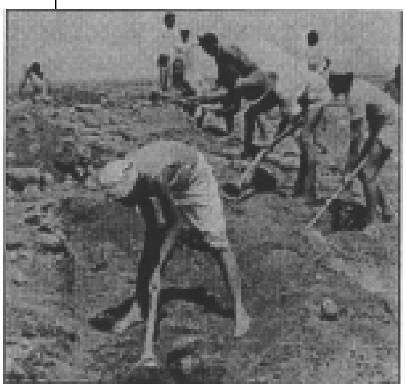
The two main characteristics of desertification, degradation of vegetation and degradation of soil, have the same result: reduced productivity.

## *Degradation of vegetation*

In arid lands vegetation adapts to the cycle of water availability by adjusting its growth. The drier the area, the further plants are spaced apart. Some plants only grow during the rainy seasons.

In forested areas, degradation of vegetation begins with deforestation, and continues after soil quality declines. The vegetative cover of an area may be described as degraded when it becomes inferior to: (a) what the land could be expected to support in view of climate site conditions and historical experience; and (b) what the area needs for the purposes of environmental protection.

There are two main forms of degradation of vegetation. The first is the overall reduction of density of vegetation cover or biomass. The second form is a more subtle change toward less productive types of vegetation. For instance, rangeland perennial grasses may be replaced by less palatable annual varieties, or, more saline tolerant crops such as barley, would have to be substituted for traditional crops because of low yields from waterlogging and salinization.



*IFAD supported project on Santiago Island, Cape Verde to reduce erosion through terracing.*

IFAD/C. Rycroft, *UNDRO NEWS, May/June 1986*

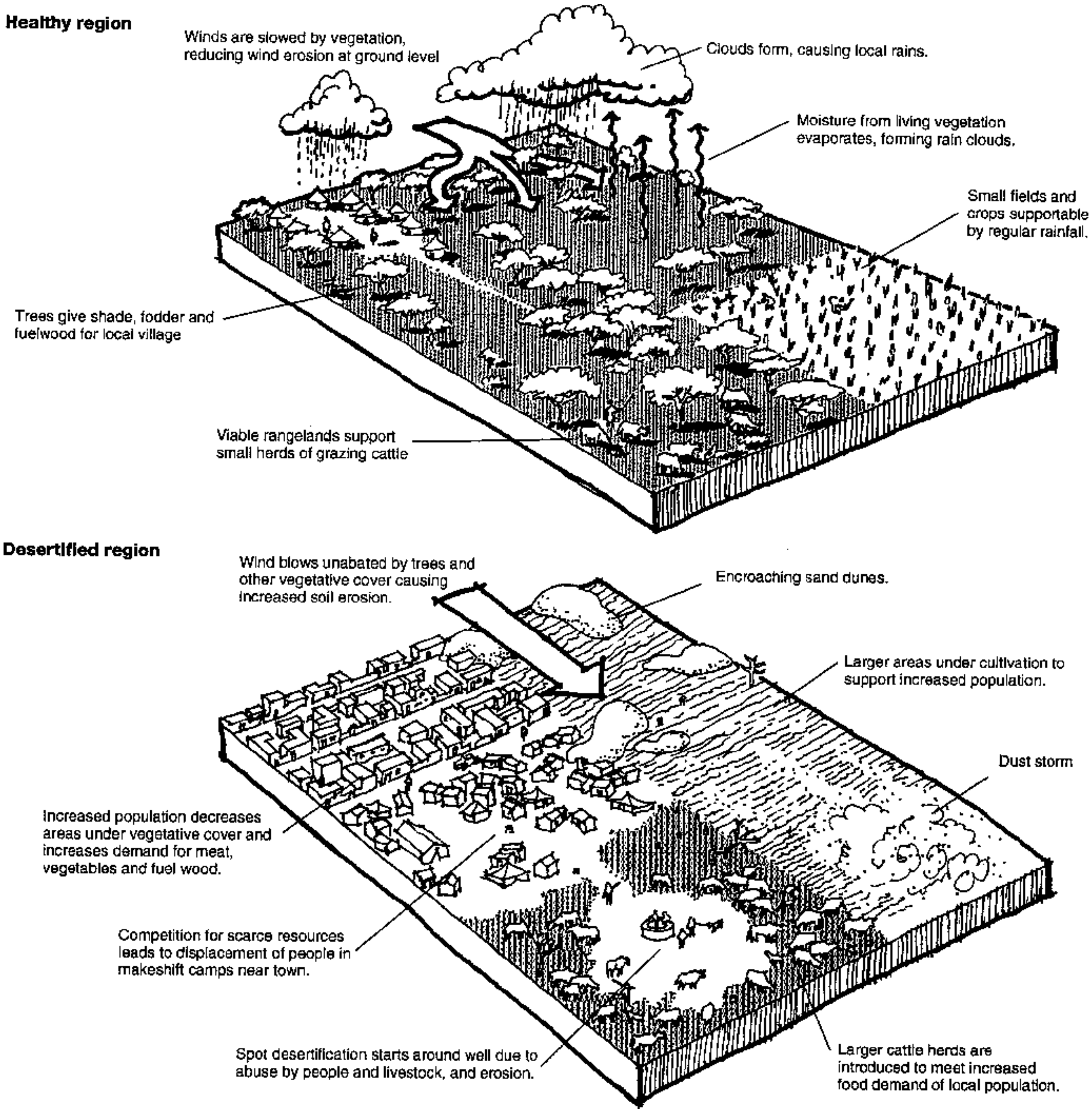



**Figure 3.3.2**

*Comparison of healthy and desertified regions.*

## *Degradation of soil*

Soil degradation occurs in four major ways: water erosion, wind erosion, soil compaction, and waterlogging which results in salinization and alkalinization.

**Water erosion** – Vegetation normally protects soil from being washed away by rain and also from "splash erosion" by impact of raindrops. The raindrops move the soil particles and pack them together on the surface, sealing the pores thereby decreasing infiltration and increasing runoff. Gullies are created by the runoff and unless they are repaired through conservation measures, will render the land completely unusable. "Sheet erosion" is a more serious form of erosion where fine layers of topsoil carrying soil nutrients wash away. Unless the nutrients are replenished artificially, crop yields will decline.

**Wind erosion** – With vegetation removal, the finer components of the soil, such as silt, clay and organic matter which contain most of the nutrients are blown away, leaving behind the less fertile sand and coarse particles. Sand itself may start to drift, forming dunes, but this accounts for a minor amount of damage and stabilized dunes may be used for grazing. Strong winds can cause severe health problems, reduce visibility, may form dust storms and damage crops by shredding leaves.

**Soil compaction** – Nearly complete compaction can occur when soil of a poor structure is compressed by heavy machinery or by hooves of large herds of animals. A less serious form of compaction, called "surface crusting" results when high speed mechanical cultivation or dry season cultivation turns particles into thin powder, which is then turned into a crust when pelted with raindrops. Crusting and compaction make the soil less permeable and less pervious for germination of new plants.

**Waterlogging** (salinization and alkalinization) – These effects result from poor management of irrigation and water supplies in general. When the soil is waterlogged, the upward movement of saline groundwater leaves salts on the surface when this water evaporates.

## The UN Convention to Combat Desertification

The international community has long recognized the detrimental effects of desertification. In 1977, the UN Conference on Desertification (UNCOD) adopted a Plan of Action to Combat Desertification, but the associated problems seemed to intensify. In 1992, the UN Conference on Environment and Development, or the "Earth Summit" called for the establishment of the Intergovernmental Negotiating Committee (INCD) to prepare a *Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification Particularly in Africa (CCD).* This convention was adopted in 1994 and is expected to be entered into force in 1997.

The CCD is based on a highly participatory approach which involves grassroot organizations and governments as well as international partners. It develops the tools to operationalize sustainable development, alleviate poverty and ensure food security to people living in the world's drylands. In the CCD, environmental and socio-economic issues are strongly connected. Agenda 21, the action plan of the Earth Summit, is concerned with strengthening the knowledge base and developing information and monitoring systems for vulnerable regions.

The work of the INCD in implementation of the CCD has promoted worldwide response Regional organizations such as the Intergovernmental Authority on Development (IGAD) in the Horn of Africa have developed networks between member states and promoted national plans and committees to combat desertification. NGOs have created a global network to facilitate information sharing and coordination among community based NGOs. The Environment Liaison Centre International (ELCI) has undertaken mobilization of community groups to take action against desertification.

***Given the potential impact, data is still inadequate to quantify the extent of the problem and its progression.***

## Predictability

Desertification is now thought to be a direct socioeconomic threat to over 200 million people and a less direct threat to over 700 million people. Given the potential impact, data is still inadequate to quantify the extent of the problem and its progression. Data bases still do not exist or are incomplete for some countries. More information is needed on the characteristics and status of dryland ecosystems including soils, water resources and salinity as well as agricultural practices. The understanding of climatic changes is crucial to predictability, such as what the effects will be of possible global warming. Socio-economic indicators showing the trends in human health, income and welfare must be collected for understanding of the related issues.

The International Soil Reference Centre in conjunction with UNEP supports GLASOD (Global Assessment of Soil Degradation) which utilizes a Geographical Information System (GIS – see chapter on floods) known as GRID, the Global Resource Information Database. GRID allows researchers to access data for different regions of the world and is useful for estimating degradation. Satellite remote sensing (see chapter on drought) combined with ground data has the potential for enhancing understanding of land degradation. Although there are many monitoring networks in operation, existing centers need to be strengthened and more extensive monitoring promoted through personnel trained to collect base-line data relevant to all aspects of desertification.

Although numbers remain controversial, it has been estimated that yearly losses to desertification include 1.0–1-3 million ha of irrigated land, 3.5–4.0 million ha of rainfed cropland and 4.5–5.8 million ha of rangelands These estimates represent an increase from estimates in 1984 of 3.4% and indicate that the situation is becoming more serious (Dregne, 1991).

## Typical adverse effects

Desertification affects drylands in more than 100 countries but Asia and Africa contain 70% of all desertified land. The physical damage, in terms of loss of vegetation and reduction of productivity of soils caused by desertification, has been described above. The number of casualties cannot be scientifically determined but it is certain that casualties do occur, perhaps directly as a result of famine or indirectly related to reduction of standards of living.

**Desertification and Regional Conflict**

Africa as a whole is losing 36,000 sq km to desertification yearly. In 1980, 200,000 sq km of arable land became desertified. Africa may require as much as US$ 80 billion to fight desertification into the next 20 years. Particularly in West African countries, where rainfall has been deficient in the past 30 years, famine victims from Mali, Niger and Chad have migrated into Nigeria and Ghana, putting further stress on already degraded systems. These migrations have resulted in many conflicts in between and within nations such as the Mauritanian–Senegalese conflict of 1989. Another major source of conflict involves control of rivers and other water sources flowing through various countries, as water supplies diminish with drought, desertification and population pressures. African countries, besieged by debts, have made little progress toward alleviating the poverty which pushes the poor in search of ever degrading resources.

## Preparedness measures

**Social solutions** – Because desertification is a slow onset disaster that ultimately threatens the livelihoods of people, the measures to combat it must have human and social objectives. Preparedness measures must:

1) **Identify people's needs** – For instance, if people need jobs, projects that offer employment opportunities may be implemented. If the major concern is securing food and fodder, then growing trees for browse would be more practical than establishing a fuelwood plantation. These needs must be identified by the affected people themselves, not by outsiders.
2) **Improve existing practices and institutions** – Traditional values and practices must be respected and are also evolving. The key is to build upon practices that are positive and reform practices that are harmful. Non-governmental organizations often are successful in project implementation because of their long associations with and respect for local populations and cultures. Projects that require total changes of behavior are not likely to succeed.

***Projects that require total changes of behavior are not likely to succeed.***

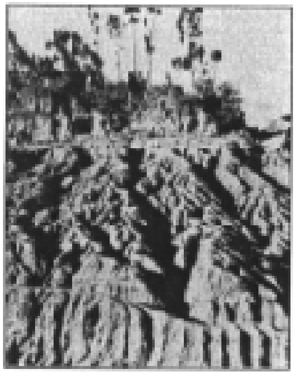
3) **Involve local people** – Move past simply imparting information to the local population and involve them as full participants or partners. In a Somali soil conservation project, farmers felt they had not been properly consulted and thus took no interest in maintaining soil conservation works after the project ended.
4) **Use the power of demonstration** – Once a farmer or nomad successfully learns a new technique, others will come to learn. Specially designated demonstration farms are publicized by the local agricultural ministries in Tigray province of Ethiopia, and farmers journey there to discuss the technology with the demonstration farmer.
5) **Use small scale approach rather than large scale** – Small scale irrigation projects such as those on the Senegal River are more likely to succeed than large scale projects such as the Rahad/Sudan project which ended in failure.
6) **Introduce technology carefully** – Stress appropriate technology rather than simply resorting to expensive high technology. In Burkina Faso farmers greatly improved water supply to fields by using stone contours rather than expensive pumps.
7) **Ensure political support** – Support for the project by members of village councils and chiefs as well as in ministries and other government offices can help to ensure success.

## Technical solutions

### *Better monitoring of desertification*

The knowledge base on the extent and rate of desertification must be improved. Areas seriously threatened by desertification should be identified through continuous monitoring by satellite, air and ground studies. These areas can then be ranked according to need for protection and conservation.

***The knowledge base on the extent and rate of desertification must be improved.***



*Land erosion*
*UNDRO News,* 1985.

### *Changes in government policy*

Policy issues and that must be addressed by governments to promote land management and combat desertification include land tenure, access to resources on common property, decentralization of political decision making, and conflict resolution. Government support services which are required include provision of extension services and credit schemes to assist agricultural development. A balance should be achieved between growing cash crops and establishing food security for the poor. The issues of nomadic pastoralism should be confronted. Nomads, although seen as problematic to governments, remain one of the only groups able to use marginal lands where cropping is not a viable alternative.

### *Improved training of personnel*

One of biggest constraints to the control of desertification is that many countries lack trained personnel. The situation is improving because many development projects now include a training component that is long term in scope. Professionals may benefit from retraining, enhancing their knowledge of other technical fields as well as their understanding of social and cultural practices. Training and education should also target the general population through schools, mass media and outreach programs.

### *Institutional development*

Institutions capable of implementing government policies to fight desertification are often short of funds and trained personnel. Links with nongovernmental organizations and international agencies such as the United Nations Environment Program (UNEP) can be established to help make up deficiencies as institutions grow. Institutions at the village level, such as village councils, should be strengthened because they and their members will be the ultimate implementers of policy.

### *Measures in soil, water, fuel and agricultural conservation*

Projects to improve agricultural production and livestock production and to mitigate effects of ongoing desertification are essential. Adequate funding must be designated to these aims by governments and development agencies. Plans of action must be established. Projects must be evaluated for effectiveness throughout. For a guide in establishing priorities, Agenda 21 and the UN-CCD should be consulted.

Some recommended measures include:

- Improvement through more careful management of rainfed and irrigated cropping systems, in particular by encouraging high yield varieties, ensuring reasonable crop prices, and replacing obsolete irrigation systems.
- Improvement of livestock raising by curbing overgrazing, increasing output (culling greater numbers to regulate herd sizes) and value of animal products and improving rangelands through fodder planting, improving routes and managing grazing areas.
- Planting trees (community forestry to satisfy local needs) for fuelwood, as windbreaks, to stabilize terraces and for food and other by products.

- Planting of trees (agroforestry for individual profit) on farmlands to protect soil or add nitrogen to the soil by use of multipurpose species such as acacia and leucaena.
- Implementation of soil conservation measures including contour bunding, planting trees on watersheds and letting land lie fallow. Sand dunes can be stabilized with dryland plants.
- Managing water resources using technologies appropriate to the area.
- Introduction of improved woodstoves and alternative fuels.

## CASE STUDY

### Using indigenous knowledge for sustainable dryland management

The majority of the rural population in arid and semi-arid areas are small scale farmers and pastoralists, who as populations grow, are faced with producing food, fodder and income from decreasing supplies of land. The process often leads to soil degradation, erosion and woodland destruction despite effort to conserve these resorces. Some dryland management schemes have failed due to inadequate understanding of the local conditions, top down rather than community-based planning, or use of systems which are too complicated or difficult to maintain.

There are increasing indications that the use of indigenous systems may be extremely valuable for sustainable approaches to dryland management and drought mitigation. Indigenous knowledge reflects experiences based on traditions and includes more recent experiences with technologies. With their knowledge of local resources and situation, local people are able to predict what will work and how one change may impact other parts of a system. Rural populations also have a variety of formal and informal organizations which seek to solve local problems. While it is likely that strengthening local capacities through use of indigenous knowledge can lead to greater sustainability, undermining this knowledge may lead to greater dependence on outside assistance. Many regional and global centers have been created which support systematic recording of indigenous systems.

The following are examples of indigenous dryland management practices:

Stone lines in Burkina Faso – The Mossi people of Burkina Faso developed stone bunding for soil and water conservation which consist of lines of stones terracing the slopes. The bunds are preferred above any introduced systems, require relatively little labor input and are also combined with pits which conserve water and organic matter. The bunds are semi-permeable, allowing some waterhazard to pass through and preventing erosion. Funding was provided by UN-IFAD to promote the bunds, resulting in rising sorghum yields in the newly bunded fields.

Farmer experimentation in Niger – It was discovered that farmers systematically carry out a wide variety of experiments and exchange the results of their research. To survive, the farmers in the Sahel must cope with rapid climatological changes and require a continuing supply of locally adapted technologies. There is evidence to suggest that farmers' experimentation is greater in highly diversified or stressed environments.

Dryland agriculture in Nigeria – Highly innovative approaches by Hausa farmers include the regeneration of soils from wasteland from ten years of mining activities. Although the wasteland was thought to be impossible to regenerate, Hausa farmers incorporated processed garbage and traditional fertilizers, resulting in soils which support a wide range of crops. Farmers have exchanged information on this new technology.

Water harvesting systems in India – The farmers in Andhra Pradesh have developed several types of water harvesting systems based on the amount of rainfall and soil type in each area. Where rainfall is more than 750 mm/year, individual farm ponds are developed for supplemental irrigation. Where rainfall is 500-1200 mm per/year, community tanks for irrigation or percolation are in use, mainly in red soil areas. In areas with very low rainfall, less than 500 mm per/year, khadims, or earthen embankments across gullies, haversts water in the root zone, recharging the roots and allowing a post-rainy season crop with the residual moisture.

Steep slope terraces in Cameroon – Farmers in the Mandara Mountains of Northern Cameroon have developed an intricate system of terracing steep slopes. They use household and animal wastes and crop residues for maintaining fertility, as well as crop rotation and intercropping. Trees such as *Acacia albida* and *Khaya senegalensis* are grown for fodder.

*Source:* Warren, D.M., and B. Rajasekaran, "Using Indigenous Knowledge for Sustainable Dryland Management: A Global Perspective", in **Social Aspects of Sustainable Dryland Management,** edited by D. Stiles, UNEP, John Wiley and Sons Ltd., 1995.

***Q.*** *1) What are some of the reasons that dryland management schemes fail?*

***A.***

***Q.*** *2) What are the benefits of indigenous knowledge?*

***A.***

## ■ REFERENCES


Disaster Management Center, **Natural Hazards: Causes and Effects,** University of Wisconsin, 1986.

Dregne, H., M. Kassas, and B. Rozanov, A New Assessment of the World Status of Desertification. **Desertification Control Bulletin** No. 20, 1991.

El-Baz, Farouk, and M.H.A. Hassan, editors, **Physics of Desertification,** Martinus Nijhoff Publishers, 1986.

Grainger, Alan, **The Threatening Desert,** Earthscan Publications Ltd, London, 1990.

Kassas, M., Y.J. Ahmad, and B. Rozanov, Desertification and Drought: An Ecological and Economic Analysis. **Desertification Control Bulletin** No. 20. 1991.

Nnoli, Okwudiba, "Desertification, Refugees and Regional Conflict in West Africa", in **Disasters,** Vol 14, No. 2, 1990, p. 132.

Ornas, Anders Hjort Af, "Pastoral and Environmental Security in East Africa", in **Disasters,** Vol 14, No. 2, 1990, p. 123.

Williams, MA. ad R.C. Balling Jr, **Interactions of Desertification and Climate,** WMO and UNEP, Arnold, 1996.

**World Resources 1988-89,** World Resources Institute, Basic Books, Inc. New York, 1988.

**World Resources 1996-97,** The World Resources Institute, UNEP, UNDP and The World Bank, Oxford University Press, 1996.


## ■ RESOURCES

For more information on UN-CCD:
Convention to Combat Desertification
Geneva Executive Centre
11/13 Chemin des Agemones, BP 76
1219 Geneva, Switzerland
Phone: (41 22) 979 91 11
Fax: (41 22) 979 90 30
E-mail: secretariat. incd@unep.ch

For more information on NGO coordination to combar desertification, contact:
Environmental Liaison Centre International (ELCI)
P.O. Box 72461
Nairobi, Kenya
Phone: (215 2) 562 015
Fax: (215 2) 562 175
E-mail: elci@elci.sasa.unep.no (or) elci@elci.gn.apc.org

*ANSWER (from page 22)*

1) Inadequate understanding of local conditions top-down planning, use of complicated systems, or systems difficult to maintain.

2) Reflects traditional expenses as well as experience with new technology, offers insight into what will work, supported by indigenous organizational networks, possible greater sustainability for projects.

# NOTES

PART 3.4

# PEST INFESTATION

This chapter of the module is designed to improve your knowledge of:

- *the ecological factors which influence the outbreak of pests*
- *the ways that pests inflict damage*
- *controlling pests through integrated management*
- *components of a national pest control plan.*

## Introduction

Food losses to pests worldwide are considerable. It is estimated that 35% of world crop production is lost in spite of pesticide and other control programs. The primary pests are insects, diseases and weeds, although mammals and birds can inflict serious crop damage. When post harvest losses are added to crop loss, the total is about 45% of all food production lost. It was estimated in 1977 that if only 20% of rice production losses could be saved, it would be sufficient to feed for one year the combined populations of Japan and Bangladesh.

PEST

A pest may be defined as any animal or plant causing harm or damage to people, their animals, crops or possessions. The pests of most importance here are those which lead to a loss in crop yield or quality, resulting in loss of profits to the farmer and reduced stocks for subsistence or export.

**DESERTIFICATION HAZARD DATA SHEET**

**Percentage of all declared disasters requiring international assistance from 1980-89: 11%**

**Selected recent pest infestations**

| Year | Location | Type | Extent |
|---|---|---|---|
| 1986 | Burkina Faso | Grasshopper | 250,000 ha |
| 1988 | Algeria | Locust | |
| 1988 | Cape Verde Islands | Locust | All islands |
| 1988 | Chad | Locust/grasshopper | |
| 1988 | Gambia | Locust | Entire country |
| 1988 | Ethiopia | Locust/armyworm | |
| 1988 | Sudan | Locust | 3.4 million ha |
| 1989 | Jordan | Locust | |
| 1993 | India and Pakistan | Locust | 12 districts |
| 1993 | Yemen | Locust | |
| 1995 | Eritrea | Locust | 30,000 ha |

Source: **OFDA Disaster History,** 1996

## Causes

Insect outbreaks are usually the result of a combination of ecological factors (see below). Information is incomplete, however, regarding the behavior and biology of all species and numbers may increase for undetermined reasons.

**Temperature** – Often the most important factor that governs insect development is temperature. For insects, like locusts and the rice leaf roller, which is a serious problem in Japan, the insect's development phase is largely temperature dependent.

**Moisture** – Most insects that attack crops rely on adequate rainfall to promote egg hatching and host plant growth. For example, locust outbreaks and plagues seem related to the cessation of extended drought.

**Monoculture of crops** – Genetically uniform crop monocultures provide greater opportunities for large infestations because there are fewer natural enemies of the pests attacking the crop. Therefore, when a single crop species replaces the natural plant community, it is more susceptible to attack by pathogens (any micro-organism or virus that can cause disease), and insects. The larger the area planted with a single crop, the greater the potential for pest problems. Also, the longer a monoculture is maintained in the same area, the greater the number and severity of pests.

**Introduction of plants to new locations** – Some pest problems occur when crops are introduced into new biological communities. For example, when the potato, which originated in Bolivia and Peru, was introduced into the southwestern United States, it acquired a serious pest, the Colorado potato beetle, which had originally fed on a different plant. The potato lacked resistance to the beetle as it had never been exposed to it. This insect has become the most serious pest to the potato in the world and has accompanied the plant to other areas.

*Swarming locusts*

FAO/G. Tortol, *UNDRO News,* May/June, 1988.

**Introduction of pest species** – Examples of introduced pests are the European rabbit into Australia, the leucaena psyllid into Asia and the new world screwworm fly into Libya (now eradicated). The spread of these species was favored mainly due to lack of natural enemies.

**Overcoming genetic resistance** – Insect pests have been shown to have the genetic capacity to evolve and overcome resistance in their host. In the United States since 1940, oat varieties have been changed every five years to counter these genetic trends.

**Host plant association and cropping patterns** – When a crop is harvested, pests move on to the next crop.

**Resistance of pests to pesticides and other effects** – Although pesticides work quickly to control pests, the effects of pesticides are short lived and pest resurgence, perhaps in greater numbers, will occur when the effects wear off. Pests may also develop resistance to pesticides. Pesticides may kill the predators of pests, allowing them to flourish.

**Weather patterns** – For flying insects such as locusts, prevailing winds are important in determining where they will fly and whether they will survive.

**Movement** – Movement to a different area with more favorable conditions, allows some pest species to escape control and increase in number.

*Q. Are insect infestations possible cases for disaster in your country or community? If so, which of the factors listed above are probable causes for an outbreak?*

*A.* ______________________________________________

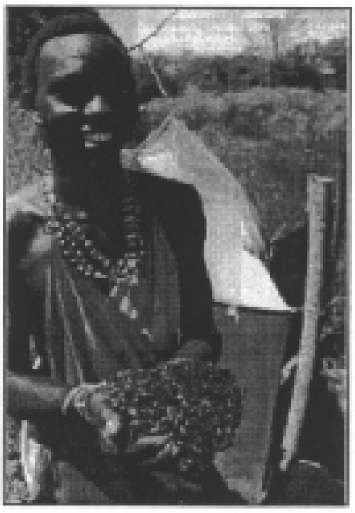
## General characteristics

Pest injury to crop yield can occur when the harvested part of the plant is directly damaged by the pest. Or injury can occur indirectly when the harvest part of the plant is diminished or lost because other parts have been damaged or lost. Biting insects may damage the plant as follows:

- Reduce the amount of leaf and photosynthetic area, hindering plant growth. Examples are leaf eaters such as locusts and armyworms.
- Tunnel in the stem and interrupt sap flow. Examples are stem borers and shoot flies.
- Destroy buds or growing points and cause subsequent distortion or proliferation, as with fruit bud weevils.
- Cause premature fruit fall, as with cherry fruit fly, codling moth and apple sawfly.
- Attack flowers and reduce seed production, as with blossom beetles and Japanese beetle.
- Injure or destroy seeds completely, or reduce germination due to loss of food reserves. Examples are maize weevil, pea pod borer and bean pod borer.
- Attack roots and cause loss of water and nutrient absorbing tissue, as with wireworms and various beetle larvae.
- Remove stored food in tuber, such as cutworms and wireworms in potatoes.

Insects with piercing and sucking mouthparts damage plants as follows:

- Cause loss of plant vigor by removing excessive quantities of sap and chlorophyll, such as the whitefly and aphids.
- Damage floral organs and reduce seed production such as chapped bugs, wheat shield bugs and chinch bugs.
- Cause premature leaf falls as do diaspidid scales.
- Inject toxins into the plant.
- Provide entry points for pathogenic fungi and bacteria.
- Reduce photosynthetic area on leaf surface.
- Transfer plant pathogens.



*Kenyan technician holds dead tsetse flies caught in cloth traps.*

Anthony Bannister, *World Development,* Jan, 1989.

**Mechanical injury** – The larvae of certain pests, such as the new world screwworm fly, can cause direct damage to the living tissue of the host (such as livestock or humans). These wounds may also be invaded by pathogens.

**Vector pests** – Certain pests serve as vectors of human and animal diseases. These include: the tsetse fly, *Glossina* species, which vectors African trypanosomiasis, the *Simulium* blackfly which vectors onchocerciasis; the *Anopheles* mosquito which vectors malaria; and the human body louse *Pediculus humanus humanus* which vectors epidemic typhus. A pathogen or parasite is passed from pest to host, where development takes place. In Africa, hogy tsetse fly passes parasites that cause trypanosomiasis, a disease that induces anemia and often leads to death in humans and livestock. Animal dependent societies have experienced significant livestock losses to the tsetse fly.

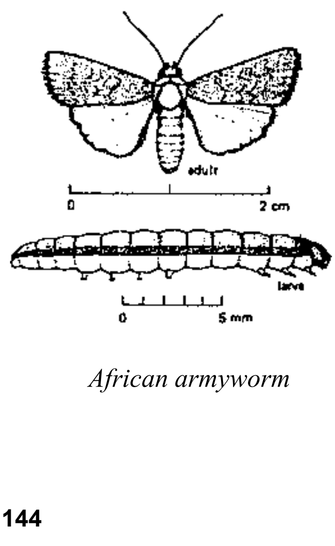
## Predictability

The purpose of pest forecasting is to determine what types of control measures to effect and particularly whether or not a pesticide will be needed or cost effective, and when it should be applied. Prediction allows better control and use of pesticides. To determine when pesticides should be used, an assessment should be made where applicable of the "economic injury levels" of the pest population. This procedure documents the density at which pests will cause unacceptable crop loss and requires the following information:

1) Density of the pest, its parasites and predators
2) Ecological factors affecting crop growth
3) Amount of damage and loss related to various pest densities
4) Monetary value of crop loss at various levels
5) Monetary value of damage prevented by control measures
6) Cost of the control measures
7) Determination of "economic threshold levels", or the density of pests where control measures should be applied to avoid the economic injury level.

The forecasting of pest attacks is rarely a simple matter. In the case of a highly mobile pest, such as the locust, a network of monitoring offices and aerial surveillance is required. For all outbreak pests, labor intensive surveys including collection and analysis of samples produce a total picture which must then be communicated to the vulnerable farmers.

Environmental factors such as wind, temperature and rainfall have been employed in predicting pest attacks. For example in South Africa it was discovered that changes in brown locust numbers were linked with the previous early summer rainfall intensity. Forecasts can also be based on the conditions occurring in an areas which are favorable for development. Forecasting desert locust population dynamics is the responsibility of the FAO Locust Group in Rome.



*African armyworm*

The African armyworm is one of the most serious pests in East Africa and can suddenly appear in large numbers over vast areas, destroying cereal crops completely. A warning service that encourages early discovery and reporting and enables the farmers and control agencies to organize operations has existed for many years. These are the basic considerations:

1) Continuous assessment of changes in adult (moth stage) and larval populations and weather conditions, particularly wind shifts and rainfall. Results from sample collection traps in Tanzania, Kenya and Uganda are communicated.
2) Changes in population of larvae are estimated and distribution extrapolated.
3) Wind and rainfall records indicate possible convergence centers.
4) Comparison is made with historical occurrences.
5) Forecasts of larval outbreaks are posted weekly in agricultural offices and released in the press and radio and television.

The above procedures are based on the following types of detailed studies of the pests' characteristics:

- Quantitative seasonal studies which determine seasonal range, variability in number and geographical distribution.
- Life history studies to find the length of the life cycle, number of eggs laid, amount of food eaten and maturation period for the females.
- Field studies to find the effects of weather on the pest and its predators and parasites.

***Q.*** *In forecasting pest outbreaks, what environmental factors are typically analyzed?*

***A.*** ______________________________________________

______________________________________________

______________________________________________

### Factors contributing to vulnerability

Vulnerability to pest infestation depends partly on the presence of the environmental factors which cause pest numbers to rise and pest damage to seriously affect food supply. These variables result from human manipulation of agricultural cropping systems and climatic conditions.

In developing countries, however, the ability to predict infestations and treat the pests are limited due to resource constraints, such as lack of trained personnel. Further, crop yields are sometimes normally insufficient to feed the local populations, many of whom may be subsistence farmers. Therefore, pest infestation poses a serious social and economic threat and renders these populations vulnerable to disaster.

### Possible risk reduction measures

#### *Integrated Pest Management (IMP)*

The concept of Integrated Pest Management was originally developed for the control of insects but its principles are now in use for control of disease and weeds as well. The driving forces behind the concept were the susceptibility of humans and animals to the effects of toxic pesticides and the fairly rapid development of pest resistance to pesticides.

The common goals of most IPM programs are to use multiple strategies to maintain pest damage below the economic injury level while providing protection against hazards to humans, animals, plants and the environment.

The development of an IPM program involves the following steps:

1. Identify the pests in the system, including:
   - major pests that usually cause damage above economic injury levels
   - minor, or secondary pests that case damage above the economic injury level only occasionally
   - potential pests that normally do not cause economic losses
   - migratory pests that can cause serious damage on a periodic basis
2. Develop suitable monitoring or forecasting techniques. This involves the measurement of pest populations (numbers of eggs, larvae, insects, spores, etc.) or amount of damage or loss.
3. Establish economic thresholds; that is, the pest population or disease incidence causing losses in crop value exceeding the cost of pest management.
4. Develop a pest management strategy. It is necessary to identify the least hazardous chemical that can be used, with minimal dose if needed, and the appropriate cultural and biological techniques to be integrated into a pest management strategy. IPM usually targets containment rather than eradication. Key elements of IPM tactical approaches are listed below.

*Villagers using traditional defense against locusts by scaring them away with noise of hitting tin cans with sticks.*

UNDP/Mary Lynn Hanley, *World Development,* January, 1989.

**Cultural control** – Some cultural practices are well established and others are experimental. All involve decisions made by the farmer. These include:

- Varying depth of tillage according to pest species.
- Planting resistant crop varieties.
- Using crop rotations and fallow periods.
- Diversifying cropping systems.
- Timing sowing and harvesting to avoid pest attacks.
- Planting "trap" crops that lure insects away from primary crops.

**Physical methods** – These include handpicking pests from plants, driving insects into a trench, placing bags around fruit, netting, greenhouses, use of lethal temperatures (both high and low), and use of electromagnetic energy such as ultraviolet light.

**Biological control** – This involves control by living organisms. Predators include birds, frogs, spiders, insects, nematodes and pathogens. Many methods which involve biological manipulation are now in use.

**Chemical methods** – This method of control is very quick in action and comes in different forms: reellants, antifeedants (block feeding response), fumigants, smokes, stomach poisons, contact poisons and systemic poisons. Pesticides have some negative side effects:

a) Insect populations may rapidly surge back after treatment wears off.

b) The pesticide may also destroy the target insects' natural enemies and the numbers resurge.

c) A secondary pest may take hold.

d) Most toxic chemicals in pesticides are absorbed into the environment.

*Chemical pesticide application.*

UNDP/Kevin Bubrisky

**Insect Behavior Modification** – Chemicals containing pheromones (hormones produced by insects released as behavior cues to other insects) and other agents can be used to disrupt mating, attract pests to traps or repel them from crops.

**Regulatory activities** – Most of these are directed at preventing the introduction of pests into new areas, mainly through quarantine measures. FAO has established a system of international plant protection whereby an International Phytosanitary Certificate is essential for importation of plant material into almost every country of the world.

Eradication reduces the pest population to the point where the economic damage is not significant. In cases of disease vectors for humans, such as the mosquito, complete eradication may be the goal. The cost in both economic and environmental terms may preclude eradication programs in developing countries unless the program involves nonchemical methods.

***Q.*** *What are the four steps required for the development of an integrated pest management program (IPM)?*

***A.*** ______________________________________________

## Specific preparedness measures

**Establishing a national plan for pest control** – The national plan for pest control should include:

- development of regulations regarding import and export of plant material.
- development and enforcement of regulations and procedures for procurement, storage, transport, and use of pesticides.
- pest forecasting and damage assessment components.
- adoption of international pest management strategies which conduct control measures over large areas and require facilities and resources not available to farmers.
- extension services to engage farmers' support, inform them and provide pest control supplies.
- a research component for study of local pests species and effects of various pest control measures.
- a training component to update and inform national staff about new discoveries and methods of control.

*ANSWER* *(from page 145)*

In forecasting pest outbreaks, environmental factors such as wind, rain, and temperatures can be analyzed in the prediction of the severity and location of the outbreak.

***It is vital that information regarding pest infestation and control is shared between government ministries, extension agents and farmers.***

**Training and extension** – In most developing countries, the small farmer is likely to bear major responsibility for agriculture production. As mentioned in the introductory paragraphs of this chapter, crop losses to pests may be significant. It is vital that information regarding pest infestation and control is shared between government ministries, extension agents and farmers. The farmers are able to describe the type of pest problems prevalent in their areas and cultural methods used to control them. They can assist extension agents to determine when a pest population is reaching a threatening level and at what point pesticides will have to be used.

The government representatives may provide technical expertise, informing farmers about new discoveries and influencing their decisions regarding use of cultural or biological control of pests. Farmers can use cost-free methods of pest control and save national expense. The extension services may demonstrate methods of pesticide application and provide a means for farmers to obtain equipment and pesticides or arrange for the farms to be treated.

***Research has shown that biological control often compares favorably with chemical control.***

**Use and care of pesticides** – The decision to use pesticides is usually an economic one. The economic threshold in pest control is the point at which a particular pest can be controlled at a cost of less than the expected market value for the expected yield increase. Just as important as when to begin application is when to stop, as at a certain point the application will no longer be economically effective.

Research has shown that biological control often compares favorably with chemical control. In developing countries, however, training or extension efforts to implement biological or cultural controls may not be as comprehensive as needed. Thus, often, pest problems get out of hand and must be controlled by use of chemicals. Insects such as locusts sometimes breed in remote places or move from great distances and do not appear until they fly in and attack crops in great numbers, overwhelming local capacity for effective crop protection.

Pesticides and application equipment should be kept in stock or available for an unexpected infestation. There are many different types of pesticides and modes of application. Further, there are many safety regulations regarding use of the pesticides and their toxicity to other living creatures.

## Typical post-disaster needs

If the scale of pest infestation is to large to be handled locally or by the nations it affects, international organizations may be called in to provide the equipment and pesticides necessary. If food losses are great and can be expected to affect the health of the population, food will have to be moved to the affected area from surplus areas. If no surplus exists, food will have to be imported or secured from donors.

ANSWER *(from page 22)*

In order to develop and adequate pest management program the following four steps should be followed:

1. identify the pests
2. develop monitoring and forecasting systems
3. establish economic thresholds
4. develop management strategy

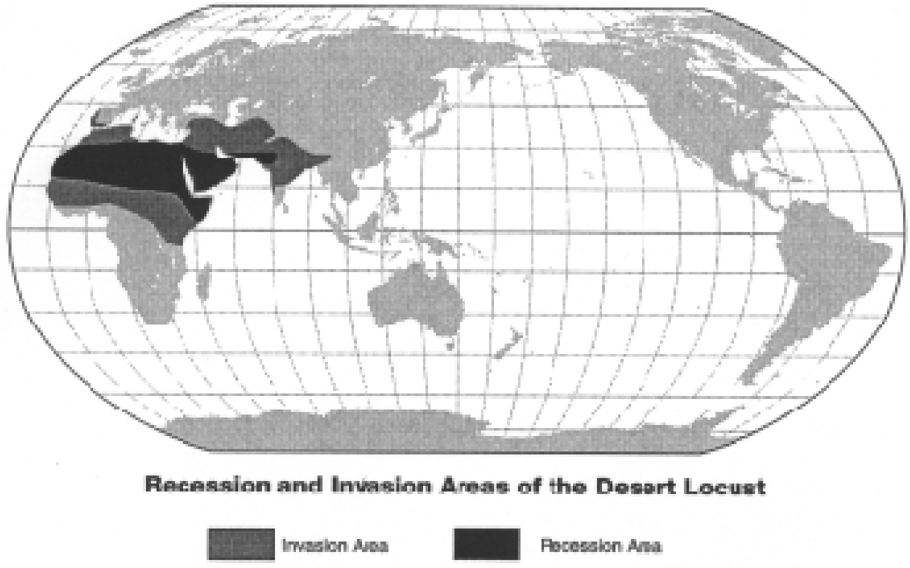



**Figure 3.4.1**
*World map showing typical habitat (recession areas) and expanded areas of oubreaks after mass reproduction (invasion areas) of the desert locust. After Steedman, 1990, and quoted in S. Krall, 1995.*

*Locusta*

## ■ CASESTUDY

### Recent desert locust outbreaks – Arguments for strategic control

The desert locust (species name: *Schistocerea gregaria*), an inhabitant of North Africa, the Horn of Africa, the Sahel and the Arabian Peninsula up to India, normally exhibits solitary behavior. When there is a sequence of good rains in these desert areas, the locusts can multiply rapidly and change from the relatively harmless solitary phase to the gregarious or swarming phase. Gregarious behavior affects the color, behavior and structure of the locust and results in swarming. When this happens, the desert locust range may spread to the Middle East, India, the sub-Sahel from Guinea to Tanzania, and parts of southern Europe.

Each swarm may be composed of billions of adult locusts flying up to 100 km per day in the direction of the prevailing winds. Gregarious nymphs march, advancing 1.5 km per day. Each locust can consume its own weight in vegetation daily, feasting on any crop, except possibly coffee. Plagues can be devastating. In 1953, crop losses reached more than US$ 50 million (in today's prices) in only six weeks in Morocco's Sousse Massa Valley.

In 1986, swarms from Sudan and Ethiopia traveled west and began breeding in foothill areas mainly in Mali, Niger, Chad and less intensely in Senegal, Mauritania, Saudi Arabia and Algeria. Swarms that emanated from these breeding areas eventually affected a total of 23 countries. The countries were taken by surprise after a 30 year locust recession. The campaign against the plague, over a four year period, was extensive involving donations of $US 310 million and pesticide treatments for 25 million ha.

Despite these inputs, the locusts spread until 1989 when their advance was halted by adverse weather conditions and control measures in North Africa and southwest Asia. Although warnings were issued by FAO, government crop protection personnel did not mobilize immediately. Fear of serious crop loss prompted widespread use of pesticides. Surveys were difficult in remote breeding areas and control efforts were hampered by presence of armed conflict in several countries and simultaneous outbreaks of other pests such as rodents and the Senegalese grasshopper. Farmer brigades in large numbers (Niger has 10,000 five person brigades) contributed to national government and international efforts to protect crops. Crop losses were <5%

in each country but the pesticide campaign failed to target breeding areas and thus contributed little to the effects.

In 1992, another desert locust outbreak began in the same region as in 1986 but with the potential to become even more threatening than the 1986-89 plague. Although the locusts became fully gregarious and swarms spread from the Horn of Africa to Mauritania and India, the outbreak was contained in infested countries because of early control efforts by governments and international organizations. In contrast to the previous plague, only 4 million hectares were sprayed at a cost of approximately US $18 m. The outbreak was brought to a halt by the end of 1994 with no appreciable crop losses.

Later, in 1995, swarms developed in interior Sudan which, despite control operations in Sudan, invaded Eritrea. The Eritrean crop protection service was able to eliminate the swarms before they reached breeding areas on the Red Sea coast. Some swarms which reached Saudi Arabia from Sudan were quickly eliminated as well. Again, early control methods prevented a full blown plague and destroyed the outbreak within two months at a cost of less than US $250,000.

**Use of strategic control** – The desert locust affected countries in partnership with FAO and the donor community have devised a program for early intervention in the Red Sea coast region and the Arabian Peninsula. The goal of the Emergency Prevention System (EMPRES) is to mitigate food security concerns by minimizing the risk of desert locust plagues through well-directed surveys and interventions that are timely and environmentally sound. EMPRES aims to promote regional self-sufficiency to avert plagues by strengthening national, regional and international components of desert locust management. As the first internationally sponsored early intervention program, EMPRES will begin in early 1997. A parallel and linked program is also planned in West Africa.

Sources:

Showler, A.T. Locust (Orthoptera: Acrididae) outbreak in Africa and Asia, 1992–1994: an overview. **American Entomologist** 41:179–185 1995.

Showler, A.T., and C.S. Potter, “Synopsis of the 1986-1989 Desert Locust (Orthoptera: Acrididae) Plague and the Concept of Strategic control”, in **American Entomologist,** Vol. 37, N. 2, Summer 1991.

Showler, A.T. Desert locust control, public health and environmental sustainability in North Africa. In: **The North African environment at risk** (A. Bencherifa & W. Swearningen, eds.). Westview Press, Boulder, CO, 1995.

***Q.*** *1) Are locust plagues still possible? Why or why not? 2) What were some of the problems experienced in controlling the 1986-89 locust plague? 3) How might the EMPRES program and others like it address some of these problems?*

***A.***

## ■ REFERENCES


Baunoun, Fay, “Integrated Pest Management: Fine Tuning Protection”, in **CERES,** FAO, Vol. 130, July/August, 1991, p. 31.

Edwards, Clive A., H. David Thurston and Rhonda Janke, “Integrated Pest Management for Sustainability in Developing Countries”, in **Toward Sustainability,** Panel for Collaborative Agriculture and Natural Resource management Program, National Academy Press, 1991.

Heitefuss, Rudolph, **Crop and Plant Protection,** Ellis Horwood Limited, West Sussex, England, 1989.

Hill, Dennis S., **Agricultural insect pests of temperate regions and their control,** Cambridge University Press, 1987.

Kane, Sid, “The Tsetse Meets Its Match”, in **World Development,** UNDP, January, 1989.

Krall, S., “Desert Locusts in Africa: A Disaster?”, *Disasters,* Vol. 19, No. 1, 1995.

Mwanza, Francis, “The Lopezi Defense”, in **CERES,** FAO, Vol., 130, July-August, 1991, p. 21.

Pimentel, David, ed., **Some Aspects of Integrated Pest Management,** Dept. of Entomology, Cornell University, Ithaca, N.Y., 1986.

Showler, A.T. Leucaena psyllid, Heteropsylla cubana (Homoptera. Psyllidae), in Asia. **American Entomologist** 41. 1995, pp. 49-54.


## ■ RESOURCES

For early warning information on locust outbreaks:
Migratory Pest Group
Plant Protection Service, AGP
FAO
vial delle Terme di Caracalla
00100 Rome, Italy
Phone: 39 6 522 54021
Fax: 39 6 522 55271
E-mail: abderrahmane.hafraoui@fao.org

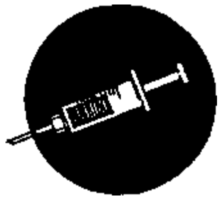
# NOTES

*ANSWER (from page 150)*

1) Locust plagues are possible when conditions permit rapid multiplication and when early control measures are not used.

2) Despite warnings, crop protectiondid not occur immediately. Pesticides were widely and heavily used and not always targetted to breeding areas. Surveys were difficult.

3) EMPRES will promote early control through supporting survey work in all partner countries and should prevent need for expensive control measures such as extensive pesticide use.



PART 4

# EPIDEMICS

This chapter of the module will improve your knowledge regarding:

- *epidemics of infectious disease and of other health-related events*
- *the factors which cause outbreaks of communicable disease*
- *the importance of epidemiological surveillance to predict and mitigate epidemics*
- *need for immediate intervention measures to control epidemics*
- *need for follow up studies to prevent future epidemics.*

## Introduction

An epidemic is defined as the occurrence of an illness or other health-related event that is unusually large or unexpected. Epidemics are commonly caused by a disease known or suspected to be of infectious or parasitic origin, however, epidemics can be associated with other hazards. For example, chemical accidents, food shortages, and civil conflict can cause epidemics of poisoning, malnutrition and micro-deficiencies, or intentional injuries respectively. An epidemic can evolve rapidly into a disaster, thus a prompt response is needed.

EPIDEMIC

This chapter mainly focuses on infectious diseases, such as cholera, meningococcal meningitis, typhoid, viral hemorrhagic fever, and hepatitis, which can pose considerable threats to a community. These diseases occur more frequently in developing countries but also occur in industrialized nations. The term epidemic can be applied to any pronounced rise in the occurrence of a disease and is not restricted to sudden outbreaks. In the past, slow epidemics of leprosy have occurred over generations. New and unrecognized epidemics occasionally arise such as AIDS (acte-immunodeficiency syndrome) which was detected in the United States in 1981 when requests for medication increased.

### *Explanation of terms*

The following explanations are useful when discussing epidemics.

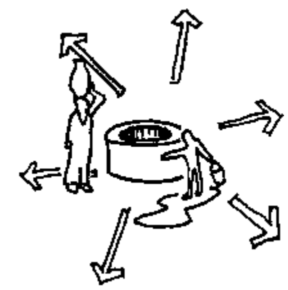
**Outbreak** – an unusually large or unexpected number of cases for a given place and time

**Epidemic of an infectious disease** – an outbreak which disrupts the community and overwhelms the capacity of local health services

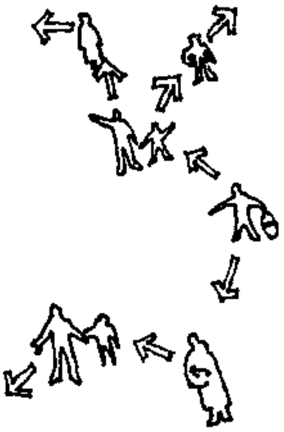
**Threatened epidemic** – circumstances in which an epidemic can be anticipated

**Point-source epidemic** – one source of toxins or organisms, such as with food poisoning, results in many cases in a short period of time

**Propagated disease epidemic** – organisms are spread by passage from person to person and the rise in cases is less abrupt



*Point-source*



*Propagated*

## EPIDEMICS HAZARD DATA SHEET

**As of late 1994, WHO estimates 18 million adults are affected by HIV, the virus responsible for AIDS.**

**Recent epidemics**[1]

| Year | Location | Type | Deaths | Affected |
|---|---|---|---|---|
| 1987 | Mali | Yellow Fever | 137 | 153 |
| 1988 | Ethiopia | Meningitis | 7,385 | 41,139 |
| 1989 | Comoros | Typhoid | 3 | 450 |
| 1991 | Peru | Cholera | 3,350 | 475,000 |
| 1991 | Malaysia | Dengue Fever | 263 | 3,750 |
| 1991 | Nepal | Gastroenteritis | 1,334 | 45,341 |
| 1992 | Brazil | Cholera | 196 | 15,240 |
| 1992 | Cameroon | Meningitis | 731 | 7,865 |
| 1992 | Cuba | Neuromylepathy[2] | 49,358 | |
| 1994 | Guinea Bissau | Cholera | 195 | 8,631 |
| 1994 | India | Pneumonic Plague | 54 | 300,000 |
| 1994 | Kenya | Malaria | 1,000 | 6,500,000 |
| 1994 | Worldwide | AIDS | | 1,025,073 cases |
| 1995 | Niger | Meningitis/measles | 3,022 | 63,691 |
| 1995 | Zaire | Hemorrhagic fever[3] | 233 | 6,000,000 |

[1] OFDA Disaster History, 1996
[2] A nervous system disease
[3] Caused by the Ebola virus

**Transmission from person to person** – occurs through nasal secretions, feces, urine, blood, saliva or semen, or articles contaminated by these

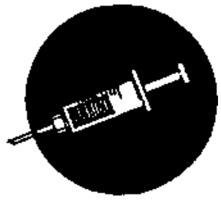
**Healthy carrier** – persons who carry the infection and can transmit the disease but show no signs of illness (as many as 90% of cholera cases)

**Endemic disease** – a disease constantly present in a certain area, such as malaria, tuberculosis and sleeping sickness, and a certain number of cases above normal must occur for an epidemic to be confirmed

**Pandemic** – A epidemic that is occurring worldwide or over a large area. AIDS is a current pandemic.

***Q.*** *What is the difference between "point source" and "propagated disease" epidemics?*

***A.*** ____________________



## Causes

Reports of outbreaks of communicable diseases are increasing for a number of reasons. Population, environmental and economic pressures increase people's exposure and vulnerability. For instance, rapid urban development may promote poor sanitary conditions, poverty and over-crowding. National and international travel is increasing and takes place over longer distances. Changes are occurring in the patterns of disease, such that the parasite responsible for malaria has become largely resistant to traditional treatment by chloroquine. Part of the increase, however, may be attributed to better coverage by health services, more accurate diagnoses, and better reporting of outbreaks.

Many endemic diseases can cause epidemics if environmental conditions, host susceptibility, or host carriers change in a way that favors transmission and infection. Possible examples include:

- Exposure of non-immune persons coming from a non-endemic area (such as refugees, economic migrants, or tourists)
- Ecological changes that favor the breeding of an insect vector, such as the mosquito in the rainy season
- Increase in human movements increasing the frequency of contacts (such as refugee or internally displaced camps, markets, pilgrimages)
- Poor sanitation causing contamination of food or water supply
- Decline in nutritional status increasing vulnerability.

***Q.*** *What are some reasons for the increase in the number of reported outbreaks of communicable disease in recent years?*

***A.*** ______________________________

## General characteristics

An epidemic emergency can only be defined within the larger context in which it occurs, but it may include the following characteristics:

1) introduction and spread of the disease in the population
2) expectation of a large number of cases
3) sufficient severity as to lead to serious disability or death

EPIDEMIOLOGY

4) risk of social and/or economic disruption
5) national authorities unable to cope with the situation because of lack or insufficiency of:
   – technical or professional personnel
   – organizational experience
   – necessary supplies or equipment (drugs, vaccines, material for laboratory diagnosis or vector control)
6) danger of international spread of the disease
7) a single case of a severe infectious disease in an area where it has been eliminated.

***Constraints to predictability occur in newly formed communities such as refugee camps or resettlement villages where medical histories are not known and immunities to local vectors may be lacking.***

## Predictability

Epidemiology is a science which deals with the incidence, distribution, and control of disease. Epidemiological studies serve to describe the health status of the community and provide clues which lead to interventions for prevention and treatment. The studies assists health workers to predict epidemics as well as provide data to plan and evaluate health care. If health care is poor or not available, the possibility of epidemics increases. Important data collected includes:

- the epidemiology of endemic diseases, such as the transmission route, and resistance to medications
- the past history of outbreaks
- identification of vulnerable populations.

*ANSWER (from page 154)*

Point source epidemics are spread to humans from a particular toxic or infectious source, and propagated disease epidemics are spread from one person to others, from these to still others, forming a *chain* of infection.

An epidemic can be anticipated when certain circumstances are present, such as a susceptible population, the presence of impending introduction of the disease agent, and/or, the presence of a mechanism for large scale transmission, such as a contaminated water supply or a vector population. An epidemic may also be predicted by an increase of the disease carriers or animals. The plague is carried by fleas on rodents and an epizootic (epidemic among animals) occurs prior to the epidemic among humans, signaled by massive deaths in rodents.

*ANSWER (from page 155)*

The increase in the number of reported outbreaks of communicable disease in recent years may be attributable to:

1) increased national and international travel
2) urban development booms causing crowding and poor sanitation
3) changes in patterns of disease
4) increased health care coverage (which may lessen incidences of outbreaks yet increase medical reporting of all cases)

Constraints to predictability are more severe in newly formed communities such as refugee camps or resettlement villages. Medical histories may not be known, immunity to local diseases may be lacking, shelter and sanitation may be unplanned or rudimentary, and the water supply may be precarious or unsafe. Health services may be superficial or not sufficiently focused on prevention, due to insufficient supplies and trained personnel.

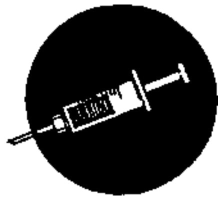
## Factors contributing to vulnerability

***Poverty is the major factor contributing to vulnerability.***

Conditions associated with poverty are the major factors contribution to vulnerability. Vulnerability is high among those subjected to poor nutrition, poor sanitation, poor water supply, poorly organized health services, and drug resistant diseases. Vulnerability is greater in individuals who are not immune to diseases or have immune systems weakened by other diseases such as AIDS.

## Typical adverse effects

Epidemics cause illness and death. Usually the number of cases reported is far lower than the number that actually occur. Secondary effects are social and political disruption and economic loss. Epidemics may worsen already traumatic or life threatening situations such as those found in famine, situation, emergency evacuations and refugee camps.



## Specific preparedness measures

For most epidemic disasters, public health measures are well known and can be planned for well in advance. The challenge for national health programs is to make emergency preparedness a part of ongoing health services while strengthening overall effectiveness. The following measures can be integrated into long-term emergency preparedness programs.


### *Organizational preparedness*

**Structures** – The delineation of responsibility must be very clear among the organizations involved in emergency response. In many countries, the Ministry of Health holds responsibility for initiating response. The chain of command, the executive structures, the roles and the coordinating mechanisms of the governmental and nongovernmental agencies should be clearly defined at local, regional, national and international levels.

**Rapid Assessment of an Epidemic**

After official notice or even a rumor of a possible epidemic is received, the situation should be assessed by a rapid site visit within 2–4 days. A systematic routine should be employed and can be summarized as follows:

1) **Confirm the existence of the epidemic** – Confirm the diagnosis by establishing a working case definition, and confirm that the number of cases are real and unusual and not, for instance, due to normal seasonal variations.

2) **Assess the impact on health** – Estimate how many people are at risk by looking for other cases of the disease, their location and their characteristics. Analyze the information gathered and decide:
   - Is the outbreak spreading?
   - What is the cause of the outbreak?
   - What is the mode of transmission?
   - Who is at greatest risk?
   - What can be done to contain the spread of the disease?

3) **Assess the existing response capacity and additional immediate needs for outbreak control.** Look for gaps in the resources needed for epidemiological surveillance, case management, preventative activities, coordination, community involvement, information, education and training.

4) **Convey the findings and the recommendations** arising from the rapid assessment to decisionmakers at local, regional, national, and international levels as appropriate.

**Contingency plans** – After identifying which epidemics are likely to occur and their probable consequences, the plan for response should include:

- early warning through a system of epidemiological surveillance
- procedures for rapid emergency assessment
- updated lists and maps of health facilities, inventory of NGOs which may assist
- standardized procedures for involvement of all agencies including international organizations
- procedures for obtaining funds and other resources such as transportation, drugs and vaccines, laboratory analysis, health workers, communications

**Training** – Train national staff at different levels in emergency preparedness and response for epidemics.

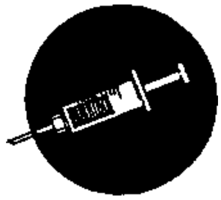
***Q.*** *That are the three major components of organizational preparedness?*

***A.***

### *Control measures for outbreaks*

Outbreak control is emergency response to a) to reduce the suffering and risk of death for the infected individuals, and, b) to limit the spread of the disease. Action for control should be implemented immediately based on the information obtained in the rapid assessment, on epidemiological data, and the choice of an effective strategy for the specific diseases. Data must be collected during the epidemic to assess and modify programs. Selection of strategies for outbreak control is also contingent on the degree of urgency, technical principles, political pressures, media coverage and public suffering, among others. Guidelines for control measures and medical assistance to treat most diseases are available through WHO country offices.

The spread of the disease can be limited or eliminated by reducing the source of infection, by interrupting transmission, and by protecting the persons at risk. Common sources of infection, such as mosquitoes, rodents, ticks, or contaminated food, water or soil, can be tackled by environmental measures. Strategies include spraying of breeding sites, use of protective nets, sanitizing food preparation areas, improving disposal of solid wastes, and disinfecting and protecting water sources. Implementation requires skilled personnel, good intersectoral collaboration, community participation and logistical support.



Person to person transmission can be reduced by to protective measures addressing the patients, their contacts and the community.

**Patients** – The best precautions are use of basic hygiene, such as hand washing, proper nursing techniques and well equipped health facilities. Some diseases such as Ebola hemorrhagic fever, require special decontamination procedures. Special precautions are needed for medical evacuations.

*AIDS education mural in downtown São Paulo*
Sid Kane/UNDP, *World Development,* June 1990.

**Contacts** – Persons who are in contact with an infectious patient can be more easily infected and become a source of infection. The risk varies with the situation and precautions may range from self-surveillance to strict isolation complemented by immunization or use of preventative medication (chemoproplylaxis). Immunization is best implemented as a preventative measure, however, it can be useful against some epidemics such as measles, poliomyelitis, yellow fever and meningococcal meningitis.

**Community** – Good management of patients and contacts decreases the risk for the community If it is impossible to identify all patients, mass gatherings may be restricted or the closure of schools may be indicated. Use of a "cordon sanitare" or quarantine may be a waste of resources as this method is usually not very effective and may have adverse economic effects. For example, quarantines cannot stop cholera which is mainly spread through healthy carriers. The most cost-effective measres are epidemiological surveillance and community participation for case finding, contact tracing, and prevention of transmission. Public information should promote specific behaviors to avoid infection or transmission.

## *Education for health*

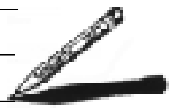
Educating for health, to avoid disease but also to promote a positive lifestyle, is a vast endeavor. Preventative measures may range from and washing to complex matters such as preventing sexually transmitted diseases. Long term health education can be incorporated into school curricula and clinic settings to help change attitudes and practices. Methods for targeting adults can range from house visits by rural health workers to publicity through newspapers, posters, radio and television.

***With the advance of life threatening epidemics such as AIDS, community participation is particularly vital.***

Community health education helps stem epidemics by alerting individuals to signs and symptoms of disease and stressing the need for reporting cases to local health authorities. With the advance of global epidemics such as AIDS, community participation is particularly vital. The death or immobilization by illness of productive individuals inflicts not only personal and economic hardships on families but also on the society as a whole.

***Q.*** *In designing a community health education program it is important to teach the methods that can be used to stop the spread of communicable disease. List the three basic ways in which an outbreak of communicable disease can be controlled. Mention ways to protect patients, contacts and the community.*

***A.***



## Typical post-disaster needs

If an outbreak cannot be contained with national resources, external help is required. Agencies that may provide assistance include the International Federation and the International Committee of the Red Cross and UN agencies such as DHA, WHO, UNICEF, UNHCR and UNDP. Experience shows that as soon as an outbreak is publicized by national authorities, international assistance is prompt, particularly if contingency plans have been prepared and shared in advance. UNICEF, WHO and some NGOs have designed special emergency kits for the most common outbreaks. Guidelines for emergency drug donations have been published by WHO.

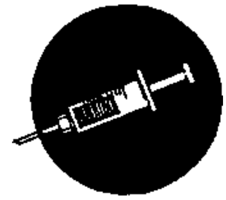
### *Evaluation of control measures*

Indicators must be chosen for monitoring the on-going control measures. Two typical indicators are the decrease in the ratio between the number of cases and deaths and the decrease of the daily rate of occurrence. After the emergency, epidemic analysis should look into the features and causes of the outbreak, the response activities and the likelihood of re-occurrence. Cost of treatment and cost of preventative measures can be compared and determinations made of the amount of human suffering that was (or cold have been) avoided. A final report containing the appropriate recommendations must be published and widely circulated.

*ANSWER* *(from page 158)*

The three components of organizational preparedness for epidemic outbreaks are:

1) Structural components of the institutions including clearly set roles and responsibilities.
2) Viable contingency plans for possible outbreaks
3) Training for national staff at all levels.

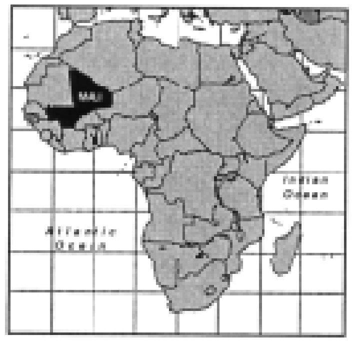


## ■ CASE STUDY

### Yellow fever epidemic in Mali – an endemic disease becomes epidemic

### *Identifying weaknesses in disease control*

Yellow fever, a mosquito-borne viral infection, continues to be a major threat in endemic zones of Africa where the virus reappears even after long periods of dormancy. Outbreaks have occurred in Africa resulting in thousands of deaths. Available statistics largely underestimate the prevalence of the disease, due to its occurrence in many remote areas where there is a lack of medical services and poor reporting. Surveys carried out in all parts of Africa since 1932 have delineated the boundaries in which the disease has occurred.



Mali

Mass yellow fever immunization campaigns were initiated in West Africa in 1940 and resultant disappearance of cases led to neglect in administering the immunizations. In 1958, some virus activity occurred in Zaire and later in Sudan. The most severe outbreak occurred in Ethiopia in 1960-62 when a dramatic epidemic affected the southwest region of the country and 3,000 deaths were reported, however, realistic estimates are closer to 30,000 deaths. Yellow fever had never penetrated this part of Ethiopia before, thus no immunity existed and many were affected. Over the past 25 years, several other outbreaks of the disease were recorded.

From September to November, 1987, a yellow fever epidemic broke out in western Mali which precipitated a wide scale immunization program. A total of 305 cases and 145 deaths were officially reported but true numbers were probably about five times higher. The Ministry of Health in Mali operates a rapid information system whereby a radio network linkage to district levels report disease information weekly to headquarters. If an unusual health problem is reported, a team is sent to the field to initiate an epidemiological investigation and recommend public health measures.

The disease was reported initially by health workers as hepatitis, a common mistake as jaundice is characteristic of both diseases. Inefficient means were used to secure blood samples for testing and resulted in delays in diagnosis. When blood samples were finally obtained, they had to be sent to a different country for analysis, further delaying the confirmation of disease. Later examination of records showed that patients at different clinics with the same symptoms received different treatments.

A post-disaster analysis concluded that four problems existed:

**Insufficient use and collection of epidemiological data** – The medical personnel were not fully aware of the history or symptoms of yellow fever and the need to differentiate these from other jaundice producing diseases. They did not process the blood samples correctly and include complete patient information. Beside the lack of training for diagnosis and treatment, the medical personnel were not aware of the correct procedure to follow once the cases were suspected. No active case finding was performed and communication to alert other stations was incomplete. Further, health workers did not demonstrate that they understood the importance of completing standardized forms for reporting.

**Lack of equipment for laboratory confirmation** – Inadequate local and national facilities caused a delay in diagnosis.

**Inadequate action plan for epidemic control** – The incident demonstrated the need for more detailed procedures of identifying and confirming the disease, assessing the magnitude and severity and implementing prevention and control. Surveillance teams needed to seek out cases by visiting rural sites.

**The low utilization of health services** was a very important feature of this case – only those cases in which people died or went to the health clinic because they were severely ill were reported. This may also explain the lack of vaccine coverage for the victims. Reasons for low utilization may include poor accessibility from remote areas or low confidence in medical care provided.

Recommendations to strengthen the disease control measures in Mali included:

1) Training of local health personnel to carry out case detection rather than wait for a specialized unit to respond perhaps from a long distance.
2) Creation of a fund to mobilize epidemic preparedness activities.
3) Development of regional coordination for surveys, immunizations and vector control, and the provision of technical assistance and pooling of resources.

Source: Kurz, Xavier, “The Yellow Fever Epidemic in Western Mali, September-November 1987: Why Did Epidemiological Surveillance Fait?, in **Disasters,** Vol. 14 No. 1, 1990, p. 46-54.

***Q.*** *1) What other reasons besides presence of jaundice might have led the Mali health workers to initially diagnose hepatitis? 2) From this description, what errors occurred in the procedures that may have caused the disease to become an epidemic?*

***A.***

*ANSWER* *(from page 160)*

Communicable disease can be controlled by eliminating or reducing the source of the infection and protecting persons at risk.

Protect patients through basic hygiene, proper nursing and well equipped facilities.

Protect contacts through self-surveillance, isolation, immunization, chemoprophylaxis.

Protect community by restricting gatherings, epidemiological surveillance and community participation in health measures.

## ■ REFERENCES

**A Dictionary of Epidemiology,** J.M. last, editor Oxford Medical Publications, 1988.

Barker, D.J.P., and A.J. Hall, **Practical Epidemiology,** Churchill Livingstone, 1991.

Bres, P., **Public Health Action in Emergencies,** World Health Organization, Geneva, 1986.

CDC Monograph, "The Public Health Consequences of Disasters", 1989, U.S. Department of Health and Human Services, Centers for Disease Control, Atlanta, Georgia, September, 1989.

"Cholera Outbreaks – Ineffective Control Measures", **Weekly Epidemiological Record,** 39, 27 Sept. 1996, p. 291-292.

**"Control of Epidemic Meningococcal Disease: WHO Practical Guidelines",** Foundation Marvel Merieux, 1995.

Gregg MB, Dicker RC, and Goodman RA. **Field Epidemiology,** Oxford University Press, New York, 1996.

Kane, Sid, "Brazil Takes Aim on AIDS", in **World Development,** UNDP, June 1990.

Sandler, R.H. and T.C. Jones, **Medical Care of Refugees,** Oxford University Press, New York, 1987.

**WHO Guidance on Formulation of National Policy on Control of Cholera,** Geneva, 1992.

**WHO Guidelines for Drug Donations,** Geneva, 1996.

**WHO Introduction to Rapid Health Assessment,** in press, April 1996.

## ■ RESOURCES

For bulletins an alerts on significant epidemiological problems:
Epidemiological Early Warning System (EEWS)
Emergency and Humanitarian action Division
WHO
Case postale Avenue Appia 20
1211 Geneva 27
Switzerland
Phone: (41 22) 791 211
Fax: (41 22) 791 4844

# NOTES

*ANSWER (from page 162)*

1) If they were unaware of the history of yellow fever, they may have believed it to be eradicated. They may also have believed that the patients had been vaccinated.

2) When patients showed signs of a contagious disease, the health workers did not go out to look for more cases to determine the scope of the problem. Emergency and control measures were not initiated until the laboratory report came in, and cases may have multiplied during that time. Different treatments indicates conflicting information in the health care system. Treatments given may not have included the control measures needed.

PART 5

# CHEMICAL AND INDUSTRIAL ACCIDENTS

This chapter of the module will increase your awareness of:

- *the threat of chemical disasters to humans and the environment*
- *the factors which increase the probability of industrial accidents and increase vulnerability of local populations*
- *options for establishing a prevention and preparedness program for chemical and industrial disasters.*

## Introduction

All over the world, people are becoming victims of industrial accidents that release hazardous substances into the environment. Trains carrying chemicals derail and trucks overturn. Pipelines rupture and chemical plants develop accidental leaks and releases. Accidents occurring in one country may seriously affect the populations of other countries or perhaps influence the ecology of the entire region. Therefore, crucial preparations must be made by governments to prevent or respond to such events and minimize harmful effects.

**CHEMICAL AND INDUSTRIAL ACCIDENTS HAZARD DATA SHEET**

**Major Chemical Accident/Incidents, 1984–1995**

| Year | Country | Type of accident | Chemicals | Deaths | Injuries | Evacuated |
|---|---|---|---|---|---|---|
| 1984 | India | Chemical plant leak | Methylisocy. | 3,598 | 100,000 | 200,000 |
| 1984 | Mexico | Tank explosion | Gas | 452 | 4,248 | 31,000 |
| 1985 | India | Leakage | Sulphur trioxide | 1 | 350 | 100,000 |
| 1986 | Ukraine | Reactor explosion | Radionuclides | 31 | 300 | 135,000 |
| 1987 | China | Accident | Methyl alcohol | 55 | 3,600 | |
| 1988 | China | Water contamination | Amm. biocarbonate | | 15,400 | |
| 1989 | USA | Factory fire | Sulphuric acid | | | 16,000 |
| 1988 | Pakistan | Munitions plant expl. | Explosives | 78 | 1,500 | 15,000 |
| 1991 | Malaysia | Fireworks plant expl. | Explosives | 22 | 125 | 260 |
| 1991 | Thailand | Spon. combustion | Mixed | 9 | many | 15,000 |
| 1992 | Mexico | Sewer explosion | Gas | 22 | 1,600 | 15,000 |
| 1992 | Haiti | Chem. plant explsion | Chemicals | 10 | 154 | |
| 1992 | Senegal | Tank explosion | Ammonia | 100 | 400 | |
| 1994 | South Africa | Burst goldmine | Cyanide | 77 | 450 | |
| 1995 | India | Oil Truck collision | Gasoline | 110 | | |

Source: **OFDA Disaster History**, 1996

## Causes

A “chemical accident or emergency” refers to an event which results in the release of a substance or substances hazardous to human health and/or the environment in the short or long term. These events can cause illness, injury, disability or death to human beings, often in large numbers, and can result in extensive damage to the environment with considerable human and economic costs (OECD/UNEP).

Chemical and industrial emergencies may arise in a number of ways:

- disaster/explosion in a plant handling or producing toxic substances
- accidents in storage facilities handling large and various quantities of chemicals
- accidents during the transportation of chemicals from one site to another
- misuse of chemicals, resulting in contamination of food stocks or the environment, overdosing of agrochemicals
- improper waste management such as uncontrolled dumping of toxic chemicals, failure in waste management systems or accidents in wastewater treatment plants
- technological system failures
- failures of plant safety design or plant components
- natural hazards such as fire, earthquakes, landslides
- arson and sabotage
- human error

## Characteristics

Chemical accidents may be classified by the chemicals involved, the sources of the release, the extent of the contaminated area, the number of people exposed, the routes of exposure an the health and medical consequences. Chemical releases may result from human or natural activities. Human sources include manufacture, storage, handling, transport (rail, water and pipeline) use and disposal. Natural origins include volcanic and other geological activity, toxins of animal, plant and microbial origin, natural fires and minerals. The four main routes of exposure are inhalation, eye exposure, skin contact and ingestion. Health effects are described in terms of the system or organ affected and may include cancer, immune system disfunctions, nerve or skin or liver disorders, or deformations.

Chemicals may be grouped as:

- Dangerous substances such as explosives, flammable liquids or solids, oxidizing agents, toxic substances and corrosives
- Additives, contaminants or adulterants, for example in drinking water, food and beverages, medicines and consumer goods
- Radioactive products.

Special characteristics of chemical accidents may include the following:

- Knowledge of the effects of some chemicals is not complete or widespread.
- Not all victims will have the same effects from exposure.
- There may be a toxic zone, that may include treatment facilities, which can only be entered by specially clothed personnel.
- Exposed persons may contaminate unexposed persons.

***Q.*** *What major chemical or industrial disasters have affected your country or community? Do you feel that these types of disasters are on the increase in your community? Why?*

***A.*** ______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

______________________________________________

***Past histories of chemical and industrial accidents are not necessarily good predictors of future incidents mainly because many incidents are not reported and near-accidents/misses are usually not reported at all.***

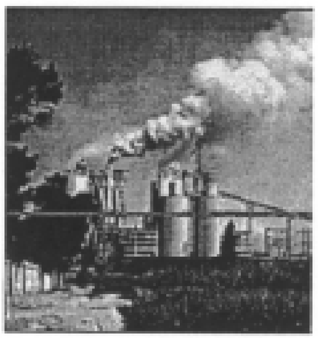
## Predictability

Emergencies involving hazardous substaces are becoming more common with increasing uses, sources, means of transporting and disposing of chemicals. Past histories of chemical and industrial accidents are not necessarily good predictors of future incidents mainly because many incidents are not reported and near-accidents/misses are usually not reported at all. Industrial development and expansion occurring in geographic areas prone to other disasters adds to the probability of greater human and economic losses caused by natural disasters.

The OECD Hazard Assessment Programme, in conjunction with other agencies worldwide, is developing hazard/risk assessment as a basis for regulation of the use of chemicals and pesticides. The process is based on a tiered assessment, which allows the effects to be progressively defined starting from the initial exposure. The basic elements of the assessment include:

- identification of the substance, its physical and chemical properties, and toxicity to animals and plants
- evaluation of the likely distribution of the agent and whether it will be toxic
- effects of possible exposure on organisms through selection of testing methods.

The hazard/risk assessment procedures will allow greater predictability of the effects of chemical hazards. Other methods being developed include use of environmental monitoring data, and modeling for Predicted Environmental Concentrations.



*Chemical lant*

William Raiford/UNDP, *World Development Annual Report,* 1988.

Although accidents may be anticipated in any industry, their causes and consequences are not always understood or predictable. Plans, therefore, must be made for any possible emergency to protect lives and property. The extent of loss (human casualties) by chemical releases from plants, trucks, ships or rail accidents depends largely on the first responders to the emergency.

### Factors contributing to vulnerability

The elements most at risk to an industrial disaster include the plant or vehicle and its employees or crew, passengers or residents of nearby settlements; adjacent buildings and the occupants; livestock and crops in the vicinity of the plant (up to hundreds of kilometers in the case of large scale releases of airborne pollutants and radioactive materials); regional water supply and hydrology; and flora and fauna.

Vulnerability is further increased by plants and operations which are poorly maintained or use antiquated equipment. Of great concern are transport vehicles and railway lines which may encounter hazardous conditions while in motion. Residents are more vulnerable if they do not know of the possible dangers and have no escape plan.

### Typical adverse effects

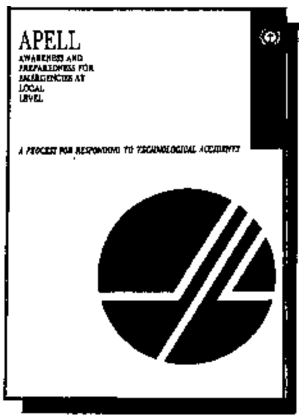
Explosions may cause destruction of buildings and infrastructure. Transportation accidents damage vehicles and other objects on impact, with possible loss of hazardous materials into the environment. Industrial fires may reach very high temperatures and affect large areas.

Many people may be killed and numerous injured may require emergency medical treatment. Hazardous substances released into the water or the air may travel long distances and case contamination of air, water supply, land, crops and livestock, making affected areas uninhabitable for humans. Wildlife may be destroyed and ecological systems disrupted. Large scale disasters may even threaten the stability of global ecology.

***The goal of APELL is to assist decision makers and technical personnel to improve community awareness of hazardous installations and aid them in preparing response plans should a disaster happen.***

### Possible risk reduction measures

The United Nations Environment Programme (UNEP) has developed a handbook describing the APELL (Awareness and Preparedness for Emergencies at the Local Level) method of planning for chemical accidents. It is not meant to replace national disaster plans but rather to augment them. The goal is to assist decision makers and technical personnel to improve community awareness of hazardous installations and aid them in preparing response plans should a disaster happen. A brief description follows.




#### *Identification of APELL partners*

**National level** – The initial response to an incident is normally provided locally and affects the overall outcome and magnitude of the incident. Responsibilities of national government include:

- Providing guidelines to encourage industries to initiate emergency response plans at the local level.
- Disseminating information on the APELL process and sponsoring workshops and training courses.
- Providing adequate resources for local communities to respond effectively if an emergency occurs.
- Follow up and assistance with the APELL process.

**Industrial facilities owners and managers** – The APELL process relies on the full commitment of both state and privately owned industries to ensure that plant managers devise, and test accident prevention and emergency preparedness plans inside the land boundaries. Responsibilities include:

- Developing outreach programs to inform the community regarding emergency response to lessen fears.
- Establishing good working relationships with local emergency response agencies.
- Establishing close links with local leader and officials and informing them about plant safety measures.
- Being the catalyst in formation of the coordinating group.

**Local Authorities** – Local governments play a critical role in first response to a crisis, mediating the roles of different interest groups and gathering necessary planning data. Responsibilities include:

- Raising public awareness and mobilizing public support for the APELL process.
- Coordinating emergency and other group participation.
- Training personnel in emergency response.

**Community leaders** – The leaders represent the concerns or view of their constituents in the community. Responsibilities include:

- Communicating with local authorities and industry leaders regarding issues of concern in the community.
- Communicating with their constituency on programs to protect public health and the environment.
- Providing leadership through community-based organizations to train the public.

**UNEP** – Information on APELL will be disseminated and implemented by assisting countries to participate. UNEP will promote workshops, enlisting participation of other UN agencies and international organizations.

***Q.*** *What types of regulations does government provide to control or monitor chemical and industrial processes in your country or community?*

***A.***

### *Community preparedness*

Although attention to accident control is increasing within industry, preparedness in the community is often much lower. The local community has a right to be informed and to participate in the response planning.

***The local community has a right to be informed about and to participate in response planning for hazardous installations.***

Furthermore, fears may be eased when people understand the workings of a plant and the safety measures being used. In general, a better scientific understanding of the hazard is desirable for all local emergency responders, such as police, fire and medical services as well as the media.

Based on data collected in regard to potential hazards and the resources available in the community to combat any disaster, the planning should proceed as follows:

1) Identify the emergency response participants (such as the fire department, military, Red Cross) and establish their roles, resources and concerns.
2) Evaluate the risks and hazards that may result in emergency situations in the community.
3) Have participants review and comment on their own emergency plans.
4) Identify the required response tasks not covered by existing plans.
5) Match these tasks to the resources available from identified participants.
6) Make the changes necessary to improve existing plans, integrate them into an overall community plan and reach overall agreement.
7) Commit the integrated community plan to writing and obtain approval from local governments.
8) Educate participating groups about the integrated plan and ensure that all emergency responders are trained.
9) Establish procedures for periodic testing, review and updating.
10) Educate the general community about the integrated plan.

## Land use planning

Although hazardous facilities will seldom be wanted by the local population, desires for economic growth by business and governments often take precedene. This has resulted in long term problems such as the need to clean up toxic waste sites in many countries. Land use zoning should separate densely populated residential areas from hazardous industrial activities and associated transportation routes, possibly through creation of buffer zones. Due to the increasing potential for dangerous incidents, better planning is required for hazardous installation, particularly for large sites and for substances which may travel over long distances. This requires a sense of responsibility on the part of governments and developers and sensitivity to the dangers for local residents.

*Airliner explosion*
QPL – *UNDRO News*, March/April, 1986

## Transportation accidents

A study of technological disasters of the past 40 years reveals a preponderance of transportation accidents, which pose daily threats to communities and usually occur without warning. Although most spills and releases are relatively small, some events, especially maritime spills, may be extremely large. In some cases ocean going tanker spills have been known to affect large areas sometimes crossing international borders.

Another special problem presented by transportation accidents is the mobility of the hazard. Unlike landslides, volcanoes, and even flooding which may be locally targeted for mitigation and preparedness measures, transportation accidents often happen in areas unprepared and ill-equipped to deal with the hazard. Local populations may be wholly unaware of the substances passing near or through their communities on route to distant factories and plants. Due to the extreme unpredictability of their occurrence and location, these accidents require a special approach for mitigation and preparedness.

In the United States, CHEMTREC (Chemical Transportation Emergency Center) established by the Chemical Manufacturers Association (CMA) provides around the clock guidance for hazardous materials accidents. The National Response Center, operated by the U.S. Coast Guard, works with CHEMTREC to assist emergency responders, carriers, shippers and all others handling hazardous materials. Some features of the program are:

- Communication and coordination with emergency response specialists and information regarding 10,000 hazardous materials shippers and 500 carriers
- Database containing over a million material safety data sheets provided by manufacturers
- Access to information from the major railroads on contents of rail cars
- Access to special materials for isolating spilled products
- Participation by response teams in drills in communities throughout the country and providing training to prevent human loss and environmental damage.

***Another special problem presented by transportation accidents is the mobility of the hazard. Unlike landslides, volcanos, and even flooding which may be locally targeted for mitigation and preparedness measures, transportation accidents often happen in areas unprepared and ill equipped to deal with the hazard.***

***Q.*** *Why are transportation accidents which involve hazardous chemicals of great concern?*

***A.*** ______________________________

## Specific preparedness measures

### *Hazard mapping*

Inventories and maps of storage locations of toxic or hazardous substances with descriptions of their physical appearance (i.e. gas, liquid, powder, etc.) should be prepared and should include the chemical characteristics (such as: may produce fumes, or may explode) and possible effects on human beings (i.e. may cause blindness, burns the skin, etc.). Common transportation routes for dangerous substances through communities should also be mapped.

An important feature of hazard mapping is determination of a possible zone of contamination and possible intensity of contamination. This requires knowledge of the nature of the chemicals themselves and may include review of historical records of accidents. The European community (EC) requires that premises storing specified quantities of very hazardous substances are designated “major hazard sites”. The operators of such sites must prepare emergency plans and communicate the dangers to the public. The EC’s Major Accident Reporting System (MARS) keeps a database on chemical accidents.

### *Hazardous materials identification*


All chemical containers should be labeled including storage boxes and barrels, vehicles, ships, and aircraft. Label information may include the name of the chemical, its toxic effects, the name of an antidote, instructions for treatment or cleanup, and where to call for further information. In the United States, pilots of crop spraying aircraft are encouraged to wear labels on their safety helmets with information about the pesticide being used.

## Other preparations

- Chemical plants and storage facilities should be inspected for safety and any needed improvements should be made immediately. If possible, storage capacities of dangerous or flammable chemicals should be limited.
- Toxic waste disposal procedures should be monitored and toxic waste dumps should be documented on a hazard map with information about the chemicals they contain.
- Fire fighting capacity both at plants and in the surrounding communities should be improved and practice drills conducted.
- Civil defense forces should be prepared to assist.
- Community members should monitor pollution levels and report any adverse effects.
- Individual citizens and communities should prepare and practice evacuation plans.
- Testing of warning sirens at plants and in the communities should be routine.
- Hazardous materials incident response training

**Insurance and compensation** – Requirements of insurance for industries handling hazardous chemicals will help to define the risks associated with vulnerable locations and operations. Compensation schemes should be encouraged which are able to provide large sums immediately to help victims.

## Typical post-disaster needs

In the event of a chemical disaster, medical and emergency teams should remove all injured persons from the scene of the emergency. All persons should leave the area unless protected by special equipment. They should

*ANSWER (from page 22)*

Transportation accidents concerning hazardous chemical substances are of special concern because:

1) They are unpredictable
2) They may occur in areas without functioning communication and other response capabilities.
3) Marine spills particularly may affect very large areas often crossing international boundaries.
4) Locally affected populations may be totally unaware of the hazard and may be unprepared to respond.

then stay away until safe return to the area has been determined and announced to the public. In the case of water contamination, alternate sources would have to be provided.

Clean-up of the effects of the disaster may require more resources than are locally available. In this case the required resources would have to be sought from other sources, such as international emergency assistance agencies. The affected area should be monitored continually following the disaster. Thorough investigation and documentation of the emergency must follow.

## ■ CASE STUDY

**Bhopal, India**

At around one o'clock on a December morning of 1984, a thick, white cloud of gas seeped out of a ruptured valve from a pesticide factory near Bhopal, India. Winds blew the fumes over a 50 kilometer area and cool temperatures kept the gas cloud low where it engulfed the houses. Citizens awoke coughing and many died in their beds. Thousands who escaped death were cared for in makeshift medical centers. May were temporarily or permanently blinded. There was no adequate warning or evacuation plans and no understanding of the nature of the chemicals among the local population.

*Child victims of Bhopal tragedy on their way to hospital*

AP: *UNDRO NEWS,* Jan/Feb, 1985

The official death toll reached 3,598 in 1989 but it is believed that actual numbers are much higher. A further, 50,000 were seriously affected and another 150,000 suffered from after effects. The seeping gas was highly toxic methylisocyanate. Within 45 minutes of the rupture, the leak had been repaired, but a lethal dose had already escaped. It is noteworthy that none of the workers at the plant were killed. Many claims against the company for compensation to the victims have not been settled.

**Chernobyl, Ukraine**

In April of 1986, the worst nuclear disaster, largely cased by human error, occurred in Ukraine (formerly of the USSR) at the Chernobyl nuclear power plant. The disaster displaced more than 400,000 people and had a devastating effect on the region's economy and environment. At the tenth anniversary of the event, in 1996, UN-DHA published a special issue of the DHA News to call the world's attention to the effects of the disaster, which has not yet ended.

An explosion at the plant sent a plume of radioactive gas and dust into the atmosphere. The plume contained iodine and cesium both of which can be absorbed by living tissue. The immediate effects on countries receiving fallout was the contamination of vegetable, milk and meat products. The extent of the long term risks associated with the disaster, such as cancers, are yet to be determined. However, thyroid cancers have increased 285 times over pre-Chernobyl levels and rates of morbidity, illness and stress related diseases are higher among the affected population, estimated to be around 3.5 million in Ukraine alone.

The small country of Belarus received 70% of the radioactive substances. More than 18,000 $km^2$ of agricultural land and 20,000 $km^2$ of forest were contaminated and one of five citizens lives on contaminated land. Some of the major drinking water sources flow through the contaminated areas and people still receive radiation from food and water from these areas. There are estimated to be at least a million children, adolescents and young adults at an elevated risk of thyroid cancer.

Source: *UNDRO News,* "Bhopal Tragedy", Nov/Dec., 1984, p. 4.
*DHA Issues in Focus,* "Chernobyl, no visible end to the menace", No. 4, UN-DHA, 1995.

## ■ RESOURCES

National Response Team, **Hazardous Materials Emergency Planning Guide,** Washington, D.C., 1987.

Organisation for Economic Cooperation and Development (OECD), **Accidents Involving Hazardous Substances,** Environment Monographs, No. 24, February, 1990.

OECD, **Health Aspects of Chemical Accidents,** Environment Monograph No. 81, Paris, 1994.

OECD, **Report of the OECD Workshop on Environmental Hazard/Risk Assessment,** Environment Monograph No. 105, Paris, 1995.

OECD, **Report of the OECD Workshop on Small and Medium Sized Enterprises in Relation to Chemical Accident Prevention, Preparedness and Response,** Environment Monograph No. 95, Paris, 1995.

OECD/UNEP, **International Directory of Emergency Response Centres,** OECD Environment Monograph No. 43, UNEP-IE/PAC Technical Report Series No. 8, November 1991.

Smith, Keith, **Environmental Hazards: Assessing risk and Reducing disaster,** Routledge, London, 1996.

UN-DHA, **Chernobyl – no visible end to the menace,** DHA, Series, No. 4, Geneva, 1995.

UNDRO, **Disaster Prevention and Mitigation, A Compendium of Current Knowledge,** Vol. 11, “Preparedness Aspects”, United Nations, New York, 1984.

UNEP, **APELL, A Process for Responding to Technological Accidents,** United Nations, 1988.

United States Department of Transportation, **1990 Emergency Response Guidebook,** DTO P 5800.5, Washington, D.C., 1990.

## ■ REFERENCES

For OECD Environmental Health and Safety Publications, contact;
OECD Environment Directorate
Environmental Health and Safety Division
2 rue Andre-Pascal
75775 Paris Cedex 16
France
Fax: 33-1 45 24 16 75
E-mail: ehscont@oecd.org
OECD’s World Wide Web Site: http://www.oecd.org/ehs/