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Acknowledgments

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Introduction

How to Get Started

This self-study course will meet the needs of people involved in managing both sudden-onset natural disasters (i.e., earthquakes, floods, hurricanes) and slow-onset disasters (i.e., famine, drought). This course is designed for government personnel, representatives of private voluntary agencies and other individuals at local and national levels who are interested in disaster management.

The procedure for self-study is:

• Complete and score the pretest. Do not be disappointed if you have a low score. If you have a high score, you probably do not need this course.
• Read the outline of course content to get a general idea of what is covered in the course.
• Read the learning objectives to get a general idea of what you are expected to learn from the course.

Turn to Lesson 1: Introduction to Natural Hazards

• Review the study guide section for a brief description of the lesson and any special suggestions on how to study.
• Again read the learning objectives.
• Carry out the learning activities listed.
• Complete the self-assessment test at the end of the lesson and score it using the answer key provided. If you have not answered most of the questions correctly, restudy the lesson.

If you score well on the self-assessment test, proceed to Lesson 2.

Continue to study each lesson and complete the self-assessment test until you have finished the course of study. When you have completed to your satisfaction all the self-assessment tests, you can request a final examination package. This will include the final examination and any other supplementary material.
Pretest

Multiple Choice
Circle the best answer(s):

1. The best foreign relief to an earthquake-stricken area is:
   a) cash
   b) food, blankets and clothing
   c) medical assistance
   d) teams of assessment workers and other volunteers
   e) long-term recovery assistance

2. The largest annual death toll during the 1970s was caused by:
   a) floods
   b) earthquakes
   c) tropical cyclones
   d) drought
   e) all other disasters

3. The majority of volcanoes are located in:
   a) the circum-Pacific belt
   b) the mid-Atlantic line
   c) East Africa
   d) the African Rift Valley
   e) Hawaii

4. Active floodproofing is most effective:
   a) with long warning lead times
   b) in flash flood areas
   c) if it is permanent
   d) in floodplain areas
   e) using volunteers

5. Supplementary feeding programs are:
   a) targeted to those people suffering from severe protein-energy malnutrition (PEM)
   b) targeted to those people suffering from moderate PEM
   c) often used to distribute general food rations over a wide geographic area
   d) of little value in large-scale famine relief operations
   e) a secondary response best handled by foreign agencies

6. Tropical cyclones often generate:
   a) high rates of injured people
   b) tidal floods
   c) very heavy rainfall
   d) agricultural soil erosion
   e) countercurrents beneath the ocean’s surface

7. The first step in desertification of rangelands is:
   a) thinning of vegetation due to grazing
   b) severe drought
   c) an increase in edible perennial plants
   d) water runoff due to sun-hardened soil
   e) an increase in groundwater level due to runoff

8. Tsunamis may strike with a force:
   a) greater than other types of disasters
   b) that radically alters the landscape
   c) that affects only lands along the world’s oceans
   d) that seriously disrupts economic and social patterns
   e) all of the above

9. The major human-made cause of deforestation today is:
   a) fuel
   b) wood pulp for papermaking
   c) unequal land tenure
   d) farming
   e) none of the above

True or False
Indicate T or F:

_____ 10. The ingredients of cyclones are a mixture of heat and moisture.

_____ 11. A natural event such as an earthquake will always result in a disaster.

_____ 12. An underwater earthquake in the ocean near your area is a natural tsunami warning.

_____ 13. A secondary effect of a volcanic
eruption may be the saturation of ash with rain, causing roofs to collapse.

14. Current international warning systems issue a “cyclone warning” when a cyclone could reach land within 24 hours.

15. The rapid rate of deforestation is a prime force in the yearly increase of flood disasters in the tropics.

16. Flash floods are rare in deserts and mountains.

17. Lands threatened by desertification cover 10 percent of the world’s surface.

18. Communicable diseases are a major threat after an earthquake.

19. Drought will occur only in semiarid climates.

20. The largest flood-related losses take place in countries with agricultural economies.
Outline of Content

Lesson 1  Introduction to Natural Hazards
• Classification of Disasters
• Phases of a Disaster
• Effects of Disasters
• Prevention, Mitigation and Preparedness

Lesson 2  Earthquakes
• Historical Examples and Geographical Distribution
• Effects of Earthquakes
• Earthquake Forecasting
• Impact of Earthquakes
• Pre-Disaster and Post-Disaster Activities
• Lessons from Past Disasters

Lesson 3  Tsunamis
• Historical Examples and Geographical Distribution
• Impact on Natural and Built Environments
• Disaster Mitigation and Preparedness
• Recovery/Reconstruction Problems and Strategies

Lesson 4  Volcanoes
• Historic Eruptions and Geographical Distribution
• Types of Volcanoes
• Volcanic Prediction
• Disaster Preparedness and Response

Lesson 5  Tropical Cyclones
• Historical Examples and Geographical Distribution
• Forecasting/Warning
• Impact on Built and Natural Environments
• Disaster Preparedness and Response

Lesson 6  Floods
• Historical Examples and Geographical Distribution
• Forecasting, Warning, and Monitoring Systems
• Impact on Built and Natural Environments
• Mitigation Strategies

Lesson 7  Drought
• Historical Examples and Geographical Distribution
• Natural Preconditions for Drought
• Impact of Droughts
• Famine
• Mitigation Strategies
• Post-Disaster Activities
• Lessons Learned

Lesson 8  Desertification
• Historical Examples and Geographical Distribution
• Natural and Human Preconditions
• Impact on the Natural Environment
• Recovery/Mitigation Problems and Strategies

Lesson 9  Deforestation
• Historic Examples and Geographical Distribution
• Economic and Social Conditions Leading to Deforestation
• Related Disasters
• Impact on Built and Natural Environments
• Recovery Strategies and Problems
• Mitigation
Course Objectives

Lesson 1  Introduction to Natural Hazards
- Distinguish between natural hazard and natural disaster
- Identify the causes or preconditions for a hazard
- Describe hazard risk
- Learn which disaster poses the greatest threat to personal safety
- Identify the phases of a disaster
- List the primary activities of government organizations and voluntary organizations in all disaster phases
- Understand community lifeline systems
- Identify components of disaster planning

Lesson 2  Earthquakes
- Understand in general terms the principles of plate tectonics
- Identify the kinds of movements occurring at fault lines
- Describe the earth movements during an earthquake
- Describe the scales of measurement of earthquake intensity and magnitude
- Identify primary and secondary effects of earthquakes
- Identify some of the earthquake mitigation measures that can be taken by various groups
- Describe some standard reconstruction activities

Lesson 3  Tsunamis
- Describe the physical characteristics of a tsunami
- Locate the geographic distribution of tsunamis
- Describe the primary impact of tsunamis on the environment and human settlements
- Identify the appropriate relief agency responses to a tsunami
- Describe various techniques of tsunami disaster mitigation

Lesson 4  Volcanoes
- Differentiate between the two extreme types of volcanic eruptions
- Describe the relationship of volcanic activity to seismic zones
- Identify the geological elements of a volcano
- Identify the four main kinds of volcanoes
- Identify primary and secondary effects of volcanoes
- Describe a technique for volcanic eruption prediction
- Know some of the volcanic eruption mitigation and preparedness measures that can be taken by various groups
- Describe the objectives of risk mapping

Lesson 5  Tropical Cyclones
- Identify the regional terms used to describe a tropical cyclone
- Describe the life of a tropical cyclone from initial seedling to final dissipation
- Describe the scale of measurement of cyclone velocity
- Identify primary and secondary effects of tropical cyclones
- Describe the major factors contributing to a storm surge
- Describe cyclone warning procedures
- Describe the various impacts of cyclones
- List some of the tropical cyclone mitigation and preparedness measures that can be taken by various groups
- Identify the important emergency response activities after a tropical cyclone

**Lesson 6  Floods**
- Describe the different types of flooding
- Inventory the ways in which human settlements on floodplains are vulnerable
- Describe the hydrological cycle
- Describe a flood management system
- Recognize the value of flood prediction
- List some of the flooding mitigation and preparedness measures that can be taken by various groups
- Identify the important emergency response activities after a flood
- Describe flood prevention techniques

**Lesson 7  Drought**
- Explain the natural and human-induced causes of drought
- Identify primary and secondary effects of drought
- Identify feeding programs to combat malnutrition caused by famine
- Recognize the value of drought prediction
- Describe techniques of drought monitoring
- List some of the drought mitigation measures that can be taken by various groups
- Identify some lessons learned from relief operations after the Sahelian drought of the 1970s

**Lesson 8  Desertification**
- Understand the concept of desertification
- Know the classifications for drylands and the natural process by which arid lands become desertified
- Identify the threats that desertification pose to humans
- Identify land management practices that mitigate against desertification
- Identify secondary effects of desertification
- List some of the desertification mitigation and prevention measures that can be taken

**Lesson 9  Deforestation**
- Recognize the economic and social conditions that lead to deforestation
- Identify primary and secondary effects of deforestation
- Identify techniques of deforestation prediction
- Understand the impact of deforestation on a country’s economy, agriculture, and construction
- Recognize some deforestation mitigation measures that can be taken
Lesson 1 - Introduction to Natural Hazards

Study Guide Overview

This lesson defines disasters. It classifies them and describes different phases of a disaster. It outlines general effects and how to prevent, prepare and mitigate these effects.

Learning Objectives

• Describe when a hazard becomes a disaster.
• Identify the conditions for a disaster to occur.
• Describe hazard risk and how a community or individual becomes vulnerable to a disaster.
• Explain how human activities both before and after the disaster takes place can add to a disaster’s impact.
• Rank disasters according to the number of people killed and the areas of the world in which they take place.
• Show how a country’s economy makes it more vulnerable to a disaster.
• List the phases of a disaster.
• Explain the primary activities of government and volunteer organizations during these phases.
• Compare the importance of disaster prevention and mitigation.
• Compare these with disaster response.
• List and explain components of disaster planning.

Learning Activities

• Read Chapter 1 in the text.
• Study Table 1.1.
• Review Appendix I.

Evaluation

Complete the self-assessment test.
Lesson 1 Self-Assessment Test

Multiple Choice
Circle the correct answer(s):

1. A natural hazard is:
   a) a flood, earthquake or similar unpredictable natural event
   b) an extreme natural phenomenon that causes death and destruction
   c) people located in a natural environment that may disrupt or threaten their safety and property
   d) any natural catastrophe targeted by government agencies as threatening to a population
   e) an unpredictable event that disturbs the natural order of the environment

2. The people living in Tokyo, Japan, are less vulnerable to earthquakes than those living in Nicaragua because:
   a) they have a higher standard of living
   b) they live farther away from the earthquake belt
   c) fewer earthquakes take place in Japan
   d) Japan has fewer active volcanoes
   e) Japan has good building codes and earthquake training

3. A disaster is defined according to:
   a) its human consequences
   b) its cause
   c) the number of deaths it causes
   d) its measurable severity
   e) the country where it takes place

4. The largest annual death toll during the 1970s was caused by:
   a) floods
   b) earthquakes
   c) tropical cyclones
   d) drought
   e) all other disasters

5. Technology can now identify hazards and estimate their impact on an area. This permits:
   a) planning evacuation routes
   b) applying for government aid and setting up monitoring stations
   c) preventing the disaster or reducing its impact
   d) reacting to the disasters when they occur
   e) knowing when the disaster will take place

6. Pre-disaster planning will make possible:
   a) the prevention of the disaster
   b) the effective application of aid where prevention is not possible
   c) self-sufficiency in dealing with natural hazards
   d) anticipating the consequences of a disaster
   e) all of the above

7. Effective hazard management will largely rely on:
   a) volunteers
   b) government agencies
   c) emergency responses
   d) pre-disaster planning
   e) establishing emergency relief agencies

8. Although each type of disaster can have a different cause, they all cause predictable problems in the following areas:
   a) environmental and health
   b) administration and managerial
   c) social and economic
   d) a and c
   e) a, b, and c

True or False
Indicate T or F:
9. The transitional period and the reconstruction period take place during the post-disaster phase.

10. Epidemics generally result from disasters.

11. Disasters create a need for total food and shelter replacement.

12. Local economies often collapse for a long time when disaster strikes.

13. Environmental effects differ greatly depending on the type of disaster.

14. Earthquakes and floods regularly cause many injuries requiring medical care.

15. Small, community-based organizations can function more effectively during a disaster than large, formal ones.

16. When community activities are back to normal following a disaster, disaster management planning has achieved its purpose.

17. A disaster strains only the resources of those directly affected by it.

Answer Key

1. c
2. e
3. a
4. b
5. c
6. e
7. d
8. e
9. T
10. F
11. F
12. F
13. T
14. F
15. T
16. F
17. F
Lesson 2 - Earthquakes

Study Guide Overview

This lesson describes how earthquakes occur and identifies their geographical distribution. It gives the naturally occurring preconditions that create an earthquake disaster. Earthquake effects, forecasting, measuring and historical examples of disasters are also described. You will learn the appropriate steps in earthquake disaster preparation and mitigation, and you will consider post-disaster activities. The lesson also demonstrates how the study of previous disasters builds our knowledge for developing effective disaster programs.

Learning Objectives

- Locate the zones of high seismic activity in the world.
- Explain the principles of plate tectonics.
- Define earthquake magnitude and intensity and how they are measured.
- Identify conditions that permit earthquakes to be destructive to human settlements. List the primary and secondary effects of earthquakes.
- Describe the best type of building construction in an earthquake zone and how to achieve proper construction.
- Justify the need for earthquake prediction and its current effectiveness.
- Relate lessons learned from past earthquakes.
- List and explain earthquake mitigation and preparation measures in the order of their effectiveness.
- Outline emergency response activities using your area as the disaster area.

Learning Activities

- Read Chapter 2 in the text.
- Study Earthquake Disaster Overview.
- Review Appendix I.

Evaluation

Complete the self-assessment test.
Lesson 2 - Self-Assessment Test

Multiple Choice
Circle the correct answer(s):

1. The basis for the theory of continental drift is:
   a) plate tectonics
   b) pressure building up within the earth's crust
   c) the earth's land area once was a single mass
   d) divergent rifts between continental land masses
   e) shear borders existing between continental plates

2. A rope snapped like a whip is an example of:
   a) P wave
   b) L wave
   c) S wave
   d) plate tectonics
   e) the amplitude pattern of an earthquake as shown on the Richter scale

3. The two separate shocks produced by an earthquake are:
   a) caused by the different rates of travel between the P and S waves
   b) called the destructive shock and the aftershock
   c) the primary cause of the high death rate associated with severe earthquakes
   d) an indication of the location of its focus
   e) an indication of its severity

4. Intensity is a measure of:
   a) human experience during an earthquake as measured on the Richter scale
   b) energy released during an earthquake as measured on the Mercalli scale
   c) human experience during an earthquake as measured on the Mercalli scale
   d) energy released during an earthquake as measured on the Richter scale
   e) none of the above

5. The majority of lives lost in an earthquake are caused by:
   a) floods
   b) landslides
   c) fire
   d) disease
   e) building collapse

6. During an earthquake the walls of buildings without lateral bracing:
   a) create a whiplash effect
   b) fall outward
   c) fall inward
   d) remain standing
   e) vibrate in an S curve

7. A house most vulnerable to an earthquake would typically be:
   a) built of flimsy wood materials
   b) built of heavy materials without frame reinforcement
   c) built of heavy materials without a solid foundation
   d) built with a weak roof and weak walls
   e) built of concrete or mud
8. Short-term earthquake forecasting would enable:
   a) choosing earthquake-free sites for new human settlements
   b) improved response capabilities
   c) safety education of the population
   d) shutting down dangerous industries
   e) evacuation of low-lying coastal areas liable to be swept by cyclones

9. The high loss of life from the collapse of weak buildings during an earthquake is:
   a) unavoidable for adobe or brick buildings
   b) can be avoided in new buildings
   c) can be avoided in both new and existing buildings but at a high cost
   d) can be avoided by seeking cover in the lowest part of the building
   e) can be avoided by low-cost modifications in old and new buildings

10. There will be a high need for emergency surgical needs after an earthquake lasting:
    a) 48 hours
    b) five days
    c) 72 hours
    d) two weeks
    e) until all the injured are treated

11. The best foreign relief to an earthquake-stricken area is:

12. Reconstruction of an area after an earthquake always:
    a) requires foreign relief
    b) takes longer than estimated
    c) is slowed by breakouts of communicable diseases
    d) requires volunteer and government cooperation
    e) should take place in an earthquake-free zone

Answer Key
1. c
2. b
3. a
4. c
5. e
6. b
7. c
8. d
9. e
10. c
11. a
12. b
Lesson 3 - Tsunamis

Study Guide Overview

This unit describes the causes and impacts of tsunamis—unusually large ocean waves that travel at a high rate of speed. It outlines recovery and reconstruction problems that follow a tsunami. It identifies those areas of the world that are vulnerable to tsunamis and the steps for mitigation and preparation.

Learning Objectives

- Describe the physical characteristics of a tsunami.
- Identify and explain its geographic distribution and mode of travel.
- Explain human factors influencing the destructiveness of a tsunami.
- Discuss the primary and secondary impacts of tsunami disaster.
- List the steps for preparation and mitigation.
- Describe emergency response.
- Devise a model tsunami warning system for your area.

Learning Activities

- Read Chapter 3 in the text.
- Study Tsunami Disaster Overview.
- Review Appendix I.

Evaluation

Complete the self-assessment test.
Lesson 3 - Self-Assessment Test

Multiple Choice
Circle the correct answer(s):

1. The best method for avoiding loss of life from tsunamis is:
   a) human-made seawalls of adequate size and length
   b) participation in a tsunami warning system
   c) timely evacuation of people from areas prior to flooding
   d) an extensive program of emergency medical assistance
   e) a public information program warning of the dangers of tsunamis

2. The majority of tsunamis take place in:
   a) earthquake zones
   b) the Pacific Ocean
   c) the Indian Ocean
   d) the coastline of Indonesia
   e) fault lines along the earth’s crust

3. Tsunamis travel at a speed:
   a) that can exceed 1,000 kilometers per hour
   b) that increases as they approach land
   c) that allows ample time for warning populations
   d) proportional to the vertical depth of the displaced column of water
   e) measured in knots per hour

4. The best protection against a local tsunami would be:
   a) a seawall or reef

5. Tsunamis may strike with a force:
   a) greater than other types of disasters
   b) that radically alters the landscape
   c) that affects only lands along the world’s oceans
   d) that seriously disrupts economic and social patterns
   e) all of the above

Answer Key

1. c
2. b
3. a
4. c
5. e
Lesson 4 - Volcanoes

Study Guide Overview

This lesson explains the geology and geography of volcanoes—how, where, and why they take place. You will learn steps for reducing the loss of life associated with volcanic effects. The lesson will also increase your awareness of how each part of a natural hazard must be considered when dealing with its impact. Examples of previous volcanic disasters will show you how the failure of local populations to heed nature’s volcanic warning signals resulted in large losses of life when eruptions took place. Preparation, mitigation and response measures are also identified.

Learning Objectives

• Relate volcanic activity to seismic zones.
• Locate areas of high volcanic activity.
• Identify the four main types of volcanoes and their geological elements.
• Explain the human factors that increase volcanic disasters.
• List the primary and secondary effects of volcanic eruption.
• Describe eruption prediction techniques and their value in mitigation and preparation steps.
• Identify and evaluate evacuation procedures from a typical volcanic zone.
• Explain risk mapping and justify its value in your disaster mitigation plan.
• Explain the long-term consequences of a volcanic eruption.

Learning Activities

• Read Chapter 4 in the text.
• Study Volcano Disaster Overview.
• Review Appendix I.

Evaluation

Complete the self-assessment test.
Lesson 4 - Self-Assessment Test

Multiple Choice
Circle the best answer(s):

1. Two appropriate secondary responses to a volcanic disaster are:
   a) emergency feeding and shelter
   b) evacuation and relocation
   c) evacuation and search-and-rescue
   d) relocation and financial assistance
   e) relocation and cash

2. Volcanoes that generate explosive-type eruptions have:
   a) silica-deficient magmas
   b) a location directly over a divergent plate boundary
   c) silica-rich magmas
   d) extremely large cones
   e) magma originating from the depths of the mantle

3. The majority of volcanoes are located in:
   a) the circum-Pacific belt
   b) the mid-Atlantic line
   c) East Africa
   d) the African Rift Valley
   e) Hawaii

4. The basic ingredients of a volcanic eruption are:
   a) gases and molten rock
   b) gases and pumice
   c) ash and gases
   d) magma and lava
   e) magma and solid rock fragments

5. Geologists group volcanoes into four types. Two of the four are:
   a) cinder cones and shield volcanoes
   b) lava domes and magma edifices
   c) cinder cones and bowl craters
   d) stratavolcanoes and summit vented
   e) none of the above

6. Volcanic ash mixed with rain or melted snow can cause:
   a) mudflows
   b) roofs to collapse
   c) blocked storm sewers
   d) serious timber damage
   e) all of the above

7. A dangerous secondary effect of an island volcanic eruption may be:
   a) ash fall on nearby islands
   b) lava flows into the waterfront
   c) tsunamis on nearby coastal areas
   d) severe oceanic wave disturbances
   e) the breakdown of interisland communications

8. A sudden break in volcanic activity during an eruption period generally means:
   a) the danger is over
   b) immediate evacuation of the area may be necessary
   c) an increased need for monitoring
   d) increased earthquake activity within the plate area
   e) a reduction in silica content of the volcano’s magma

9. Useful volcanic prediction methods currently under study use:
a) frequency of tremors
b) upward movement of magma
c) analysis of chemical content of volcanic gases
d) infrared air photographs
e) study of animal behavior

10. A volcanic disaster will pose both:

a) an immediate and a long-term disease problem
b) loss of crops and disruption of migration
c) deaths and high surgical needs
d) loss of crops and disruption of markets
e) loss of housing and long-term lung disease

Answer Key

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Lesson 5 - Tropical Cyclones

Study Guide Overview

Tropical cyclones have different names around the world. You will learn in this lesson the conditions that make up the conventional definition of this type of storm. The regions where cyclones take place are also defined. You will study how cyclones are formed. This knowledge will help you determine the times and temperatures when high-danger or low-danger conditions may exist for your area. The primary and secondary effects such as storm surges and tidal floods are also evaluated. Long-range planning goals are explained. The effectiveness of local regulatory controls in reducing losses is examined. Social and cultural factors such as ownership patterns, existing land use, and the established way of life are also studied since they influence inhabitants' perceptions of how cyclones can best be handled.

Learning Objectives

• Identify the regional terms used to describe a cyclone.
• Locate areas of highest cyclone activity in the world.
• List the natural conditions necessary for a cyclone to form.
• Describe the different scales used to measure cyclones.
• Identify primary and secondary effects of cyclones.
• Identify vulnerable land areas.
• Explain storm surges.
• Set up a model cyclone warning system.
• Describe structure failure due to cyclones.
• Assess the impact of a cyclone on a country’s development.
• List steps used in preparation, mitigation and response to a cyclone disaster.

Learning Activities

• Read Chapter 5 in the text.
• Study Tropical Cyclone Disaster Overview.
• Review Appendix I.

Evaluation

Complete the self-assessment test.
Lesson 5 - Self-Assessment Test

**Multiple Choice**
*Circle the best answer(s):*

1. The difference between a harmless thunderstorm and a cyclone is:
   a) vorticity
   b) Coriolis effect
   c) the doldrums
   d) the direction of spin
   e) negative climatic depressions

2. The percent of tropical depressions that become cyclones is:
   a) 60 percent
   b) 70 percent
   c) 80 percent
   d) 90 percent
   e) 33 percent

3. A tropical depression becomes a tropical storm when:
   a) its winds reach 120 kilometers per hour
   b) its winds reach 62 kilometers per hour
   c) its winds reach 82 kilometers per hour
   d) its winds contract into a 50 kilometer circle
   e) its winds widen to a 50 kilometer storm front

4. Cyclones cannot develop when the ocean temperature is below 24 degrees Centigrade (76°F) because:
   a) of insufficient heat
   b) of insufficient temperature difference between the air and water
   c) cooler water temperatures prevent doldrums
   d) of insufficient evaporation
   e) thunderstorm seedlings are unable to form

5. When two wind currents travel side by side, the faster current:
   a) curls away from the slower one
   b) curls away from the vorticity of the earth’s force
   c) curls in the direction of the earth’s rotation
   d) curls around the slower one
   e) creates trade winds in the equatorial trough

6. Wind velocity is measured:
   a) on the Saffir/Simpson scale.
   b) by the National Hurricane Center in the Hawaiian Islands.
   c) on the Richter scale.
   d) by the Seamen’s Multinational Wind Bureau.
   e) on the Beaufort scale.

7. Tropical cyclones often generate:
   a) high rates of injured people
   b) tidal floods
   c) very heavy rainfall
   d) agricultural soil erosion
   e) countercurrents beneath the ocean’s surface

8. Modern technology usually first identifies and follows a cyclone using:
   a) World Weather Watch
   b) satellite photos
   c) weather radar
   d) automatic weather stations
9. Errors in cyclone forecasting are:
   a) seldom
   b) frequent
   c) increasing
   d) declining
   e) unimportant

10. Two items affecting the capacity of communities to develop warning systems are:
    a) population size and miles of coastline
    b) miles of coastline and number of cyclones
    c) number of volunteer watchers per mile of coastline
    d) linkages with media and financial resources
    e) none of the above

11. The death rate due to cyclones is _____ in areas where communications are poor.
    a) lower
    b) higher
    c) about the same
    d) not readily determined
    e) easily determined

12. Persons most severely affected by a cyclone are those who:
    a) have a large amount of buildings and property
    b) participate extensively in the area economy
    c) participate marginally in the area economy
    d) have large crop areas and livestock herds
    e) are responsible for communications and public safety

13. Safe housing in a cyclone area requires:
    a) concrete block or similar building materials
    b) strict building regulations covering local building materials
    c) strong foundations and structural integrity
    d) flexible building performance standards
    e) area-wide disaster-proof house plans

14. Cyclone disasters can create a climate:
    a) different from previous temperatures and humidity
    b) that will cause more cyclones within six months
    c) that will induce long-term rainfall
    d) where social changes are demanded by the populace
    e) where negative social changes will result

15. Houses damaged in a cyclone usually:
    a) explode
    b) get blown over
    c) collapse
    d) remain standing
    e) require new roofs

16. Effective land-use controls to reduce cyclone disasters must be:
    a) relevant to local conditions
    b) relevant to the degree of physical hazard
    c) relevant to the future of the area
    d) a and b only
    e) a, b and c

17. Disaster assessment and short-term food supplies are:
    a) two primary responses handled best by local authorities
b) two secondary responses handled best by local volunteers
c) two primary responses best handled by foreign agencies
d) necessary for long-term disaster recovery
e) necessary only in a Class A emergency

18. Income security and re-establishing agriculture are _____ to cyclone victims than _____.
   a) more important....material assistance
   b) less important....material assistance
   c) less important....foreign aid
   d) more important....re-establishing the local economy
   e) none of the above
Lesson 6 - Floods

Study Guide Overview

In this lesson you will learn the characteristics of different types of floods and the areas of the world where they occur. Knowing these, you will also consider flood mitigation measures that will work effectively for your area. Flood prevention, preparation and post-flood emergency responses are detailed. You will inventory the ways human settlements become vulnerable to floods. You will study effective flood prediction and overall flood management systems for areas prone to flooding.

Learning Objectives

• Describe the different types of flooding.
• Locate areas in the world subject to flooding.
• Explain why human settlements are often located in floodplains.
• Explain the hydrological cycle.
• List the physical factors that affect flooding severity.
• Justify the value of flood prediction.
• Describe a flood management system.
• List and explain long-term and short-term preparation methods available to volunteers. Set up a model emergency response plan for a hypothetical flood area.

Learning Activities

• Read Chapter 6 in the text.
• Study Flood Disaster Overview.
• Review Appendix I.

Evaluation

Complete the self-assessment test.
Lesson 6 - Self-Assessment Test

Multiple Choice
Circle the best answer(s):

1. The primary measurement of flood damage is:
   a) the quantity of water discharged
   b) how high the water goes above normal restraints
   c) the dollar amount of economic damage
   d) the number of deaths
   e) the area of environmental degradation

2. The 1974 flood in Bangladesh caused:
   a) 450,000 deaths due to drowning
   b) severe starvation
   c) major silting of rivers and deforestation
   d) an increase in jute exports to compensate for food shortages
   e) a severe drop in the inflation rate

3. Water vapor enters the air:
   a) by osmosis
   b) by transition
   c) by transpiration
   d) by transformation
   e) by precipitation

4. Flash floods may result from:
   a) dam failures or cloudbursts
   b) riverine terrain and conditions
   c) rainfall due to tropical cyclones
   d) inadequate catchment areas
   e) eroded hillsides and coastal flooding

5. Timing and reliability of flood warnings:
   a) are difficult to insure
   b) decrease as the downstream distance increases
   c) increase as the downstream distance increases
   d) are easy to insure using Landsat technology
   e) are two characteristics of pre-flood planning

6. A severe flood in a rural area could cause:
   a) a substantial increase in snakebite victims
   b) a housing shortage in the cities
   c) little damage if the waters stagnate
   d) little effect on the national economy of an industrial nation
   e) an increase in the number of small farms

7. Risk mapping indicates:
   a) the number of casualties if a flood occurs
   b) the extent of property damage if a flood occurs
   c) both A & B
   d) the extent of the 100-year floodplain
   e) areas likely to be covered by water during floods of a given size

8. Digging a channel in a floodplain:
   a) is foolish
   b) is an example of a preventive approach
   c) is an example of a remedial approach
   d) is an example of a government incentive
   e) will help the local economy
9. One disadvantage of a permanent levee is:
   a) it hampers river access
   b) disruption of prime development land
   c) a false sense of security
   d) constant maintenance and inspection
   e) it will help the local economy

c) can be dealt with by offering an alternative
d) should be included in the plan
e) none of the above

10. Active floodproofing is most effective:
    a) with long warning lead times
    b) in flash-flood areas
    c) if it is permanent
    d) in floodplain areas
    e) using volunteers

  a) a public information program
  b) local government support
  c) insufficient funding
  d) a, b, and c
  e) a & b only

11. Public flood warning-systems should be:
    a) practiced
    b) made up of high technology to be effective
    c) made up of warning sirens and rain gauges
    d) based on population density studies
    e) left to the government to implement

12. A local jurisdiction’s complaints about a part of a master plan:
    a) should be ignored
    b) must be proved wrong

13. An effective flood-control master plan will have:
    a) a public information program
    b) local government support
    c) insufficient funding
    d) a, b, and c
    e) a & b only

Answer Key

1. b
2. b
3. c
4. a
5. c
6. b
7. e
Lesson 7 - Drought

Study Guide Overview

In Lesson 7 you will learn to identify the conditions for drought. You will study its primary and secondary effects, its natural and human causes, and where it occurs. Examples of previous drought relief operations will help you in planning a drought relief program. You will examine drought mitigation measures and preparation activities. You will estimate and assess the impact of drought on a country and identify steps to combat famine in a population.

Learning Objectives

- Define drought.
- Locate drought zones throughout the world.
- Explain the natural causes of drought.
- Explain the human-induced causes of drought.
- Identify primary and secondary effects of a drought.
- Indicate the value of drought prediction and describe monitoring techniques.
- Illustrate the types of feeding programs used in a drought-induced famine.
- Assess the impact of drought’s effects on a country’s economy.
- List drought mitigation and emergency steps proved useful in previous relief operations. Describe long-term programs that are useful in combating drought when it does take place.

Learning Activities

- Read Chapter 7 in the text.
- Study Drought Disaster Overview.
- Review Appendix I.

Evaluation

Complete the self-assessment test.
Lesson 7 - Self-Assessment Test

Multiple Choice
Circle the best answer(s):

1. One reason why misery due to drought is increasing on a world-wide basis is:
   a) an increase in world population
   b) a decrease in rainfall world-wide
   c) an increase in human activities that aggravate drought conditions
   d) a decrease in water table levels
   e) no reason: misery is decreasing

2. Rain is caused by:
   a) the travel of organized disturbances over an area
   b) the absence of humid airstreams
   c) subsidence that migrates from the subtropical latitudes of both hemispheres
   d) the warming of westerly currents across physiographic topography
   e) the absence of cyclonic disturbances in the weather cycle

3. An increase in disease among a population may be:
   a) an example of poor hygiene.
   b) unavoidable during a migration caused by drought
   c) a primary result of lack of water
   d) a secondary result of malnutrition caused by drought
   e) avoided by isolating migrating groups of people

4. Long-term drought can cause _____ changes in social and living patterns.
   a) temporary
   b) major ecological
   c) permanent
   d) minor
   e) few

5. Famines occur:
   a) because of lack of modern technology such as refrigeration
   b) unexpectedly
   c) only because of drought
   d) because of crop destruction by insects
   e) predictably

6. The mechanics of distributing general food rations to famine victims:
   a) is generally the same process throughout the world
   b) follows a chain of command established by the United Nations
   c) requires large storage and distribution networks
   d) will change according to the location and other local factors
   e) is the primary responsibility of volunteer agencies

7. Supplementary feeding programs are:
   a) targeted to those people suffering from severe protein-energy malnutrition (PEM)
   b) targeted to those people suffering from moderate PEM
   c) often used to distribute general food rations over a wide geographic area
   d) of little value in large-scale famine relief operations
   e) a secondary response best handled by foreign agencies

8. Creating land-use planning guidelines is:
   a) linked to public acceptance
Lesson 8 - Desertification

Study Guide Overview

This lesson explains the process of desertification. It describes the natural and human preconditions that turn the process into a disaster. It relates the short- and long-term impacts upon the environment and identifies those people that rely on it for a livelihood. It gives effective measures to prevent and mitigate desertification. It explains the social implication of land-use planning.
Learning Objectives

- Define the concept of desertification.
- Locate the zones of desertification in the world.
- Describe natural desertification.
- Identify human land-use patterns that encourage desertification.
- Explain how desertification threatens humans.
- Identify the conditions for desertification that will have an impact on human settlements or nomadic inhabitants.
- List the secondary effects of desertification.
- Describe the sequence of a typical desertification at a given location.
- Identify land-management practices that mitigate against desertification.
- Prove the value of desertification prediction.
- Assess the impact of desertification upon a country’s development.
- Describe the role of government in desertification prevention.
- A volunteer can practice a variety of measures to reduce and prevent desertification.
- List these measures.

Learning Activities

- Read Chapter 8 in the text.
- Study Figure 8.1.
- Review Appendix I.

Evaluation

Complete the self-assessment test.
Lesson 8 - Self-Assessment Test

**Multiple Choice**
*Circle the best answer(s):*

1. Two of the four primary areas of desertification are:
   a) Asia and the Atlantic
   b) The Sahara Desert and the Mediterranean Basin
   c) the Kalihari Desert and the Gobi Desert
   d) the Mediterranean Basin and sub-Saharan Africa
   e) southwestern United States and western Russia

2. The real problem in the desertification of the southern edge of the Sahara is:
   a) severe drought
   b) naturally occurring thermodynamics of climate
   c) an overgrowth of livestock
   d) a wood shortage
   e) erosion

3. An area’s susceptibility to desertification is:
   a) a function of climatic cycles
   b) a function of land-use pressure
   c) a function of the soil-water energy use
   d) the result of inadequate irrigation systems
   e) a function of atmospheric heating

4. Scanty vegetation found in arid regions:
   a) provides protection for the surface of the ground
   b) provides no protection for the surface of the ground
   c) has little attraction for grazing livestock
   d) always consists of species with short life cycles
   e) is made up of perennial ephemerals

5. Nomadic herding of several kinds of animals is an example of:
   a) an outdated way of life
   b) a traditional system that lightens the grazing load
   c) a lack of flexibility in dealing with desertification
   d) a highly specialized ecosystem
   e) a system that adapts well to deep-well technology

6. Indirect large-scale climatic changes upon an arid region are:
   a) less destructive than human-made upsetting of the soil-water balance
   b) more destructive than human-made upsetting of the soil-water balance
   c) certain to follow a two to four year cycle
   d) a way to introduce stress that will desertify the area
   e) undesirable since they upset the ecosystem

7. The first step in desertification of rangelands is:
   a) thinning of vegetation due to grazing
   b) severe drought
   c) an increase in edible perennial plants
   d) water runoff due to sun-hardened soil
   e) an increase in groundwater level due to runoff

8. Desertification in areas of farming begins on:
   a) land exposed to overgrazing
   b) land exposed to soil stripping and gully extension
   c) original ground cover exposed to accelerated wind erosion
   d) land with the original land cover removed
   e) redoposited silts that are susceptible to wind erosion

9. A primary need for early warning of desertification is:
   a) a comprehensive study of land-use regulations
b) regular monitoring of dryland status
c) a study of the relationship between water and cereal crops
d) electronic monitoring of rainfall in arid regions
e) none of the above

10. A good pilot project for fighting desertification will:
   a) rely on outside experts
   b) enlist government support
   c) use Landsat mapping to prove its worth
   d) discourage traditional methods since they are part of the problem
   e) be practical and enlist community support

11. Removal of marginal lands from traditional livelihood systems is:
   a) possible with financial inducements
   b) possible by establishing forest reserves
   c) not possible at all
   d) not likely to succeed without offering acceptable alternative livelihoods
   e) possible through police regulation

12. Two factors in determining priorities of programs to fight desertification are:
   a) severity of impact and the degree of vulnerability
   b) amount of area available for reclamation and community response
   c) land-use-practice enforcement and water supplies
   d) effect of resettlement and feasibility of grazing studies
   e) none of the above

13. The first step in the assessment of dryland pastures is:
   a) to take a survey of land use
   b) mapping
   c) topographic photography
   d) statistical analysis of people and livestock
   e) to secure foreign aid

14. Green belts are a form of:
   a) irrigation
   b) open range
   c) livestock disease
   d) controlled reserves
   e) water conservation

15. Terracing is a method used to combat:
   a) gulling
   b) wind erosion
   c) sheet erosion
   d) overgrazing
   e) drought

16. A program to fight desertification will use:
   a) a single set of remedies
   b) applications of newly discovered solutions
   c) flexibility
   d) imported systems of monitoring
   e) none of the above

**Answer Key – Lesson 8**

1. d
2. c
3. b
4. a
5. b
6. a
7. a
8. d
9. b
10. e
11. d
12. a
13. b
14. d
15. c
16. c
Lesson 9 - Deforestation

Study Guide Overview

This unit explains deforestation, a process closely related to the process of desertification studied in the previous lesson. Its impact on the built and natural environments and the economic and social conditions leading to deforestation are described. Recovery strategies and problems are outlined. Steps to mitigate or prevent the process are also covered.

Learning Objectives

• Define deforestation.
• Locate the zones of deforestation in the world. Identify the primary and secondary effects of deforestation.
• Describe the impact of these effects on a country’s economy and development.
• List the economic and social conditions that lead to deforestation.
• Indicate the value of deforestation prediction.
• List deforestation prevention and mitigation measures that can be implemented by a volag.
• Explain ways of inducing cooperation from government agencies and affected populations.

Learning Activities

• Read Chapter 91 in the text.
• Review Appendix I.

Evaluation

Complete the self-assessment test.
Lesson 9 – Self-Assessment Test

Multiple Choice
Circle the best answer(s):

1. Tropical forests are disappearing at the annual rate of:
   a) 3.7 million hectares
   b) 7.3 million hectares
   c) 4.2 million hectares
   d) 6.7 hectares
   e) 7.6 hectares

2. Two countries that have substantially increased forests are:
   a) Africa and Asia
   b) Philippines and Malaysia
   c) China and South Korea
   d) Canada and the United States
   e) Brazil and Argentina

3. According to a U.N. study, deforestation has reduced the natural area of tropical rain forests by:
   a) 15 percent
   b) 20 percent
   c) 25 percent
   d) 35 percent
   e) 40 percent

4. The major human-made cause of deforestation is:
   a) logging
   b) fuel
   c) wood pulp for papermaking
   d) unequal land tenure
   e) farming

5. Shifting cultivation is still practiced:
   a) even though it is very inefficient
   b) in backward regions of the world
   c) in harmony with nature
   d) by landless people
   e) by logging companies

6. Governments in South and Central America have provided tax incentives that:
   a) encourage forest conservation
   b) transform forests into grazing lands
   c) relieve deforestation of rain forests
   d) provide for tree replanting
   e) none of the above

7. According to a World Bank study, firewood planting must increase _____ to avoid serious forest damage
   a) five times the current rate
   b) twice the current rate
   c) 10 times the current rate
   d) 50,000 hectares a year
   e) three times the current rate

8. Determining where deforestation has taken place is difficult because:
   a) it does not respond well to measurement
   b) of definitional problems
   c) deforestation is an overall trend
   d) of reliable data
   e) of lack of government cooperation

9. Most Third World countries are _____ of forest products.
   a) able to satisfy their need
   b) careful users
   c) exporters
   d) importers
   e) wealthy owners
10. One method holding great promise for reforestation is:
   
   a) government restoration of large woodlots
   b) government tax incentives to create wood plantations
   c) protecting and sustaining current woodlots
   d) increased technology yielding better tree growth
   e) small, well-run woodlots on individual farms

11. Many of the real causes of deforestation are:
   
   a) difficult to discover
   b) the result of bad logging practices
   c) found in national development patterns outside of forestry
   d) found in the lack of sufficient energy sources in Third World countries
   e) solved by extensive tree planting and careful harvesting

Answer Key

1. b
2. c
3. e
4. e
5. c
6. b
7. a
8. c
9. d
10. e
11. c
Course Evaluation

Self-Study Course on Natural Hazards: Causes and Effects

1. What is your present position?

2. How many years have you spent in disaster-related work?

3. How many years of formal education do you have?  
   _____ 0 to 6 years  _____ 7 to 12 years  _____ 12 to 16 years  _____ more than 16 years

4. How was the level of content in this course?  
   _____ too difficult  _____ about right  _____ too easy

5. Was the course material relevant to your work?  
   _____ yes  _____ no

6. How useful to you were the various components of the course?  
   Study Guide  
   Very Useful  _____ 1  OK  _____ 2  Not Useful  _____ 3  4  5
   Study Text  
   _____ 1  _____ 2  _____ 3  4  5
   Self-Assessment Tests  
   _____ 1  _____ 2  _____ 3  4  5

7. How valuable to you was the total course?  
   Very Valuable  _____ 1  Of Some Value  _____ 2  Not Valuable  _____ 3  4  5

8. Additional comments :

Please return this to:  Disaster Management Center  
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Thank you for taking a moment to complete this course evaluation.
Natural Hazards: Causes and Effects

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Introduction

This course is an introduction to the topic of natural hazards, their causes and their consequences. The subject is so vast that this course cannot begin to provide a definitive treatment of all aspects of these hazards. Instead, it seeks to present an overview of the general subject.

The course begins with a definition of each major natural hazard that disaster managers may encounter in developing countries. Historical examples are presented to give perspective to the potential scope of these natural events and their actual effects within a community or country. The geographical distribution of the hazard type, indicating the possibility of its occurrence in all parts of the world, is shown. The natural pre-conditions that must exist for the phenomenon to occur are described. The actual event is described in its physical/natural manifestation, with a detailed account of what happens and why, before, during and after the event. The impact on the natural and human-produced environment—the reason it becomes a “disaster” rather than simply a natural phenomenon—is reviewed. Each lesson then discusses what disaster managers in particular and the public in general can do to prepare for disasters, to reduce their effects, or to respond to them in case they occur.

There are extensive libraries covering all the aspects that are touched on in this course, and it is not possible to give a definitive treatment to each topic within the context of an introductory text. Consequently, the editors of this course have sought to identify and utilize the most current and authoritative information and resources on the issues addressed here. In some cases, this has meant not using the most scholarly or in-depth resource, but rather the most useful to a professional disaster manager who is probably a lay person in terms of the earth sciences.

Disaster management as an identifiable profession is relatively new. The tasks of a disaster manager, however, have been around for a long time. They have typically been thought of as disaster relief assistance, or as specific ad hoc activities during and after a disaster emergency. Many people have been disaster managers without thinking of themselves in that term.

There has been a growing awareness in recent years that all of these activities, in fact, comprise the process of disaster management. By understanding this as an identifiable role, we can describe a coherent and cohesive direction for people who are involved in the field of disasters. This, of course, includes the spectrum of activities from administration to project implementation: disaster prevention, disaster mitigation, disaster preparedness, and disaster response.

Disaster management is not necessarily a full-time activity. Indeed, for most people in the field, concerns for disaster issues form only a part of their total responsibilities. Similarly, this course is not designed for only full-time professional disaster managers. Rather it is intended to be useful even for individuals who expect to be active only during some aspect of disaster-related operations.

One of the ideal objectives of this course and of the Disaster Management Center (DMC) is that disaster managers eventually work themselves out of their jobs. The ultimate success of disaster management would be the elimination of the underlying causes of disasters; this would contribute to minimizing the people’s vulnerability to disaster. Positive responses to emergencies will make an enormous impact on the current deadly state of disaster events.

To move towards those idealized objectives will require more from disaster managers than an understanding of the aim and scope of their jobs. It will also require development of several skills and technologies. The Disaster Management Center views this course as one component of a training program that will contribute towards those skills and techniques.
**Chapter 1**

**Introduction to Natural Hazards**

This course is about natural hazards, disasters caused by some of those hazards, the effects they have on people living in areas where they occur, and the effects on the environment in general.

Within nature nothing is constant. Indeed, nature is typified by continual changes, in some cases by predictable evolution or the normal sequence of cyclical events as in seasonal weather. Much of nature, though, is unpredictable. When unpredictable natural events become extreme in their occurrence, they may constitute a danger to humans and to the other members of an environment. Such an event, then, defines a natural hazard.

Another way of conceptualizing natural hazard is as the coexistence of people in a natural environment that may disrupt or threaten their safety, property, or livelihood at an unpredictable time. There are many such natural events that, when experienced in an extreme degree, may become a risk to the inhabitants of an environment. These include avalanche, coastal erosion, drought, earthquake, flood, fog, frost, hail, landslide, lightning, snow, tornado, tropical cyclone, volcano, and wind. Some forms of environmental degradation may also contribute to the creation of hazards or be an extension of them, such as deforestation and desertification.

This course will focus on high priority/high incidence hazards in developing countries. These are hazards that governments or other agencies have targeted to reduce the social dislocations from catastrophes.

Another focus of the course will be to demonstrate the relationship between natural hazards and disasters. In fact, the hazard may be viewed as the triggering device for the disaster to occur. Often times the disaster is brought on by the mere presence of human settlement in an area that perhaps should not be occupied, as in flood plains. Or the impact of human intervention in natural processes may trigger a disaster, as in a flash flood in a deforested area.

Why are natural hazards such a universal concern? The disasters they cause kill and injure people worldwide. They cause emotional stress and trauma. They destroy homes and businesses, damage agriculture and disrupt both local and national economies. And disasters are increasing, both in number and in people affected.¹

The disasters that have increased during the past decade include floods, storms, earthquakes, tsunamis, and droughts. Only in less important categories such as epidemics, avalanches and fires has there been some decrease (see Fig. 1.2 and 1.3). The average number of disasters per year was greater in the 1970s than in the 1960s (See Fig. 1.1).

Many more people died per year in disasters in the 1970s (142,820) than in the 1960s (22,570). The difference is far too great to be explained by statistical bias or population growth alone. Figures for the number of people affected per year also increased: 27.7 million in the 1960s and 48.3 million in the 1970s, according to the Swedish Red Cross report.

- Drought led the list, affecting 24.4 million a year in the 1970s up from 18.5 million the previous decade.
- But floods showed the steepest rise, from 5.2 million in the 1960s to 15.4 million in the 1970s.²
Figure 1.1
Victims of Natural Disasters 1970-1980
## Number of People Killed per Year in Disasters

<table>
<thead>
<tr>
<th>Type of Event</th>
<th>1960s</th>
<th>1970s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drought</td>
<td>1,010</td>
<td>23,110</td>
</tr>
<tr>
<td>Flood</td>
<td>2,370</td>
<td>4,680</td>
</tr>
<tr>
<td>Civil Strife/Conflict</td>
<td>300</td>
<td>28,840</td>
</tr>
<tr>
<td>Tropical Cyclone</td>
<td>10,750</td>
<td>34,360</td>
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<tr>
<td>Earthquake</td>
<td>5,250</td>
<td>38,970</td>
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<tr>
<td>Other Disasters</td>
<td>2,890</td>
<td>12,960</td>
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</tbody>
</table>

## Number of People Affected per Year in Disasters

<table>
<thead>
<tr>
<th>Type of Event</th>
<th>1960s</th>
<th>1970s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drought</td>
<td>18,500,000</td>
<td>24,400,000</td>
</tr>
<tr>
<td>Flood</td>
<td>5,200,000</td>
<td>15,400,000</td>
</tr>
<tr>
<td>Civil Strife/Conflict</td>
<td>1,100,000</td>
<td>4,000,000</td>
</tr>
<tr>
<td>Tropical Cyclone</td>
<td>2,500,000</td>
<td>2,800,000</td>
</tr>
<tr>
<td>Earthquake</td>
<td>200,000</td>
<td>1,200,000</td>
</tr>
<tr>
<td>Other Disasters</td>
<td>200,000</td>
<td>500,000</td>
</tr>
</tbody>
</table>

Figure 1.2 & 1.3
Victims of Natural Disasters
If the number of “people affected” actually included the people who pay tax or otherwise contribute to the disaster response, then the number of people affected would be far greater. Not included in the above statistics is the growing threat from technological hazards such as liquid nitrogen gas, cyanide, nuclear reactors, etc. Nor is the disaster created by civil strife treated here. A discussion of these dangers is beyond the scope of this course.

**What Are Disasters?**

Natural hazards such as earthquakes, hurricanes, floods, and droughts spring to mind when the word “disaster” is mentioned. But a disaster should be defined on the basis of its human consequences, not on the phenomenon that caused it. An earthquake, for example, is simply an event in nature. Even a very strong one is not a disaster unless it causes injury or destroys property. Thus an earthquake occurring in an uninhabited area (as do scores of major tremors each month) is only of scientific interest and is not considered a disaster.

When a natural event does affect a human settlement, the result may still not be a major disaster. Consider the earthquake that struck San Fernando, California, in 1971. The quake registered 6.4 on the Richter scale, yet the region around San Fernando Valley (with a population of over seven million people) suffered only minor damage and 58 deaths. Two years later, though, an earthquake of a magnitude of 6.2 struck Managua, Nicaragua, and reduced the center of the city to rubble, killing an estimated 6,000 people.

A disaster can be more precisely defined as an occurrence of widespread severe damage, injury, or loss of life or property with which a community cannot cope and during which the society undergoes severe disruption.

While some developed nations may be as prone to disasters as poor nations, the people of wealthier nations are not as vulnerable to disasters; they do not die in as large numbers nor does their environment collapse as easily. Both Tokyo, Japan, and Managua, Nicaragua, are prone to earthquakes. But the people of Tokyo are far less vulnerable to injury by earthquake because Tokyo has strictly enforced building codes, zoning regulations and earthquake training and communications systems. In Managua, there are still many people living in top-heavy mud houses on hillsides. They are vulnerable.

This difference is shown by a list of disaster events and fatalities over 1960-81 (Fig. 1.4).

- Japan suffered 43 earthquakes and other disasters and lost 2,700 people: 63 deaths per disaster.
- Peru suffered 31 disasters with 91,000 dead, the vast majority lost in the single event of the 1970 earthquake.

Analysis of Fig. 1.4 shows that the vast majority of the deaths occurred in just two catastrophic events, the 1970 Bangladesh cyclone killing nearly 500,000 and the Tangshan, China, earthquake in 1976, killing over 240,000 people.

Rapid population growth, urban migration, inequitable patterns of land ownership, lack of education, subsistence agriculture on marginal lands, etc. lead to vulnerable conditions such as unsafe siting of buildings and settlements, unsafe homes, malnutrition, unemployment and underemployment, illiteracy, etc. The poor within the poor countries are the most vulnerable.
### Disaster Impact vs. Country Economy

**Number of Disaster Events 1960-1981**

<table>
<thead>
<tr>
<th>Low-income Economy</th>
<th>Number of Disaster Events</th>
<th>Number of People Killed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afghanistan</td>
<td>12</td>
<td>540</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>63</td>
<td>633,000</td>
</tr>
<tr>
<td>Burma</td>
<td>26</td>
<td>1,500</td>
</tr>
<tr>
<td>Chad</td>
<td>14</td>
<td>2,300</td>
</tr>
<tr>
<td>China</td>
<td>20</td>
<td>247,000</td>
</tr>
<tr>
<td>Ethiopia</td>
<td>16</td>
<td>103,000</td>
</tr>
<tr>
<td>Gambia</td>
<td>11</td>
<td>200</td>
</tr>
<tr>
<td>Haiti</td>
<td>17</td>
<td>6,400</td>
</tr>
<tr>
<td>India</td>
<td>96</td>
<td>60,000</td>
</tr>
<tr>
<td>Laos</td>
<td>11</td>
<td>400</td>
</tr>
<tr>
<td>Madagascar</td>
<td>13</td>
<td>420</td>
</tr>
<tr>
<td>Mali</td>
<td>13</td>
<td>540</td>
</tr>
<tr>
<td>Mozambique</td>
<td>13</td>
<td>1,100</td>
</tr>
<tr>
<td>Nepal</td>
<td>19</td>
<td>2,900</td>
</tr>
<tr>
<td>Niger</td>
<td>12</td>
<td>320</td>
</tr>
<tr>
<td>Pakistan</td>
<td>21</td>
<td>7,400</td>
</tr>
<tr>
<td>Somalia</td>
<td>11</td>
<td>19,000</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>18</td>
<td>1,900</td>
</tr>
<tr>
<td>Sudan</td>
<td>11</td>
<td>310</td>
</tr>
<tr>
<td>Tanzania</td>
<td>12</td>
<td>590</td>
</tr>
<tr>
<td>Upper Volta</td>
<td>16</td>
<td>870</td>
</tr>
<tr>
<td>Vietnam</td>
<td>22</td>
<td>8,800</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Middle-income Economy</th>
<th>Number of Disaster Events</th>
<th>Number of People Killed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>20</td>
<td>3,800</td>
</tr>
<tr>
<td>Argentina</td>
<td>17</td>
<td>650</td>
</tr>
<tr>
<td>Bolivia</td>
<td>21</td>
<td>530</td>
</tr>
<tr>
<td>Brazil</td>
<td>39</td>
<td>4,100</td>
</tr>
<tr>
<td>Chile</td>
<td>17</td>
<td>8,000</td>
</tr>
<tr>
<td>Colombia</td>
<td>26</td>
<td>1,800</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>16</td>
<td>70</td>
</tr>
<tr>
<td>Dominican Republic</td>
<td>10</td>
<td>3,300</td>
</tr>
<tr>
<td>Ecuador</td>
<td>21</td>
<td>640</td>
</tr>
<tr>
<td>Greece</td>
<td>15</td>
<td>190</td>
</tr>
<tr>
<td>Honduras</td>
<td>13</td>
<td>8,400</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>10</td>
<td>680</td>
</tr>
<tr>
<td>Indonesia</td>
<td>59</td>
<td>17,000</td>
</tr>
<tr>
<td>Iran</td>
<td>38</td>
<td>48,000</td>
</tr>
<tr>
<td>Malaysia</td>
<td>10</td>
<td>310</td>
</tr>
<tr>
<td>Mauritius</td>
<td>11</td>
<td>20</td>
</tr>
<tr>
<td>Mexico</td>
<td>37</td>
<td>2,600</td>
</tr>
<tr>
<td>Morocco</td>
<td>18</td>
<td>13,000</td>
</tr>
<tr>
<td>Nicaragua</td>
<td>17</td>
<td>106,000</td>
</tr>
<tr>
<td>Panama</td>
<td>11</td>
<td>100</td>
</tr>
<tr>
<td>Peru</td>
<td>31</td>
<td>91,000</td>
</tr>
<tr>
<td>Philippines</td>
<td>76</td>
<td>17,000</td>
</tr>
<tr>
<td>Senegal</td>
<td>16</td>
<td>70</td>
</tr>
<tr>
<td>South Africa</td>
<td>11</td>
<td>830</td>
</tr>
<tr>
<td>South Korea</td>
<td>27</td>
<td>2,900</td>
</tr>
<tr>
<td>Thailand</td>
<td>10</td>
<td>1,300</td>
</tr>
<tr>
<td>Turkey</td>
<td>33</td>
<td>12,000</td>
</tr>
<tr>
<td>Yugoslavia</td>
<td>14</td>
<td>1,500</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>High-income Economy</th>
<th>Number of Disaster Events</th>
<th>Number of People Killed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>24</td>
<td>6,100</td>
</tr>
<tr>
<td>Japan</td>
<td>43</td>
<td>2,700</td>
</tr>
<tr>
<td>Spain</td>
<td>12</td>
<td>1,900</td>
</tr>
</tbody>
</table>

---

**Figure 1.4**

Source “Prevention Better than Cure,” Based on League of Red Cross and (US) OFDA figures
Landslides or flooding disasters are closely linked to rapid and unchecked urbanization that forces low-income families to settle on the slopes of steep hillsides or ravines, or along the banks of flood-prone rivers.

Famines can be closely linked to shortages of purchasing power caused by rural unemployment or a sudden influx of refugees into a country from a strife-torn neighboring country.

High numbers of deaths accompanying earthquakes almost always result from structural collapse of poor, low-cost houses.

In other disasters, such as cyclones and tsunamis, humans can increase their vulnerability by removing bits of their natural environment that may act as buffers to these extreme natural forces. Such acts include destroying reefs, cutting natural wind breaks and clearing inland forests.

The poor countries that suffer the worst disasters are the same countries in which environmental degradation is proceeding most rapidly. Countries with severe deforestation, erosion, overcultivation and overgrazing tend to be hardest hit by disasters.

Therefore, it can be said that nature causes extreme events (called “hazards” when they threaten people), but people create disasters by:

- making faulty assessments of natural hazard risks
- undermining the resilience of impacted natural and social systems, and
- failing to practice appropriate protective measures.

Natural hazards are agents or trigger mechanisms that can come into contact with a vulnerable human condition to result in a disaster.

**Classifications of Disasters**

Hazards and the disasters they cause are classified as rapid onset or cataclysmic, and long-term or continuing. In a cataclysmic disaster, one large-scale event causes most of the damage and destruction. Following this event, there may be a tremendous amount of suffering and chaos, but things soon begin to improve. In a long-term, continuing disaster, the situation after the event remains constant or may even deteriorate as time passes. Cataclysmic disasters include earthquakes, volcanic eruptions, cyclonic storms, and floods. Continuing natural disasters include droughts, crop failures, and environmental degradation such as deforestation and desertification. The damaged area in a cataclysmic disaster is usually relatively small, while the area affected in a continuing disaster may be extremely large.

Cataclysmic disasters destroy buildings and entire human settlements. Loss of life is sudden and therefore dramatic. In terms of food and food distribution, cataclysmic disasters are normally more disruptive than destructive. For example, they may disrupt the transport and marketing systems. They can disrupt or damage irrigation systems and, to a limited extent, they may destroy food supplies. But the extent of destruction depends on the season, the location of the disaster, and the total area affected. On the other hand, while continuing disasters disrupt transportation and distribution networks, they can also bring them to a complete halt and ultimately destroy the system itself.
Phases of a Disaster
Disaster specialists have consistently made efforts to classify the time periods of a disaster. Among the standard classifications used are: the pre-disaster periods, the warning phase, the emergency phase, the rehabilitation phase, the recovery phase, and the reconstruction phase.\(^6\)

The length of time any one period will last can vary greatly depending on the type of disaster and other factors. People involved in disasters must recognize the different phases and the appropriate activities that occur in each phase.

It is difficult to set time limits on the post-disaster time phases or to accurately define the limits of each, even for one specific type of disaster. For example, the emergency phase of a hurricane or a flood may be only a few days, or as long as a week. A volcano may precipitate an emergency period of only a few days or up to a month and may cause immediate danger to the area for years. An earthquake may have continuing aftershocks after the first major tremor, thus prolonging the emergency for a number of weeks. This was the case in China in 1976. A drought and a resulting famine can last for months or even a year or more. And of course wars and the refugee crises they can initiate may last for many years.\(^7\)

Disaster Related Activities

**Pre-disaster Activities**
These activities are normally subdivided into disaster prevention, disaster mitigation and disaster preparedness. In general, disaster prevention is event-focused. In other words, the objective of prevention is to prevent the disaster from occurring at all. Disaster mitigation accepts the fact that some natural event may occur but tries to lessen the impact by improving the community’s ability to absorb the impact with little damage or disruptive effects. Disaster preparedness assumes that the disaster will occur and focuses on structuring response and laying a framework for recovery.

**Emergency Response Activities**
Emergency response activities are those carried out during the actual emergency or immediately prior to it. This may involve evacuation of threatened communities, emergency assistance during the disaster, and actions taken in the immediate aftermath during the time when the community is rather disorganized and basic services and infrastructure are not fully functioning. Because the emergency period is both dramatic and traumatic, most attention by the press and international community is focused here. Yet in most disasters (with the exception of droughts and civil strife), the emergency passes rather quickly and, in reality, only accounts for a very small percentage of the total picture.

**Post-disaster Activities**
Post-disaster recovery can be subdivided into two phases. The first begins at the end of the emergency phase. It is a transitional phase (often called the rehabilitation phase) when people and community systems try to reestablish a semblance of normalcy. This period is usually characterized by such activities as business reopening in damaged structures, farmers returning to reclaim and clear their land, and resumption of basic infrastructure services such as water and sanitation systems in urban areas. The reconstruction phase is marked by large-scale efforts to replace damaged buildings, revitalize economies or restore agricultural systems to their full pre-disaster production capacity.\(^8\) See Table 1.1 for a summary of activities.
## Disaster – related Activities

<table>
<thead>
<tr>
<th><strong>Pre-disaster Activities</strong></th>
<th>Disaster Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Disaster Mitigation</td>
</tr>
<tr>
<td></td>
<td>Disaster Preparedness</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Emergency Response</strong></th>
<th>Warning (beginning before the actual event)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Evacuation / Rescue</td>
</tr>
<tr>
<td></td>
<td>Emergency Assistance (food, shelter, medical)</td>
</tr>
</tbody>
</table>

### Post-disaster activities

<table>
<thead>
<tr>
<th><strong>Transitional Period</strong></th>
<th>Repair Structure and lifelines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reclaim and clear land</td>
</tr>
<tr>
<td></td>
<td>Resume services</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Reconstruction Period</strong></th>
<th>Replace buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Restore services</td>
</tr>
<tr>
<td></td>
<td>Revitalize economy</td>
</tr>
<tr>
<td></td>
<td>Restore agriculture</td>
</tr>
</tbody>
</table>

Table 1.1 Disaster-related Activities
Effects of Disasters

Each type of disaster can have a number of disruptive effects. These in turn cause generally predictable problems and needs of four kinds: environmental; health; social, economic, and political; and administrative and managerial.

Environmental Effects

Disasters can have any number or combination of four effects: destruction and damage to homes and buildings; decreased quantity or quality of water supplies; destruction of crops and/or food stocks; and the presence of unburied human bodies or animal carcasses.

These environmental effects vary considerably from disaster to disaster. For example, earthquakes affect buildings but usually not crops, while tropical cyclones may affect both. Close related to the environmental effects is the impact that disasters have on land tenure and values. These effects also vary with the disaster type; for example, land values after earthquakes will go up in zones that were not heavily damaged, but land values go down in zones of active volcanoes.

Effects on Health

Sudden natural disasters are often believed to cause not only widespread death but also massive social disruption and outbreaks of epidemic disease and famine, leaving survivors entirely dependent on outside relief. Systematic observation of the effects of disaster on human health has led to rather different conclusions, both about the effects of disaster on health and about the most effective ways of providing relief. Though all disasters are unique in that they affect areas with differing social, medical, and economic backgrounds, there are still similarities between disasters that, if recognized, can optimize the management of health relief and use of resources. The following points may be noted:

• There is a relationship between the type of disaster and its effect on health. This is particularly true of the immediate impact in causing injuries: earthquakes regularly cause many injuries requiring medical care, while floods, storm surges and seismic sea waves cause relatively few.

• Some effects are a potential rather than an inevitable threat to health. For example, population movement and other environmental changes may lead to increased risk of disease transmission, although epidemics generally do not result from disasters.

• The actual and potential health risks after disaster do not all occur at the same time. Instead, they tend to arise at different times and to vary in importance within a disaster-affected area. Thus, casualties occur mainly at the time and place of impact and require immediate medical care. The risks of increased disease transmission take longer to develop and are greatest where there is crowding and reduced standards of sanitation.

• Disaster-created needs for food, shelter, and primary health care are usually not total. Even displaced persons often salvage some of the basic necessities of life. Further, people generally recover quickly from their immediate shock and spontaneously engage in search and rescue, transport of the injured, and other private relief activities.
**Economic, Social, and Political Effects**

Disasters disrupt rather than destroy economies. During an emergency, people must leave their jobs and devote their time to disaster-related activities, such as search and rescue, or to care of survivors. During this period normal economic activities are severely curtailed, even if the sources of employment are unaffected by the disaster. This period is short-lived, however, and in the later phases of a disaster economic activities quickly assume a high priority for both businesses and victims alike. Whether or not an economy can recover quickly depends on the losses sustained. Physical damage to businesses and industry may temporarily halt some activities, but most enterprises can operate at reduced levels even with the loss of equipment. Often the workers in a damaged factory can be put to work helping to repair or rebuild the facility. In any case, the loss of jobs is usually only temporary.

Of far more concern is the impact of disasters on persons who are participating only marginally in the economy, people such as subsistence farmers, small shopkeepers, and fishermen. After a disaster it is not uncommon for many small enterprises to fail. For the owners, a disaster can wipe out not only their investments but also their savings.

Several observers have noted that boom economies often develop after a widespread disaster such as an earthquake or hurricane requiring major physical reconstruction. Long-term effects are not yet known, but at least one study indicates that if low-income victims are given priority in job hiring, boom economies can be a means of adjusting some of the losses.\(^{11}\)

**Administrative and Managerial Effects**

Administrative problems in disaster are made more difficult by four factors, which increase in importance with the extent of the disaster.

1. **Effects on community leadership.** The loss of leaders due to death or injury can impair disaster response.

2. **Disruption of formal organizations.** When a disaster strikes, large formal organizations are most disrupted. Small, community-based organizations are generally better able to function, even with loss of leaders.

3. **Damage to critical facilities and lifelines.** Widespread disasters can destroy or damage facilities that may be critical not only for responding to the disaster but also for maintaining a safe environment and public order. Among these are communications installations; electrical generating and transmission facilities; water storage, purification, and pumping facilities; sewage treatment facilities; hospitals; police stations; and other private buildings.

4. **Disruption of transportation (and isolation of resources).** During the initial stages of most types of disasters, almost all surface means of transportation within a community are disrupted. Bridges can be knocked out; roads can be cut by landslides; rubble can block streets and highways.\(^{12}\)

**Prevention, Mitigation and Preparedness**

Up until this point, disasters have been discussed in terms of reaction, both by the affected societies and the relief agencies. An underlying theme, however, has been that disasters are not unforeseen events. The technology now exists to identify the hazards that threaten a community and to estimate the areas and the settlements that will be affected. One can then
take steps to prevent the disaster, or prepare for the disaster and substantially reduce, or mitigate, its impact. These actions are known as pre-disaster planning. Frederick Krimgold pioneered the early conceptualization of pre-disaster planning, which he describes as follows:

Planning may be defined as the process of preparing a set of decisions for action in the future directed at achieving goals by optimal means. The stated goals of disaster relief are the reduction of human suffering, the improvement of material well-being, and the increase of personal security. It goes without saying that these goals are best served if disaster, in the first place, can be avoided or reduced. Thus, the primary goal of pre-disaster planning may be seen as the prevention or mitigation of disaster. If we refer to the definition of disaster in terms of the need for outside help, we may describe the goal of pre-disaster planning as the creation of self-sufficiency in dealing with natural phenomena. In those cases where prevention is not possible, the goal must be to plan for the effective application of aid... (1974)

Disaster prevention and mitigation should be in the forefront of the reader’s mind throughout this course. Indeed, all disaster managers, whether full-time professionals or part-time volunteers, are challenged to accept disaster prevention and mitigation not only as a role to play but as their responsibility to their society, constituency, or clientele. One of the primary objectives of this course is for its students to become advocates for programs in disaster prevention, mitigation or improvements in the disaster response system.

Individuals working within government will have opportunities to increase their country’s safety by promoting several activities. The most appropriate activity will obviously depend on their position in government. By the end of this course, each individual will no doubt be able to identify opportunities for personal and official involvement. For example, a person within a ministry devoted to natural resource development will see the need to conduct hazard mapping of seismic risk areas, flood prone areas, and perhaps zones subject to landslides. An employee within a ministry in charge of communication will see the need to integrate a complete disaster warning system with the national communication networks and to develop guidelines on communicating disaster emergencies to the central government and the public.

An official of a national bank will become aware of the need to include disaster mitigation measures and also criteria for the financing of projects that take into account disaster risks.

Non-government organizations including private voluntary organizations (volags) have other possible opportunities to implement improved disaster management programs. The traditional role of these groups is to react to disasters in the form of emergency relief and sometimes long-term recovery programs. As other courses offered by the Disaster Management Center will show, there are many areas where other professional and effective disaster response is achievable. It is also expected that the volags who are aware of disaster issues will support projects that improve a community’s disaster risk awareness, promote economic or social development in ways that encourage disaster prevention or mitigation, and train their own staff and local individuals in disaster management.

The objectives for all participants in effective hazard management are many. Some, such as the reduction of loss of life, injury and property, have already been mentioned. Beyond those primary concerns are the related benefits of the maintenance of economic and social stability and the utilization of scarce resources for development instead of disaster recovery.
The ultimate objective of this course, indeed the purpose of the Disaster Management Center at the University of Wisconsin, is to contribute to those objectives stated by Krimgold. An understanding of the nature of natural hazards is the first step in preparing for them. Being able to anticipate their consequences is a prerequisite not only to appropriate action following disaster events but also to prevention of them. The following lessons seek to provide an introduction to that process.

Notes

5 Cuny, Disasters and Development. p. 39.
6 Ibid. p. 40.
7 Ibid. pp. 40-41.
11 Cuny, Disasters and Development pp. 49-50.
12 Ibid pp. 44-56.
13 Frederick Krimgold, The Role of International Aid for Pre-disaster Planning in Developing Countries, audelringen for Arkitektur, KTH Stockholm, 1974, p. 65.
Chapter 2
Earthquakes

Introduction
Earthquakes are one of the most dangerous and destructive forms of natural hazards. They strike with sudden impact and little warning. They may occur at any time of day or on any day of the year. An earthquake can devastate an entire city or a region of hundreds of square kilometers. They can reduce buildings to a pile of rubble in seconds, killing and injuring their inhabitants.

Earthquakes are caused by the movement of massive land areas, called plates, on the earth's crust. Often covering areas larger than continents, these plates are in a constant state of motion. As the plates move relative to one another, stresses form and accumulate until a fracture or abrupt slippage occurs. This sudden release of stress is called an earthquake.

Historical Examples

Managua, Nicaragua, December 23, 1972

On December 23, 1972, a series of earthquakes shook the Central American nation of Nicaragua. The largest earthquake registered 6.2 on the Richter scale. The earthquake’s epicenter was located precisely at the capital city of Managua. The earthquake resulted in the destruction of the heavily populated central zone and damage to a total area of about 27 square kilometers (10 square miles). Subsequent fires blazed throughout the city, compounding the damages. In the wake of the disaster, at least 8,000 of Managua’s total population of 430,000 had died, 20,000 were injured, over 260,000 had fled the city, 50 percent of the employed were jobless, and 70 percent were left temporarily homeless. In the wake of the disaster, at least 10 percent of the nation’s industrial capacity, 50 percent of commercial property, and 70 percent of government facilities were rendered inoperative. Overall, the U.S. dollar damage was estimated at $845 million.¹

The city had been destroyed by previous earthquakes, but the capital was always rebuilt and expanded on the same location. It is, therefore, understandable that a major issue after the 1972 earthquake concerned future decentralization or relocation of the city.

As is common in many developing countries, the capital is the focal point of the most productive activities, including those of trade, industry, and financial services, as well as the site of the central government. Thus, in addition to the loss of life and to property damage, the cost of temporary upsets in public administration and disruption of economic activity must be taken into account.

The sectors that were hardest hit by the earthquake were housing, retail trade, and small manufacturing. These were concentrated in the over-crowded city-center closest to the epicenter of the earthquake. The massive destruction was due in part to their location, but also to inadequate building materials, structural deficiencies, and the absence of laws regulating construction.

Although this earthquake was quite localized, it struck directly at the economic and administrative heart of Nicaragua and left its mark for years to come. The public sector entered
a deteriorating deficit situation that showed no signs of improving. The country’s balance of payments also registered an unprecedented deficit that continued to grow.

The dramatic increase in economic growth rates during the period is somewhat deceiving. This was due in large part to dynamism in construction, but this was construction to replace and rebuild.2

Chimbote, Peru, May 31, 1970

On May 31, 1970, about 25 kilometers (16 miles) west of the coast city of Chimbote, Peru, occurred an earthquake with a magnitude of 7.75. In an area of 75,000 square kilometers (about 30,000 square miles) in west-central Peru there were more than 50,000 deaths, and 50,000 injuries. Roughly 200,000 homes and buildings were destroyed and 800,000 people were left homeless. Within the region affected by the earthquake, roughly 100,000 square kilometers (40,000 square miles), numerous villages were almost totally demolished.

A large proportion of the people were killed in a secondary effect of the earthquake. At least 18,000 people were buried beneath the great rock avalanche from Mt. Huascaran that covered the towns of Ranrahirca and most of Yungay.

The avalanche amounted to 50,000,000 or more cubic meters of rock and snow, ice and soil, traveling 15 kilometers (9 miles) from the mountain to the town of Yungay with an estimated speed of 320 kilometers per hour (200 miles per hour). Ridges as high a 140 meters (460 feet) were overridden and boulders weighing several tons were projected 1,000 meters (3,300 feet) beyond the avalanche margins.

A most graphic eyewitness account of the Huascaran avalanche was later given by Senor Mateo Casaverde, a Peruvian geophysicist.

“As we drove past the cemetery in Yungay the car began to shake. It was not until I had stopped the car that I realized that we were experiencing an earthquake. We immediately got out of the car and observed the effects of the earthquake around us. I saw several homes as well as a small bridge crossing a creek near Cemetery Hill collapse. After about one-half minute the earthquake shaking began to subside. At that time I heard a great roar coming from Huascaran. Looking up, I saw what appeared to be a cloud of dust and it looked as though a large mass of rock and ice was breaking loose from the north peak. My immediate reaction was to run for the high ground of Cemetery Hill 200 meters (700 feet) away. I began running and noticed that there were many others in Yungay who were also running toward Cemetery Hill.

“The crest of the wave had a curl, like a huge breaker coming in from the ocean. I estimated the wave to be at least 80 meters (260 feet) high. I reached the upper level of the cemetery just as the debris flow struck the base of the hill and I was probably only 10 seconds ahead of it.”3

Geographical Distribution

Fig. 2.1 shows that the majority of earthquakes occur in the seismically active Pacific basin forming a belt around the region, along the Sundra arc, and as a diffuse band through the mountain ranges of Asia and Europe also referred to as the Mediterranean and Trans-
Himalayan zone. Most earthquakes appear to follow tectonic boundaries. These will be explained below.

Although most earthquakes occur within the well-defined earthquake zones, there have been notable exceptions in the past, i.e., the New Madrid (1811) and Charleston (1886) earthquakes in the United States, the Agadir earthquake (1960) in Morocco, the Koyna earthquake (1967) in India, and others. ⁴
Natural Precondition for Disaster Occurrence

The regions of the world where earthquakes occur are characterized by certain geological aspects. The earth’s crust is broken into a series of blocks or “plates” that are separated by deep fractures called faults. Faults form lines of weakness in the masses of rock at the earth’s surface. Pressures that build up below the surface eventually force a sudden shift between two of these blocks. This sudden shift is the earthquake.

Why these pressures build up and cause the movements is explained by the theory of continental drift or “plate tectonics.” Briefly, this theory holds that all the earth’s land area once was a single mass. This mass broke apart, and the pieces began drifting. Wherever plates meet there is a high degree of earthquake activity or “seismicity.”

The meeting of these plates can be classified as three distinct types of borders: divergent rifts, where new ocean floor is created by basaltic magma (the molten rock from beneath the earth’s crust) that rises and spreads out from the earth’s interior; convergent zones, where two plates meet, either colliding head on or one being forced under the other; and shear borders, where the plates grind slowly past each other. At each of these borders, or faults, strain builds up, eventually resulting in earthquakes.

The fault movement, at these meetings of plates, is the result of elastic rebound, the slow build-up and sudden release of strain within masses of rock. At the place where stresses are released, mechanical energy is initiated in the form of waves that radiate in all directions through the earth. When this energy arrives at the earth’s surface, it forms secondary surface waves. The frequency and amplitude of the vibrations produced at the surface, and thus the severity of the earthquake, depend upon the amount of mechanical energy released at the focus, the distance and depth of the focus, and the structural properties of the rock or soil on or near the surface.

Disaster Event

The earthquake event is a complex set of movements in the earth’s crust. It is necessary to describe the physical character of these movements to understand their impact on the natural and built environment. (See Fig. 2.2 and 2.3.)

Earthquake Magnitude and Moment

There are three identifiable types of earthquake movements or shock waves. The P wave is the fastest moving wave, traveling at about five kilometers a second, (three miles a second). Having the characteristic of sound waves, it moves longitudinally, creating a “push-pull” effect on the rock as it passes.

The S, or shear wave, travels about three kilometers a second (two miles a second) near the surface, causing the earth to move in right angles to the direction of the wave. An example of this kind of motion is a rope snapped like a whip. The waves move the length of the rope, but the actual motion is at right angles.

The L, or long wave, is a slow surface wave. These long-period waves cause swaying of tall buildings and slight wave motion in bodies of water at great distances from the earthquake center.
The different rates of travel between the P and S waves produce two separate shocks. The farther from the center, the longer is the time lag between the different shocks.

A major earthquake is never an isolated phenomenon. The violent and destructive main shocks may be preceded by preliminary tremors or foreshocks, which are less severe and few in number, but important to study in order to predict the destructive shocks and take protective measures. Sometimes seismic activity in a region increases gradually in intensity up to a climax. Then there are aftershocks, which are belated shocks of decreasing intensity occurring at increasing intervals. The disturbance may last for months or years, keeping the threatened population in a state of anxiety. This may cause them to evacuate the area.

The main shock rarely lasts even a minute in any local area. Generally the duration is only several seconds, although to people experiencing it the time seems much longer.

Strong shaking from a major shock frequently lasts only 30-60 seconds. The major shock of the 1906 San Francisco earthquake lasted only 40 seconds. However, the major shock of the Alaska earthquake lasted 3-4 minutes.

The times of arrival of seismic waves at selected seismograph stations throughout the world indicate where and when the earthquake occurred and, sometimes, its focal depth. The recorded amplitudes of seismic waves indicate the amount of energy released by the quake.

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**The Triggering Mechanism: Slippage Along a Fault**

![Diagram of slippage along a fault](image)


Figure 2.2
Description of an Earthquake

Figure 2.3

Description of an Earthquake
## Modified Mercalli Intensity Scale of 1931

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>I</td>
<td>Not felt except by a very few under especially favorable circumstances.</td>
</tr>
<tr>
<td>II</td>
<td>Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.</td>
</tr>
<tr>
<td>III</td>
<td>Felt quite noticeably indoors, especially on upper floors of buildings but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated.</td>
</tr>
<tr>
<td>IV</td>
<td>During the day felt indoors by many. Outdoors by few. At night some awakened. Dishes, windows, doors disturbed, walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.</td>
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<tr>
<td>V</td>
<td>Felt by nearly everyone, many awakened. Some dishes, windows, etc., broken. A few instances of cracked plaster. Unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.</td>
</tr>
<tr>
<td>VI</td>
<td>Felt by all, many frightened and run outdoors. Some heavy furniture moved, a few instances of fallen plaster or damaged chimneys. Damage slight.</td>
</tr>
<tr>
<td>VII</td>
<td>Everybody runs outdoors. Damage negligible in buildings of good design and construction, slight to moderate in well-built ordinary structures, considerable in poorly built or badly designed structures. Some chimneys broken. Noticed by persons driving motor cars.</td>
</tr>
<tr>
<td>XII</td>
<td>Damage total. Practically all works of construction are damaged greatly or destroyed. Waves seen on ground surface. Lines of sight and level are distorted. Objects are thrown upward into the air.</td>
</tr>
</tbody>
</table>

Figure 2.4
Measuring Earthquakes

The severity of an earthquake can be expressed in several ways. The magnitude of an earthquake, as expressed by the Richter scale, is a measure of the amplitude (total range of fluctuation) of the seismic waves. Magnitude is related to the amount of energy released—an amount that can be estimated from seismograph recordings. The intensity, as expressed by the modified Mercalli scale (see Fig. 2.4), is a subjective measure that describes how severe a shock was felt at a particular location. Damage or loss of life and property is another, and ultimately the most important, measure of an earthquake’s severity.

The Richter scale is the best known scale for measuring the magnitude of earthquakes. The scale is logarithmic so that a recording of 7, for example, indicates a disturbance with ground motion 10 times as large as a recording of 6. A quake of magnitude 2 is the smallest quake normally felt by humans. Earthquakes with a Richter value of 6 or more are commonly considered major in magnitude.

The modified Mercalli scale expresses, in values ranging from I to XII, the intensity of an earthquake’s effects in a given locality. The most commonly used adaptation covers the range of intensity from the condition of "I.—Not felt except by a very few under especially favorable conditions," to “XII.—Damage total. Lines of sight and level are distorted. Objects thrown upward into the air.” Evaluation of earthquake intensity can be made only after eyewitness reports and results of field investigations are studied and interpreted. (See Fig. 2.5 for comparison between the scales.)

An earthquake’s destructiveness depends on many factors. In addition to magnitude, these include the focal depth, the distance from the epicenter, local geologic conditions, and the design of buildings and other human works. The extent of damage also depends on the density of population and construction in the area shaken by the quake.6

### The Measurement of an Earthquake

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<th>Modified Mercalli Scale</th>
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<th>6</th>
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<td>7.94x10^{14}</td>
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<td>7.94x10^{17}</td>
<td>2.51x10^{19}</td>
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<td>In Multiples of Base</td>
<td>1.31</td>
<td>1,000</td>
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<td>1,000,000</td>
<td>31,600,000</td>
<td>1,000,000,000</td>
<td>31,600,000,000</td>
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Intensity is a measure of the human experience and impact of earthquakes; magnitude is an estimate of energy release. They are roughly comparable, as shown. With remote seismographs magnitude can be estimated for almost all earthquakes but, in the absence of people or their property, there is no meaningful measure of intensity.


Figure 2.5
**Frequency of Earthquakes**

More than one million earthquakes shake the earth each year, on an average of about two each minute. Some scientists say there may be about five million a year, counting all the microearthquakes and tremors that are picked up only on highly sensitive seismographs.

From 1900 to 1964 there was a yearly average, the world over, of about 20 major earthquakes, one or two of which were usually great. Since 1964, the year of the great Alaskan earthquake, the annual total of major earthquakes has been distinctly less, with none exceeding magnitude 8 until mid-January 1971.

**Effects of Earthquakes**

*Primary Effects*

The initial effect of an earthquake is the violent ground motion. Additionally the ground often fissures or cracks, and there can be large permanent displacements horizontally—sometimes as much as 10-15 meters (30-50 feet).

The San Francisco earthquake of April 18, 1906, occurred along the San Andreas fault over a length of 470 kilometers (300 miles), displacing the lips by a few centimeters up to one meter and causing a slip between the sides varying from 25 centimeters to seven meters. (10 inches to 20 feet) The Mino-Avari earthquake in Japan caused changes in level of about six meters (20 feet) and horizontal slips of two meters (seven feet) along the Neo fault, which, unlike that at San Francisco, is not rectilinear, but divided into stepped sections. The consequences of such ground movements are, of course, disastrous for buildings near to or on the line of a fault.

During the Tokyo earthquake (September 1923) in Japan, the coast of Sagmi Bay rose two meters (seven feet), whereas on the north side of the bay the bottom rose 250 meters (820 feet). At the center it subsided 100 to 200 meters—even 400 meters at some points. In addition, there was horizontal displacement of up to 4 meters (13 feet) in the land surrounding Tokyo Bay.

Another primary effect is known as liquefaction. Loose sandy soils with a high moisture content separate when shaken by an earthquake. The water moves upward, giving the surface a consistency much like that of quicksand. Heavy structures resting on these soils slowly sink into the ground. Large portions of Port Royal, Jamaica, were damaged in this way during the earthquakes that struck the city in 1694 and 1970.

*Secondary Effects*

Often as destructive as the earthquake itself are the resulting secondary effects such as landslides, fires, tsunamis, and floods. Landslides are especially damaging and often account for the majority of lives lost. During the 1970 earthquake in Peru a very large portion of those killed were swept away by a landslide that covered the town of Yungay. Similarly, in the Guatemala earthquake of 1976, most deaths that occurred in Guatemala City were caused by the collapse of the unstabilized hillsides where thousands of urban squatters had settled.

Of far more concern are tsunamis, the large seawaves caused by an earthquake abruptly moving the ocean floor. The waves move at a high velocity and can cross thousands of kilometers before they run up on shore. At sea, their low wave height gives little evidence of their existence; however, as they reach shallower depths, their velocity decreases and their height increases. In this way a five-meter crest moving at 600 kilometers per hour in the open
ocean becomes a devastating 30-meter-high wave moving at 50 kilometers per hour when it reaches shore. (See chapter 3 on tsunamis.)

The risk of fire immediately after an earthquake is often high because of broken electrical lines and gas mains. In recent years, officials in most of the world’s major cities have installed devices that shut these services down automatically if an earthquake strikes. Yet the threat still exists in many of the smaller cities and the squatter settlements of the larger cities where open fires are used for cooking.

Finally, disturbance of the subsoil causes changes in the course of groundwater flows. This can cause abrupt changes in the level of the water table and sudden drying up of surface springs.

**Behavior of Buildings during Earthquakes**

As the vibrations and waves continue to move through the earth, buildings on the earth’s surface are set in motion. Each building responds differently, depending on its construction.

When the waves strike, the earth begins to move backward and forward along the same line. The lower part of a building on the earth’s surface immediately moves with the earth. The upper portion, however, initially remains at rest; thus the building is stretched out of shape. Gradually the upper portion tries to catch up with the bottom, but as it does so, the earth moves in the other direction, causing a “whiplash” effect, speeding up the top of the building and creating a vibration known as resonance. The resonance can cause structural failure in itself, or adjacent buildings having different response characteristics because different building materials can vibrate out of phase and pound each other to pieces. The walls of buildings without adequate lateral bracing frequently fall outward, leaving the upper floors or roof to collapse into the inside of the structure. (See Fig. 2.6)

**Earthquake Forecasting**

The study of regional seismicity and the outline of seismic zones make it possible, within the framework of historical incidence and global tectonics, to predict the regions in which earthquakes will occur; the real problem in prediction is to be able to specify in advance the exact place, day (as precisely as possible) and magnitude of a future earthquake. Only recently has a strictly scientific approach been applied to the short-term prediction of earthquakes. The first successes now achieved by certain research workers give reason to hope that such forecasting will be possible in the fairly near future. It would then be possible, thanks to two kinds of prediction, to adopt a preventive strategy that might greatly reduce human and material losses.

Long-term forecasting could be used:
- for determining the optimum structures of existing buildings;
- for encouraging local authorities to issue new regulations on building and land use and, in particular, for improving the choice of sites for new human settlements;
- for launching campaigns to inform and educate the population on safety rules and general preventive measures;
- for drawing up relief plans;
- for improving response capabilities.

Short-term predictions, on the other hand, would make it possible:
- to mobilize relief in the event of a disaster;
- to implement procedures for evacuating endangered buildings and dangerous areas (fire risk);
- to shut down certain dangerous industries (nuclear reactors, electric power stations, oil and gas pipelines, etc.);
- to evacuate low-lying coastal areas liable to be swept by tsunamis.
How an earthquake damages a house

Figure 2.6
**Regional Prediction (long-term)**

Systematic study of the distribution of the epicenters of major earthquakes and of their aftershock zones along the boundary between the Pacific and American plates shows that the zones of activity migrate from east to west along the Aleutian arc and from north to south along the coasts of Chile. Between the zones of recent activity there are quiet regions. The map in Fig. 2.7 shows a characteristic example in Central America: the six quiet zones (seismic gaps) have not had an earthquake for 45 years or more.

Recent studies show that major destructive earthquakes do not recur in the same place along faults until several decades or more have elapsed—the time needed for sufficient stress to build up. In the main seismic regions, the present quiet zones present the greatest danger of future earthquakes. In these quiet zones, seismic activity is very slight and not even micro-shocks are observed. It is not yet known whether the quiet zones will become more active within years, weeks or days before major earthquakes occur again. Monitoring these zones by the various geophysical methods available therefore seems to be one of the tasks now required of seismologists. It can be seen, however, that for the time being “prediction” is limited to relatively large areas in which earthquakes are liable to occur within a period that it is not yet possible to determine.

**Short-Term Prediction**

The most remarkable case of prediction is that relating to the Haicheng earthquake in China (1975). The people were evacuated 5 1/2 hours before the heaviest shocks (magnitude 7.3), thus avoiding considerable loss of life (90 percent of the houses were destroyed). Similarly, in the province of Yunan (May 1976) two earthquakes of magnitude 7.6 and 7.5 were predicted, which made it possible to give the alarm eight minutes before the first shock, evacuate the population and shut down dangerous industries (electricity generation, etc.). These predictions were based on observation of the water level in deep wells, the presence of radioactive gas (radon) in the water, foreshocks and the unusual behavior of animals.

In the United States of America several earthquakes have been predicted, in particular in California (November 1974), but their lesser magnitude (5) did not justify large movements of the population, as was the case in China.

**Artificial Earthquakes**

For several years the attention of seismologists has been drawn to the fact that in some cases human activities, such as the filling of certain lake reservoirs, the injection of water into deep wells or the exploitation of oil and gas deposits are followed by seismic activity. In France, for example, several earthquakes have occurred since 1969 at the Lacq oil and gas field. The significant seismic activity accompanying the injection of waste fluid into a well sunk to a depth of 3,700 meters (12,000 feet) near Denver, Colorado in the United States led scientists to study this phenomenon in the laboratory and on the ground. The injection of fluid into a faulted zone reduces the friction and thus diminishes the stresses in the fault. In simple terms, the injection of fluid weakens a fault, whereas pumping out strengthens it. Where there is a substantial stress in a fault, the injection of fluid will “release” the fault, thus causing an earthquake.
Rupture Zones and Epicenters in Central America in the Twentieth Century

The shaded areas are rupture zones since 1928: the triangles and circles show the epicenters of earthquakes, which occurred before and after 1928, respectively. Note the six gaps in which there has been no rupture for 45 years or more, and three areas which last ruptured between 30 and 45 years ago.

Figure 2.7
Impact of Earthquakes

The principal concern about an earthquake is the impact it has on the built environment and its inhabitants. Approximately 90 percent of the loss of life in all earthquakes is the result of structural collapse. There are five primary elements that influence damage to human-produced structures:

1. **Strength of the earthquake waves reaching the surface.** The stronger the fault movement, the stronger the earthquake waves.
2. **Length of earthquake motion.** The fluctuating series of tremors, lasting from 10 seconds to 3-5 minutes, produces a cumulative effect of this motion that works on structural walls. It is the usual cause of collapse.
3. **Proximity to the fault.** Generally there is greater danger closer to the fault than farther away. However, there are other important considerations such as structural inadequacies and type of ground conditions.
4. **Geologic foundation.** Structures built on solid rock fare better than those built on softer ground or, worse yet, those built partly on solid ground and partly on soft ground or fill—a condition commonly found on hillsides.
5. **Building design.** To resist damage in an earthquake, a building must be adequately braced. It must have structural continuity with secure anchoring and bonding of all elements, and it must be well balanced and tied together.

Until recently, the great loss of life and property was unavoidable. However, now that more is known about the nature of earthquakes and their effects, engineering techniques have been developed to make new structures reasonably earthquake-resistant at a small additional cost. Techniques to make older buildings safer are also being rapidly developed. A high loss of life from the collapse of weak buildings is now avoidable. Even in the poorest settlements of the Third World, structures made of materials such as adobe and brick can be made relatively safe, thus substantially reducing the loss of life.12

**Impact on Development**

Widespread destructive earthquakes can have a significant impact on economic development. Because they damage human-produced structures, reconstruction costs can be substantial. When thousands of buildings must be replaced, the costs can exceed the national budget. This means that reconstruction will compete with development projects for money and other resources. In many economies it becomes necessary to place an emphasis on the private sector and especially on self-help activities. This emphasis provides many opportunities to expand development. Technical assistance in self-help construction, credit and public works can all contribute to improving people’s capabilities to deal with their own needs.

In their rush to help survivors, relief agencies often offer a wide range of services and relief materials. Unless caution is exercised, expectations can be raised that can actually become a disincentive to self-help and local initiative. This is especially true in the housing sector. (This is one of the reasons why some relief agencies provide building materials instead of tents as emergency shelter. Materials imply that the emphasis will be on self-help.) Earthquakes also heighten awareness of social stratification. It is usually obvious that the poor, living in low-quality buildings, will suffer the greatest number of deaths, injury and loss of property. This awareness has been called “instant consciousness-raising.” It can be a powerful force for change if properly directed. If ignored, adverse political consequences can result. It is not uncommon in the aftermath of an earthquake to see an increase of land invasions, major shifts
of population from rural to urban areas, and a decline in the number of skilled workers in rural areas. How governments and development agencies respond to these changes can have a major impact on future development. 

**Impact on Land**

After an earthquake there is usually a substantial impact on land values, land controls, and sometimes land tenure. Typically land values increase especially in urban areas and even in marginal areas. The cost of land is driven up because of the increased demand for “safe” sites for rebuilding. There may be a large number of people who have lost their land or who live on sites still threatened by aftershocks. Since earthquakes have no effect on agriculture, agricultural lands may experience the same increase in price as urban land.

**Pre-disaster Activities**

Fortunately, a great deal can be done to prevent earthquakes from becoming disasters. First, the general public as well as engineers, planners, politicians and others need to understand the nature of earthquakes. Based on that understanding, a decision and various levels of commitment are needed to implement measures to mitigate earthquake damage.

The first level of commitment requires that government and policymakers create strategic development and investment programs. A comprehensive approach would establish geographic zones and a target population. A second level is design of an extensive public awareness program. This program informs the public about the earthquake hazard and illustrates what can be done to prevent a disaster.

The third level is a technical assistance program. This could include architectural and engineering assistance in improved building design, construction, and siting; training local residents in these techniques; and conducting projects that demonstrate the nature of these techniques.

The implementation of these mitigation measures must be preceded by collection of background information. 

There are many ways to reduce earthquake damage. Possible actions include:

- Developing construction techniques that are seismic resistant;
- Conducting a program to introduce improved construction techniques to the building industry and the general public;
- Analyzing soil type and geological structure to determine which sites are safe for construction;
- Instituting incentives to remove unsafe buildings and buildings on unsafe sites or, more probable, to upgrade their level of safety;
- Instituting incentives to encourage future development on safer sites and safer methods of construction through:
  - land-use control (zoning);
  - building codes and standards and means of enforcing them;
  - favorable taxation, loans or subsidies to qualifying and building methods sites;
  - 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 to resist earthquake forces, and upgrading as necessary.¹⁵

**Earthquake Preparedness**

Vulnerable communities should institute preparedness programs. Preparedness includes educating the public about what they should do in case of an earthquake and preparing public officials and services to react to the emergency. Activities include:

• Training teams for search and rescue operations;
• Training teams for disaster assessment;
• Identifying safe sites where people living in areas threatened by landslides in secondary tremors could be relocated;
• Training adequate personnel in trauma care;
• Maintaining stocks of trauma-related medical supplies;
• Reviewing the structural soundness of facilities that are essential for the operation of disaster response, e.g. hospitals, fire stations, government buildings, communications installations, and upgrading them as necessary;
• Preparing plans and necessary equipment for alternative water supply if the current system is vulnerable;
• Preparing plans for clearing streets on a priority basis (to provide emergency access);
• Preparing emergency communication systems as well as messages to the public regarding matters of their health, safety and security;
• Training teams to determine if buildings are safe for reoccupancy.

**Post-disaster Activities**

**Earthquake Response**

The immediate impact of an earthquake affects virtually all sectors of the community. Initial response by local authorities should include implementing the activities identified in the preparedness stage. Initial emphasis will be on *search and rescue* of the victims, attempting as far as feasible to account for all members of the affected population.

Second, *provide emergency medical assistance*. There will be a high incidence of surgical needs during the first 72 hours; additional medical needs will fall off sharply after that time. Contrary to myth, there are no actual immediate epidemiological threats or patterns of disease resulting directly from an earthquake.

Third, *conduct a damage and needs assessment*. The local government as well as international donors need to know as quickly as possible the scale of the disaster and what sort of assistance (and how) is needed.

Fourth, *provide relief* to the survivors. Response can take several forms. Of the greatest value is cash, allowing survivors and local agencies discretion to focus resources where the most urgent needs are. International donors can assist in reopening roads, reestablishing communications, making contact with remote areas, conducting disaster assessment, and providing building materials for reconstruction. The popularly known forms of foreign relief such as food, blankets and clothes are totally inappropriate.
In all emergency activities it is of prime importance that information for the public about what they should do and where they can go for services be immediately available and accurate, and that decision-makers act according to priorities.

**Earthquake Rehabilitation, Reconstruction and Recovery**

At the end of the emergency period, a transition to long-term recovery occurs. Local authorities should concentrate their assistance in the following areas:

- repair and reconstruction of “lifelines,” i.e. water, sewer, electrical services and roads;
- technical, material and financial assistance for the repair and reconstruction of housing and public buildings;
- economic programs that create jobs to help rejuvenate the economy;
- financial assistance to survivors, including lines of credit and assistance to businesses, enabling them to participate in recovery efforts.

Internal donors will be able to provide assistance in all of these same activities. The most cost-effective support they can provide is technical and financial assistance.

**Myths and Lessons from Past Disasters**

The study of geology, specifically the nature and causes of earthquakes, has been relatively recent. It is, therefore, understandable that people throughout history have created their own explanations for the occurrence of earthquakes.

Frequently, traditional cultures believe that earthquakes are caused by a god. They believe their god uses an earthquake to express displeasure for some fault or sin of the community. Other people claim there is a correlation between earthquakes and weather patterns. More current speculation has suggested that the explosion of nuclear bombs provokes earthquakes.

These misconceptions, in turn, affect what people think they can do about earthquakes. For example, they may simply resign themselves to suffer the “act of God” if that is God’s intention.

Examining past earthquakes has, of course, demonstrated many lessons:

- Because people often assume there is nothing they can do to avoid the impact or destruction of an earthquake, there is a tendency for survivors to reconstruct buildings in the same manner (and with the same degree of danger) as the pre-disaster buildings.
- Designs that affect reconstruction planning are usually made in the first month following the earthquake. This means that technical assistance and improvements must be provided soon after the quake in order to have an effect.
- Most survivors will build an emergency shelter from the rubble of their house. They prefer these shelters to tents because the makeshift houses provide more protection and serve as a means of protecting recoverable building materials.
- Earthquakes and the threat of continuing tremors rarely are sufficient reason to evacuate an affected area.
- Health threats in the aftermath are grossly exaggerated. Communicable diseases almost never “break out” unless people are forced to evacuate an area and move into camps.
- Reconstruction always takes longer than estimated. Full recovery may take 10 years or more.

Earth scientists are placing a high priority on earthquake prediction. They are even investigating methods of earthquake prevention. In the meantime it is the disaster manager’s role to implement programs that will avoid human and property losses from earthquakes or to minimize their impact when they do strike.
Earthquake Disaster Overview

1. Environmental Effects

Effects
- Tremors
- Liquifaction
- Ground failure
- Ground rupture (horizontal displacement)
- Tsunamis

Consequences
- Damage buildings, dams; can cause avalanches; collapse to underground structures.
- Landslides; settlement.
- Offset streams, roads, bridges.
- Flooding, damage to buildings and crops.
- Buildings on surface sink into soil.

2. Patterns of Injury and Surgical Needs in Disasters

Deaths exceed injuries. High surgical needs within the first 72 hours.

3. Patterns of Disease Resulting from Disasters

<table>
<thead>
<tr>
<th>Actual Immediate Epidemiological Threat</th>
<th>Secondary Epidemiological Threat</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

4. Immediate Social and Economic Consequences of Disasters

| Loss of housing                          | Damage to infrastructure       |
| Loss of industrial production            | Disruption of marketing systems|
| Loss of business production              | Disruption of transport        |
| Looting                                 |                                |

5. Effects of Natural Hazards

<table>
<thead>
<tr>
<th>On Land</th>
<th>Structures</th>
<th>Agriculture</th>
<th>Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>fissures</td>
<td>damages buildings, roads, etc.</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>landslides</td>
<td>bury buildings, block rivers, etc.</td>
<td>minor crop loss</td>
<td>minor timber loss</td>
</tr>
<tr>
<td>liquifaction</td>
<td>damages buildings</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>underground</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>caves, etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Response to Disasters (Ideal)

Initial Response:

By Local Authorities
Search and rescue; medical assistance, disaster assessment.

By Foreign Intervenors
Cash; assistance in clearing roads, re-establishing communications, contact with remote areas; disaster assessment.

Secondary Response:

By Local Authorities
Repair/reconstruction of infrastructure, housing, public buildings; jobs; credit; assistance to business

By Foreign Intervenors
Repair/reconstruction of housing, jobs; credit; technical assistance; assistance to small business and institutions.

7. Appropriate Aid

| cash                     | blankets |
| short-term feeding (normal foods) | loans or credit |
| surgical aid             |          |
Notes

2. Ibid.
9. UNDRO, pp. 39-42.
13. Ibid., p. 98.

References


Burton, Ian, *Environment as Hazard*, Kates,


Mombasa Peace Corps/AID Conference Briefing Papers on “Disasters and Development.”


Chapter 3
Tsunamis

Introduction and Definition
A tsunami is a sea wave that may become one or more massive waves of water as it makes landfall. These sea waves are often called popularly “tidal waves,” but this is a misnomer. They are not caused by tidal action of the moon and sun like the regular ocean tides. Rather, they are long water waves generated by sudden displacement of the land under water, the most common cause of significant tsunamis being the sudden displacement along a submarine fault, caused by an earthquake. (See Fig. 3.1.) Submarine volcanic eruption and large submarine landslides may also cause a tsunami. In short, a tsunami is a natural hazard generated or created by other natural hazards, that is, a secondary effect of other natural hazards that can potentially have far greater impact on a population than the original hazard event.

Historical Examples
Hawaii, April 1, 1946

The 1946 tsunami was the most destructive in the history of the Hawaiian Islands. Over 150 persons were killed principally by drowning, and many more were injured, while damage to property amounted to U.S. $25,000,000.

The breeding ground was the Aleutian trench where displacements of the sea bottom were caused by an earthquake of magnitude 7.5. The earthquake occurred 3,500 kilometers (2,200 miles) north of Hawaii. The first rise of the ocean around Hilo appears to have started six hours later, giving an approximate speed of the tsunami of 780 kilometers per hour (490 miles per hour).

The waves that swept up on the Hawaiian shores varied greatly from place to place. In some places the water rose gently and most of the damage there resulted from the violent run-back of the water to the sea, whereas in most places the waves swept ashore with great turbulence.

Most observers reported seeing the first tsunami effect as a withdrawal away from the shore, a common occurrence. Some of the wave heights advancing across the reef appeared to be as much as six meters (20 feet) and in some localities the sixth, seventh and eighth waves were said to be the highest.

The island coasts protected with reefs reduced the intensity of the waves compared with the unprotected coasts. There is not much evidence that the wave height was amplified near the heads of V-shaped bays, such as had been noticed previously in Japan and elsewhere.

Structural damage occurred to buildings, roads, railroads, bridges, piers, breakwaters, fish-pond walls and ships: frame buildings along the shorelines suffered extensively, often by being knocked over by the force of the waves and sometimes by the destruction of their foundations. Some houses well-built and tied together internally were moved considerable distances without suffering severe damage (as in earthquakes). Railroads along the northern coasts of Oahu and Hilo were wrecked, usually by destruction of the road bed and shifting of tracks. Several highway and railway bridges were destroyed, most of them by being lifted entirely from their
foundations by the water buoyancy. Damage was also caused by erosion of sand beaches and foreshores, and water flooding produced considerable loss in house furnishings and personal property.

**Description of a Tsunami**

**Figure 3.1**

*Chilean Tsunami, May 22, 1960*

The earthquake and tsunami arose from a massive disturbance of the ocean bottom along the coast of central Chile under the South American trench and the Andes. The tsunami traveled over the Pacific Ocean, hitting the coast of Japan about 22 hours after the shock and spreading around the Pacific Ocean, creating damage at many places.

The coastal deformation in this earthquake was enormous, extending from 38 to 43 degrees south along the Chilean coast. Uplift of the ground was observed from one to two meters (13 miles) at Isla Mocha and Isla Guafo at the ends of the fault area, while at Corral and Maullan, in the middle part of the region, the ground subsided about two meters. With three large waves, the tsunami attacked the coast about 15 minutes after the earthquake. Inundation caused a great deal of damage. The dead were estimated at 909 and the missing at 834, of which many were due to the tsunami waves. When the tsunami reached the coastal regions of Japan a great deal of damage resulted. About 120 people lost their lives. Thousands of houses were washed away or flooded and many hundreds of ships were sunk or destroyed.

**Geographical Distribution**

Tsunamis have occurred in all the oceans and in the Mediterranean Sea, but the great majority of them are observed in the Pacific Ocean, which is ringed, from New Zealand through East Asia, the Aleutians and the western coasts of the Americas as far as the South Shetland Islands, by zones of high seismic and volcanic activity. About 180 tsunamis were recorded in
the Pacific between the years 1900 and 1970. (See Fig. 3.2.) Of these, 35 caused casualties and damage near the source only, whereas nine spread destruction throughout the Pacific.

**Natural Preconditions for Disasters**

Tsunamis are believed to originate as vertically displaced columns of ocean water. Seismic or volcanic action on the ocean floor may cause tsunamis by creating a pulse or force on a wall of water equal to the depth of the ocean at the point of the movement. Tsunamis spread outwards in all directions from the point of origin, traveling at a speed proportional to the square root of the depth of water and reaching 1,000 kilometers per hour (600 miles per hour) in the deep ocean. The distance between successive wave crests may be as much as 500 kilometers (310 miles). As the waves reach coastal areas, this speed decreases, though the interval of time between the passage of successive waves remains unchanged (usually between 20 and 40 minutes). A single tsunami may comprise up to 12 large wave crests.

The destructive power of tsunamis derives from the fact that the amplitude of the waves, which is usually less than one meter (three feet) in the deep ocean, increases sharply as the waves reach shallow water near the coast, and may be further enhanced by funnelling or resonance effects on bays and estuaries. In extreme cases, wave heights may reach as much as 20 or 30 meters (65 or 100 feet). In such cases, waves may sweep a considerable distance inland.

![Approximate Epicenters of Tsunami Generating Earthquakes 1900 – 1969](image)
Impact on Natural and Built Environment
The effects of these waves on the coastal areas of the Pacific are characterized by maximum destructive force at the water’s edge.

Damage further inland is potentially high, even though the force of the wave has diminished, because of the floating debris, which batters the inland installations. Ships moored in harbors often are swamped and sunk or are left battered and stranded high on the shore. Breakwaters and piers collapse, sometimes because of scouring actions that sweep away their foundation material and sometimes because of the sheer impact of the waves.\(^4\)

Recovery/Reconstruction Problems and Strategies
As indicated by Table 3.1 a tsunami can seriously disrupt major elements of a community. The responses required are typical of those required by sudden onset disaster. They are summarized below.

Initial response by local authorities:
• Receive and 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

Initial response by foreign intervenors:
• Provide cash
• Assistance in re-establishing infrastructure, lifelines, and communications
• Conduct disaster assessment

Secondary response by local authorities:
• Repair/reconstruction of infrastructure, housing, public buildings
• Generate or reestablish employment
• Provide assistance for agricultural areas

Secondary response by foreign intervenors:
• Repair/reconstruction of housing
• Create employment opportunities
• Provide credit
• Provide technical assistance to agricultural recovery and to coastal industries\(^5\)

A particular problem created by a tsunami is that the land struck by the disaster may have a radically altered condition. Industries, businesses and some agricultural owners may decide that the land is too high risk to rebuild or reestablish the pre-disaster operation. This would produce falling land values and dislocation of these enterprises. Or the owners may bring political pressure on the government to provide protective measures that they feel (or hope) will enable them to rebuild and continue their activities with safety and economic security.
## Impacts and Effects of Tsunamis

<table>
<thead>
<tr>
<th>Environmental Effects</th>
<th>Flooding and impact damage from giant waves destroy or damage buildings, bridges, irrigation systems; localized destruction of crops; scour's land; salinates wells and standing water, destroys trees along shoreline.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patterns of Injury</td>
<td>Deaths exceed injuries.</td>
</tr>
<tr>
<td>Surgical Needs</td>
<td>Low, needed during first 72 hours.</td>
</tr>
<tr>
<td>Patterns of Disease</td>
<td>No actual immediate epidemiological threat.</td>
</tr>
<tr>
<td>Immediate Social and Economic Consequences</td>
<td>Loss of housing</td>
</tr>
<tr>
<td></td>
<td>Loss of industrial production</td>
</tr>
<tr>
<td></td>
<td>Loss of business production</td>
</tr>
<tr>
<td></td>
<td>Loss of crops</td>
</tr>
<tr>
<td></td>
<td>Damage to infrastructure</td>
</tr>
<tr>
<td></td>
<td>Disruption of communications</td>
</tr>
<tr>
<td></td>
<td>Damage to ships in harbor and fishing fleet</td>
</tr>
</tbody>
</table>

Table 3.1
Disaster Mitigation
The most systematic measures to protect coastal areas against tsunamis have been taken in Japan, the country in which the largest number of people live in areas liable to tsunami attack. The measures have consisted of the seawall construction along low-lying coastal stretches, breakwater construction at the entrances to bays and harbors, and the planting of pine tree belts.

Although they do not afford protection against flooding, belts of pine trees can play an important role by ridding the tsunami of some of its energy and by acting as a filter for solid objects carried by the tsunami, thus reducing its destructive power. To be effective they must be at least 200 meters (655 feet) broad (perpendicular to the coast). They should be planted with dense undergrowth in addition to the trees themselves.

The town of Yoshihima, Japan, which was completely destroyed by a tsunami in 1896, is now protected by a sea-wall some 800 meters (2,600 feet) long and six meters (120 feet) high. This proved effective against the Chilean tsunami of May 1960 which, being of distant origin, produced waves of long period, but there is some doubt as to whether it would provide complete protection against a tsunami of local origin.

It is obvious that large engineering works are extremely costly. They can be undertaken only when the value of the property to be protected and the frequency of occurrence of tsunamis are sufficiently high to justify them on economic grounds. In most exposed coastal areas, there is little hope of providing effective protection to property. All that can be done is to ensure that loss of life is reduced to a minimum by the timely evacuation of people from areas liable to flooding by tsunamis. Civil defense authorities must therefore prepare detailed plans for the rapid evacuation of people to high ground, or far enough inland to be out of danger.

This requires the ready cooperation of the population. It is obvious that timely and reliable warnings of approaching tsunamis are an indispensable element of any such evacuation procedures.

Disaster Preparedness
The only permanent tsunami warning system in operation at the present time is that operated for the entire Pacific basin by the United States National Weather Service, based at the Tsunami Warning Center in Honolulu, Hawaii. Since 1965, it has operated under the auspices of the Intergovernmental Oceanographic Commission, which in 1966 set up an “International Coordination Group for the Tsunami Warning System in the Pacific.” As of March 1975, this group comprised the following countries: Canada, Chile, China, Ecuador, France, Guatemala, Japan, Korea, New Zealand, Peru, the Philippines, Thailand, the United States and the Soviet Union.

A tsunami originates in or near the epicentral area of the earthquake that creates it. It travels outward in all directions from this epicenter at a speed that depends on depths. In the deep ocean, the speed may exceed 1000 kilometers per hour; thus, the need for rapid data handling and communication becomes obvious. Because of the time spent in collecting seismic and tidal data, the warnings issued by the Honolulu Warning Center cannot protect areas against tsunamis generated in adjacent waters. To provide some measure of protection against local tsunamis in the first hour after generation, regional warning systems have been established in some areas.
In order to function effectively, these regional systems generally have data from a number of seismic and tide stations telemetered to a central headquarters. Nearby earthquakes are located, usually in 15 minutes or less, and a warning based on seismological evidence is released to the population of the area. Since the warning is issued on the basis of seismic data alone, it is to be anticipated that warnings will occasionally be issued when tsunamis have not been generated. Since the warnings are issued only to a restricted area and confirmation of the existence or nonexistence of a tsunami is rapidly obtained, dislocations due to the higher level of protection are minimized.

Thanks to this international warning system, civil defense organizations in most of the countries bordering the Pacific Ocean now receive warnings of tsunamis several hours before they reach the coasts of their respective countries. They are thus able to put into action previously prepared plans for the evacuation of people from the endangered coastal areas.

However, despite the development of the ocean-wide warning system, which uses the most advanced techniques of detection, measurement and communication, in many countries there are still obstacles to the rapid diffusion of warnings in thinly-populated areas or in regions where modern communication networks do not yet exist. In such areas, it is essential that the local population be informed about tsunamis. The population must be educated to recognize the signs that portend an approaching tsunami and to take appropriate action on their own initiative. The following "Tsunami Safety Rules," issued by the United States Department of Commerce, provide an example of information that is useful in such situations:

• All earthquakes do not cause tsunamis, but many do. When you hear that an earthquake has occurred, stand by for a tsunami emergency.
• An earthquake in your area is a natural tsunami warning. Do not stay in low-lying coastal areas after a local earthquake.
• A tsunami is not a single wave but a series of waves. Stay out of danger areas until an "all-clear" is issued by competent authority.
• Approaching tsunamis are sometimes heralded by a noticeable rise or fall of coastal water. This is nature’s tsunami warning and should be heeded.
• A small tsunami at one beach can be a giant a few kilometers away. Don't let the modest size of one make you lose respect for all.

The Tsunami Warning Center does not issue false alarms. When a warning is issued, a tsunami exists. The tsunami of May 1960 killed 61 in Hilo, Hawaii, who thought it was “just another false alarm.”

• All tsunamis—like hurricanes—are potentially dangerous, even though they may not damage every coastline they strike.
• Never go down to the beach to watch for a tsunami. When you can see the wave, you are too close to escape it.
• Sooner or later, tsunamis visit every coastline in the Pacific. Warnings apply to you if you live in any Pacific coastal area.
• During a tsunami emergency, your local civil defense, police and other emergency organizations will try to save your life. Give them your fullest cooperation.
• Unless otherwise determined by competent scientists:
  – for tsunamis of distant origin, potential danger areas are those less than 15 meters (50 feet) above sea level and within 1 1/2 kilometers (one mile) of the coast.
– for tsunamis of local origin, potential danger areas are those less than 30 meters (100 feet) above sea level and within 1 1/2 kilometers of the coast

**Conclusion**

The impact of tsunamis is very limited geographically, affecting only land mass at the edge of some of the world’s oceans. However, where they do strike, it can be with a destructive force greater than the other types of disasters. Protecting lives and property from such losses begins with good land planning, placing high economic investments out of reach of a potential tsunami and implementing a warning/evacuation system that will maximize the safety of persons living and working near the coastlines.

**Notes**

2. Ibid.
7. Ibid. p. 117.

**References**


Tsunami Disaster Overview

1. Environmental Effects

<table>
<thead>
<tr>
<th>Effects</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>High sea waves</td>
<td>Flooding and impact damage to buildings and crops,</td>
</tr>
<tr>
<td>High winds</td>
<td>scour land, salinate wells and standing water.</td>
</tr>
</tbody>
</table>

2. Patterns of Injury and Surgical Needs in Disasters

Deaths exceed injuries. Low surgical needs within the first 72 hours.

3. Patterns of Disease Resulting from Disasters

<table>
<thead>
<tr>
<th>Actual Immediate Epidemiological Threat</th>
<th>Secondary Epidemiological Threat</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>waterborne diseases (except cholera)</td>
</tr>
<tr>
<td></td>
<td>vectorborne diseases</td>
</tr>
</tbody>
</table>

4. Immediate Social and Economic Consequences of Disasters

<table>
<thead>
<tr>
<th>Consequences</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of housing</td>
<td>Damage to infrastructure</td>
</tr>
<tr>
<td>Loss of industrial production</td>
<td>Disruption of communications</td>
</tr>
<tr>
<td>Loss of business production</td>
<td></td>
</tr>
<tr>
<td>Loss of crops</td>
<td></td>
</tr>
</tbody>
</table>

5. Effects of Natural Hazards

<table>
<thead>
<tr>
<th>Structures</th>
<th>Agriculture</th>
<th>Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flooding</td>
<td>Destroying or damaging buildings, bridges, irrigation systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Localized destruction of crops, minor salt water contamination of soils, wells.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loss of trees along shoreline</td>
<td></td>
</tr>
</tbody>
</table>

6. Response to Disasters (Ideal)

**Initial Response:**

**By Local Authorities**
Search and rescue; medical assistance, disaster assessment.

**By Foreign Interveners**
Cash; assistance in clearing roads, re-establishing communications, contact with remote areas; disaster assessment.

**Secondary Response:**

**By Local Authorities**
Repair/reconstruction of infrastructure, housing, public buildings; jobs; credit; assistance agriculture, small business fisherman.

**By Foreign Interveners**
Repair/reconstruction of housing, jobs; credit; technical assistance; assistance to agriculture, small business and institutions.

7. Appropriate Aid

<table>
<thead>
<tr>
<th>Appropriate Aid</th>
<th>Appropriate Aid</th>
</tr>
</thead>
<tbody>
<tr>
<td>cash</td>
<td>loans or credit</td>
</tr>
<tr>
<td>short-term feeding (normal foods)</td>
<td>agricultural assistance</td>
</tr>
</tbody>
</table>
Chapter 4
Volcanoes

Introduction

Over a time span longer than human record, volcanoes have played a key role in forming and modifying the planet upon which we live. More than 80 percent of the earth’s surface—above and below sea level—is of volcanic origin. Gaseous emissions from volcanic vents over hundreds of millions of years formed the earth’s earliest oceans and atmosphere, which supplied the ingredients vital to evolve and sustain life. Over geologic eons, countless volcanic eruptions have produced mountains, plateaus, and plains, which subsequent erosion and weathering have sculpted into majestic landscapes or reduced to fertile soils. Ironically, these volcanic soils and inviting terrains have attracted, and continue to attract, people to live on the flanks of volcanoes. Thus, as population density increases in regions of active or potentially active volcanoes, an awareness of the hazards must increase so people will learn not to “crowd” the volcanoes. People living in the shadow of volcanoes must live in harmony with them, expecting and planning for periodic violent unleashings of their pent-up energy.¹

A volcano is a vent or chimney to the earth’s surface from a reservoir of molten matter, known as magma, in the depths of the crust of the earth. The material ejected through the vent frequently accumulates around the opening, building up a cone, called the volcanic edifice. The tallest mountains on earth are volcanic edifices. The term volcano includes both the vent and the accumulation (cone) around it.

Volcanic eruptions vary between two extremes. In one, the lava rises more or less quietly to the surface and overflows the lip of the crater. The gases bubble through the lava and escape undramatically, or, in some instances, rush out with sufficient force to form lava fountains hundreds of meters in height. Nevertheless, the lava is not disrupted but flows away as a river of lava, with little resulting damage except to objects in the path of its flow. On the other extreme, tremendous explosions occur in the chimney, and as the lava rises into zones of less pressure it “froths” and is ejected in the form of ash and pumice. Thus, in these volcanoes the molten rock never reaches the surface as a liquid (lava) but is disrupted and ejected as ash.

The explosions are sometimes so severe that they disrupt the cone, frequently blowing away large sections of it and spreading the debris over the countryside. The essential difference in the two types is in the gas content and the manner in which the gas is released when the molten rock reaches the surface. Another factor is the chemical composition of the magma.

The great majority of the volcanoes of the world are intermediate between the two extremes described, yielding both lavas and fragmental products.²

Historical Volcanic Eruptions

La Soufriere, St. Vincent Island, 1902, 1979

The volcano La Soufriere occupies the northern end of the island of St. Vincent, 140 kilometers (87 miles) to the south of Martinique in the Caribbean. The summit of La Soufriere, which rises 1,277 meters (4200 feet) above sea level, consists of two craters, the 1812 crater and the so-called “old” crater, immediately to the southwest, which was the site of the 1902 eruption.
The first symptoms of unrest in the volcano were evident in April 1901. Earthquakes were severe enough that people living on the western slope of La Soufriere became alarmed. Some considered leaving the area, but the shocks ceased and the people resumed their normal activities until in April 1902, when the shocks were again felt. By the first of May the inhabitants on the leeward side of the volcano north of Chateaubelair had sought refuge elsewhere. If this had not happened, the death toll of the eruption would have been much higher. Those living on the windward side were not particularly disturbed and continued their activities as usual. It was felt that in the event of an eruption the ash and gases would be carried towards the west by the prevailing winds. When the great eruption occurred on May 7, few people were killed on the leeward side (one report says only one) while 1,350 were killed in the windward side (other estimates place the loss of life as high as 1,600).

The hot blast overturned trees, scorching them on the side facing the volcano, destroyed houses, and set fire to inflammable objects. The hot ash, which fell in great quantities, killed all vegetation and devastated an area comprising about one-third of the island. Red-hot stones up to 15 centimeters (six inches) in diameter fell in Georgetown, nine kilometers (5.5 miles) from the crater. The orientation of trees blown down revealed that the blast swept outward in all directions from the crater.

At the end of the eruption La Soufriere still showed no signs of “dome” development and was therefore considered capable of further destructive eruptions.

A minor eruption occurred in 1971, but St. Vincent Island was shaken by a violent eruption again on April 14, 1979. This eruption sent stones raining down on parts of the island while a cloud of smoke and ash blocked out the sun after the eruption just before noon. The state-run radio reported that lava was coming from one side of the volcano’s crater. People in the northern half of the island were told to head for the beaches where boats could take them to safety. The eruption hurled ashes and smoke 6,100 meters (20,000 feet) into the air, showering Barbados, 160 kilometers (100 miles) to the east, with volcanic dust. Rumblings could be heard as far away as Kingstown, more than 20 kilometers (12 miles) to the south.

Seven small explosions shook the volcano again on April 18. The explosions, at intervals of only a few minutes, threw a small amount of ash and steam into the air north of the Larikai Valley, where lava had poured down the volcano’s sides the day before following the eighth violent eruption in five days.

On April 22 the volcano erupted intermittently for three hours, sending a column of ash more than 11 kilometers (seven miles) into the air and shaking the earth with tremors. The government evacuated the northern two-thirds of the island and cared for the 17,000 refugees until the volcano was declared quiet.

Jorullo, Mexico, 1759

The volcano Jorullo was born on September 29, 1759, in the midst of an area that was being cultivated at the time. It is one of the best known volcanoes born during historic times.

Jorullo is located in western Mexico in the state of Michoacan, about 240 kilometers (150 miles) west of Mexico City. The general elevation is about 750 meters (2,460 feet), and the climate is tropical. The region is relatively inaccessible but can be reached by a truck road. At the time of the eruption the Hacienda de Jorullo was one of three farms operated in the general area for the
production of sugar and cattle. Because of the fertility of the soil and the tropical climate, the area was known as Jorullo, which in the language of the Tarascan Indians means “Paradise.”

Near the end of June 1759, the people living at the Hacienda de Jorullo were alarmed by subterranean noises that, accompanied by mild earthquakes, continued until September 17. At this time the noises became much louder, being compared to cannonfire, and the earthquakes were strong enough to seriously damage the chapel. The frightened people fled to the surrounding hills for safety. At 3:00 A.M. on September 29, about a kilometer to the southeast of the Hacienda in a ravine known as Cuitinga Creek, a very dark and dense steam cloud rose, accompanied by sharp earth tremors and loud explosions, and soon flames burst through the cloud, which was becoming thicker and denser. For two days the volcano threw out masses of “sand [cinders], fire and thunder without one minute cessation.” On October 1 a mass of “sand so hot it set fire to whatever it fell upon” rose from the outlet of the volcano, which was little more than a cleft, and flowed for a kilometer down Cuitinga Creek.

Violent eruptions continued until February 1760, and with decreasing intensity until about 1775, making the total life of Jorullo’s activity about 15 years. The outpouring of lava consisted of at least four separate flows, forming a great wasteland that covered nine square kilometers to depths up to a hundred meters. The flows are believed to have appeared in 1764, considered to be the year of maximum activity. The first three flows are covered with ash and cinders, indicating that these materials were still being ejected after the outpourings of lava. However, the last flow, which issued from a breach on the north rim of the crater and flowed as a great cascade down the north side of the cone, is free of any ash or cinder cover. This “frozen” cascade of black lava is still quite “new” and “fresh” looking and is one of the striking features of Jorullo. It seems likely that this was the end of the explosive activity of the volcano and that thereafter it was in a venting or fumarolic state.

Jorullo is presently 1,330 meters (4,360 feet) high. The crater is an oval-shaped depression with a diameter at the rim of 400 meters by 500 meters (1,300 feet by 1,640 feet). Its depth is 150 meters (500 feet) below the highest point. The bottom of the crater appears to have collapsed since its last eruptive activity, and the bottom is filled with rubble that has fallen from the sides. At a depth of less than a meter below the rubble the heat is too intense for the hand but not sufficient to brown a piece of paper or to make water “hiss.” However, the fact that Jorullo is continuing after 200 years to give off heat as well as gases indicates the life of volcanoes.\(^5\)

**Geographical Distribution of Volcanoes**

About 500 volcanoes around the world can be considered active, in that they have erupted during historic times. Many more can be described as dormant: they are not known to have erupted for thousands of years but could return to activity at any time. For example, Mount Lamington, in New Guinea, erupted violently in 1951 when it had been thought to be inactive. Volcanoes are described as extinct when there is no chance of renewed eruption. This is usually only when a change in the geological environment has effectively defused a once-active volcano. Over the millions of years of geological history volcanoes have existed in almost every part of the world and have formed enormous volumes of rock. The entire landmass of Iceland has been thrown up out of a continuous series of volcanoes. Today volcanoes are generally found in restricted belts around the world.\(^6\)
A map of the world’s 500 or so volcanoes that have erupted in historic times shows clearly defined volcanic belts (see Fig. 4.1), with the circum-Pacific belt containing the majority. The other obvious belt is in a line down the middle of the Atlantic Ocean, and these volcanic zones correlate with two other worldwide patterns—the distribution of earthquakes and the plate boundaries of the earth’s crust. Like earthquakes, volcanoes are essentially plate-boundary phenomena that indicate the enormous geological forces involved where the plates of the earth’s crust move against each other. The Pacific “Ring of Fire” and the mid-Atlantic line are well-known plate boundaries, and the Mediterranean and East and West Indies boundaries also have their share of volcanoes. But there are other volcano areas, and the concentration in East Africa is particularly obvious. The volcanoes there are associated with the Rift Valley system, which is probably a very young plate boundary where Africa would be splitting apart if it were not for the far more powerful mid-Atlantic plate boundary compressing Africa. But even if we call the African Rift Valley a plate boundary, other volcanoes are exceptions to the rule. The temporarily inactive volcanoes of the Saharan Tibesti mountains, as well as the better known and more active ones on Hawaii, are situated in the middle of plates. Totally unrelated to plate boundaries, they owe their origins to hot spots in the earth’s internal structure, that have penetrated through the overlying plates.7

Natural Preconditions for Disaster

To understand the forces and potential dangers of volcanoes it is necessary to understand what they are and what causes them to occur. (See Fig. 4.2.)

The basic ingredients of a volcanic eruption are molten rock and an accumulation of gases. Driven by buoyancy and gas pressure, the molten rock, which is lighter than the surrounding solid rock, forces its way upward and may ultimately break through zones of weakness in the earth’s crust. If so, an eruption begins, and the molten rock may pour from the vent as nonexplosive lava flows, or it may shoot violently into the air as dense clouds of lava fragments. Larger fragments fall back around the vent, and accumulations of fall-back fragments may move downslope as ash flows under the force of gravity. Some of the finer ejected materials may be carried by the wind only to fall to the ground many kilometers away. The finest ash particles may be injected kilometers into the atmosphere and carried many times around the world by stratospheric winds before settling out.

Molten rock that rises in volcanic vents from below the earth’s surface is known as magma. After it erupts from a volcano it is called lava. Originating many tens of kilometers beneath the ground, the ascending magma commonly contains some crystals, fragments of surrounding (unmelted) rocks, and dissolved gases, but it is primarily a liquid composed principally of oxygen, silicon, aluminum, iron, magnesium, calcium, sodium, potassium, titanium, and manganese. Magmas also contain many other chemical elements in trace quantities. Upon cooling, the liquid magma may precipitate crystals of various minerals until solidification is complete, forming igneous rock.

Lava is red hot when it pours or blasts out of a vent but it soon changes to dark red, gray, black, or some other color as it cools and solidifies. Very hot, gas-rich lava containing abundant iron and magnesium is fluid and flows like hot tar, whereas cooler, gas-poor lava high in silicon, sodium, and potassium flows sluggishly, like thick honey in some cases or in others like pasty, blocky masses.

All magmas contain dissolved gases, and as they rise to the surface to erupt, the confining pressures are reduced and the dissolved gases are liberated either quietly or explosively. If the
lava is a thin fluid (not viscous), the gases may escape easily. But if the lava is thick and pasty (highly viscous), the gases will not move freely but will build up tremendous pressure, and ultimately escape with explosive violence. Gases in lava may be compared with the gas in a bottle of a carbonated soft drink. If you put your thumb over the top of the bottle and shake it vigorously, the gas separates from the drink and forms bubbles. When you remove your thumb abruptly, there is a miniature explosion of gas and liquid. The gases in lava behave in somewhat the same way. Their sudden expansion causes the terrible explosions that throw out great masses of solid rock as well as lava, dust, and ashes.

The violent separation of gas from lava may produce rock froth called pumice. Some of this froth is so light—because of the many gas bubbles—that it floats on water. In many eruptions, the froth is shattered explosively into small fragments that are hurled high into the air in the form of volcanic cinders (red or black), volcanic ash (commonly tan or gray), and volcanic dust.⁸

**Volcano Environments Map**

![Volcano Environments Map](image)

**Figure 4.1**

Source Robert I. Tilling, *Volcanoes*
Types of Volcanoes
Geologists generally group volcanoes into four main kinds—cinder cones, composite volcanoes, shield volcanoes, and lava domes.

Cinder Cones
Cinder cones are the simplest type of volcano. They are built from particles and blobs of congealed lava ejected from a single vent. As the gas-charged lava is blown violently into the air, it breaks into small fragments that solidify and fall as cinders around the vent to form a circular or oval cone. Most cinder cones have a bowl-shaped crater at the summit and rarely rise more than 300 meters (1,000 feet) above their surroundings.

In 1943 a cinder cone started growing on a farm near the village of Paricutin in Mexico. Explosive eruptions caused by gas rapidly expanding and escaping from molten lava formed cinders that fell back around the vent, building up the cone to a height of 360 meters (1,200 feet). The last explosive eruption left a funnel-shaped depression called a crater at the top of the cone. After the excess gases had largely dissipated, the molten rock quietly poured out on the surrounding surface of the cone and moved downslope as lava flows. This order of events—eruption, formation of cone and crater, lava flow—is a common sequence in the formation of cinder cones.

During nine years of activity Paricutin built a prominent cone, covered about 260 square kilometers (100 square miles) with ashes, and destroyed the town of San Juan.

Composite Volcanoes
Some of the earth’s grandest mountains are composite volcanoes—sometimes called stratovolcanoes. They are typically steep-sided, symmetrical cones of large dimension built of alternating layers of lava flows, volcanic ash, cinders, blocks, and bombs. Composite volcanoes may rise as much as 2,500 meters (8,200 feet) above their bases. Some of the most conspicuous and beautiful mountains in the world are composite volcanoes, including Mount Fuji in Japan, Mount Cotopaxi in Ecuador, Mount Shasta in California, Mount Hood in Oregon, and Mount St. Helens and Mount Rainier in Washington.

Most composite volcanoes have a crater at the summit that contains a central vent or a clustered group of vents. Lavas either flow through breaks in the crater wall or issue from fissures on the flanks of the cone. Lava, solidified within the fissures, forms dikes that act as ribs, greatly strengthening the cone.

The essential feature of a composite volcano is a conduit system through which magma from a reservoir deep in the earth’s crust rises to the surface. The volcano, built up by the accumulation of material erupted through the conduit, increases in size as lava, cinders, ash, etc., are added to its slopes. Many of the composite volcanoes are typified by explosive eruptions.

Shield Volcanoes
Shield volcanoes, the third type of volcano, are built almost entirely of fluid lava flows. Flow after flow pours out in all directions from a central summit vent, or group of vents, building a broad, gently sloping cone of flat, domical shape, with a profile much like that of a warrior’s shield. They are built up slowly by the accretion of thousands of highly fluid basaltic (from basalt, a hard, dense dark volcanic rock) lava flows that spread widely over great distances and
then cool as thin, gently dipping sheets. Some of the largest volcanoes in the world are shield volcanoes. The Hawaiian Islands are composed of these volcanoes. Kilauea and Mauna Loa on the island of Hawaii are two of the world’s most active volcanoes. The floor of the ocean is more than 4,900 meters (15,000 feet) deep at the bases of the islands. Mauna Loa, the largest of the shield volcanoes (and also the world’s largest active volcano), projects 4,700 meters (13,677 feet) above sea level. Its top is over 9,200 meters (28,000 feet) above the deep ocean floor.

**Lava Domes**

Volcanic or lava domes are formed by relatively small, bulbous masses of lava too viscous to flow any great distance; consequently, on extrusion, the lava piles over and around its vent. A dome grows largely by expansion from within. As it grows its outer surface cools and hardens, then shatters, spilling loose fragments down its sides. Some domes form craggy knobs or spines over the volcanic vent, whereas others form short, steep-sided lava flows known as “coulees.” Volcanic domes commonly occur within the craters or on the flanks of large composite volcanoes.
Impact of the Disaster

The impact on the countryside around a volcano depends on the topographic and environmental conditions. On and close to the volcano, falling bomb-like masses and blocks may break branches from trees, crash through roofs and walls of houses, start fires, and injure or kill animals and people. During the 1968 eruption of Arenal, Costa Rica, falling blocks crashed through houses 3 kilometers (2 miles) from the erupting vent. On Heimaey, Iceland, bombs started fires in the town of Wetmannaeyjar.

The finer ash is seldom hot enough when it reaches the ground to start fires. Commonly, however, the weight of deposited ash causes roofs to cave in. Thus, during the 1971 eruption of Fuego, in Guatemala, a thickness of 30 centimeters (12 inches) of ash eight kilometers (five miles) west of the volcano caused about one fifth of the roofs in the town of Yepocapa to collapse. When it is dry, the ash may be light enough for the roof to support it, but rain may rapidly increase its weight and result in sudden collapse of the roof.

Working outdoors during a heavy ash fall may be difficult, however, due to breathing of the ash-laden air and to the intense darkness that often prevails. The sharp ash particles are extremely irritating to the respiratory passages, and inhalation of excessive amounts of ash may result in death.

The darkness and poor visibility are harder to combat. They are due partly to the shutting out of daylight by the ash-laden atmosphere, and partly to a decrease in the transparency of the air because of the load of fine particles in suspension.

The intense electrical storms that frequently develop in the ash cloud may make radio communication impossible and cause severe noise and spontaneous ringing of bells on telephone circuits. Some fires are started by lightning.

Heavy ash loads often break the branches of broad-leafed trees and may do serious damage to fruit and nut orchards. This can be averted to some extent by shaking the ash from the trees from time to time. Conifers, with their adaptation to winter snow loads, commonly suffer much less. Deeper ash piling up around the trunks of trees may kill them. At Paricutin, Mexico, within the area where the ash was more than one meter deep, even the largest trees were killed. Ordinarily, however, many of them can be saved by digging the ash away from their trunks.

In addition to direct damage to agriculture, some damage to crops may be surprisingly indirect. Thus, near Paricutin, sugar cane was killed by an infestation of cane borers, because the ash had destroyed another, predatory insect that normally kept the population of stem borers at a low level. During the eruption of Cerro Negro in Nicaragua in 1971, the cotton harvest was lost over a wide area because ash deposited on the cotton bolls damaged the harvesting machines.

Heavy ash falls may disrupt water supplies by clogging streams and wells, or filters in water systems. Water may become acid from leaching of the ash. During the eruption of Irazu, Costa Rica, in 1963, ash suspended in river water clogged the filters in the water works of the city of San Jose. Suspended ash can be removed from piped water by a temporary filter, or even a cloth bag tied over the faucet. As soon as the possibility of a dangerously heavy ash fall becomes apparent, sufficient water to serve essential needs for several days should be stored indoors. Ash washed from the streets of San Jose during the Irazu eruption blocked the storm
drains, causing flooding during subsequent rains. In such circumstances, drains should be cleared as soon as possible to prevent flooding.⁹

Enormous quantities of dust, ash and pumice—called tephra—heaped on the steep slopes of a classical conical volcano provide a dangerously unstable situation, especially if saturated with water from the heavy local storms often generated by an eruption. The finer tephra—the ash—can very easily move down the volcano, and although it may do so when it is dry and even still hot, it more usually moves as an almost liquid mudflow. Mudflows are very common on some of the Indonesian volcanoes, where they are known as lahars. Although modern examples are limited in extent, prehistoric volcanic mudflows cover 10,000 square kilometers (3,900 square miles) in the Yellowstone Park area of the United States. The most fluid and mobile mudflows are caused by enormous amounts of water being added suddenly to the ash through the volcanic melting of snow or ice. In 1877 an eruption melted the summit icefield on Cotopaxi, in Ecuador, and the resulting floodwater mixed with unconsolidated ash to form a really fluid mudflow that damaged a village 240 kilometers (150 miles) downstream.¹⁰

The eruption of the Krakatau volcano, in 1883 generated tsunamis that destroyed coastal villages on nearby Java and Sumatra and killed more that 36,000 people. Such tsunamis are to be expected during cataclysmic eruptions of other island volcanoes.¹¹

Volcanic activity should not be regarded as a totally unavoidable catastrophe. Ash falls do not present a major hazard, unless they are exceptionally heavy or of the hot weldable type, or unless they are not treated with due respect and precaution. Grazing animals may suffer from very slight ash cover and their evacuation to uncontaminated pastures is an immediate necessity. In urban areas the most urgent task is to prevent excessive ash accumulation on roofs, which can lead to their collapse under the weight—especially when the ash is wetted by the rain storms commonly generated around erupting volcanoes. Loose cold ash is easily swept off house roofs. The danger of ash accumulation was shown by the villagers of Ottaviano in southern Italy when Vesuvius erupted in 1906: they all rushed to the church to pray, where most of them were killed when the church roof collapsed under the weight of ash.¹²

**Volcanic Prediction**

The avoidance of loss of life and property damage during eruptions is heavily dependent on reasonably accurate prediction of the time, place and nature of the eruptions, as well as the behavior and course of different sorts of flows and the distribution and thickness of tephra. The type, severity, and duration of the eruption are at least as important as the time. To date, the best basis for predicting the nature of a coming eruption is by analogy with past eruptions of the same volcano, coupled in some cases with the length of time since the last eruption. Individual volcanoes are likely to continue similar behavior over many centuries and through many eruptions.

Determination of the history of the volcano entails a geologic study to ascertain the composition and types of lava flows and tephra; the proportion of tephra and its distribution; the presence or absence of domes and deposits of glowing avalanches, ash flows, and lahars; the extent of the flows, etc. Dating of the rocks may give some idea of the frequency of past eruptions. Thorough studies of this sort have as yet been made on only a small proportion of the earth’s potentially active volcanoes.¹³

Also useful are patterns of activity within the period of eruption. For example, it was observed that lava always started to pour out of Mexico’s Paricutin volcano a short time after ash
explosions had built up to a maximum before suddenly stopping. The danger of a sudden break in activity in the potentially explosive silica-rich volcanoes is now recognized. In 1902 Mount Pelee in the Caribbean built up to a crescendo of activity before suddenly stopping; for four hours the gas pressure built up inside the volcano before it exploded in its now famous and catastrophic fashion. A similar sequence of events today would be taken as a sign for immediate evacuation of the area—as happened at the nearby Mount Soufriere in 1976. Some volcanoes appear to erupt more commonly at times dictated by external processes, such as climatic changes or earth-tide effects, and Chile’s Puyehue erupted in 1960 just 48 hours after a major earthquake centered 290 kilometers (180 miles) away. Such trigger mechanisms are unfortunately so little understood as yet that they can only be useful in alerting volcanologists to intensify their search for more precise methods of prediction.

As magma starts to rise towards the vent inside a volcano, some of its heating effects may be detectable before the actual eruption. Thermally sensitive infrared air photographs have been used to detect surface heating of this nature, but as yet, recognizable increases in temperature give too little notice of any impending eruption to be of much use. This same heating may cause the waters of perennial springs and fumaroles to rise in temperature, and this effect is noticeable rather earlier than the rock heating. The 1965 eruption of Taal, in the Philippines, was predicted because of a temperature rise in the crater lake water; consequently there was a rapid evacuation of the area and only 190 people died in what proved to be a very violent eruption.

Heating also has the effect of demagnetizing rock. This effect can be monitored by surface magnetic surveys. On the Japanese volcano of Oshima a marked magnetic loss prior to an eruption has been recorded from a pool of relatively shallow magma. Magnetic effects have not been found significant on the Hawaiian volcanoes, which are seemingly fed from deeper magma accumulations.

The gases from fumaroles may yet provide one of the most useful means of prediction. On some Japanese volcanoes, fumarole or vent gases have been found to contain much higher contents of chlorine and sulphur dioxide just before eruptions—though this has not been confirmed on other similar volcanoes. As the gases of a volcano are so clearly related to the details of the mechanism of any eruption, their study may yet reveal very useful methods of prediction.

Since the upward movement of magma involves the upward displacement and deformation of millions of tons of surrounding rock, it is possible to detect the movement before an eruption actually takes place. This can be done in two ways: by measuring small surface displacements, and also by seismic recording of shocks and tremors from underground movements. Magma is generated at considerable depths within the earth’s crust and then moves upwards due to its low density compared with surrounding, cooler, solid rocks. Just before its eruption on the surface, its movement into the heart of the volcano causes a regional tumescence—a doming and uplift of the volcano itself. Accurate surveying of the surface can detect and measure this by measuring either elevation, distances between points across the tumescence, or tilting. The latter is usually measured because tiltmeters consisting of fluid-filled pipes connecting two reservoir containers are relatively simple and inexpensive to make, with a sensitivity to detect a change in slope of one in a million.

The other effect of magma’s upward movement in a volcano is the generation of small earthquakes, and these can be detected on standard seismographs. Many small tremors shook the area around Vesuvius for 16 years before its eruption of A.D. 79. The significance was not
then recognized, but today an increase in the frequency of tremors is one of the most reliable methods of volcanic prediction. A network of seismographs can not only detect tremors but also determine the position and depth of their origin—which is important when tracing the movement of magma up through the core of a volcano. Eruptions of Japan’s Asama volcano are predicted on the frequency build-up of tremors within 1,000 meters (3,300 miles) laterally or vertically of the vent.14

**Animal Behavior before Volcanic Eruptions**

On several occasions animals on and near a volcano have been observed to be uneasy for several days before an eruption. Thus, cattle started to move off the Arenal volcano two weeks before the outbreak in 1968, although persons in the area felt the first earthquakes only two days before the outbreak. About four days before the outbreak at Kilauea in 1955, dogs became uneasy and started digging in the ground and sniffing in holes as though in pursuit of some burrowing animal. Observers could detect no odor of gas or anything else to cause the dogs' uneasiness. However, a seismograph a few kilometers away was recording hundreds of earthquakes too small for people to feel, and these may have been disturbing the dogs. Disturbance of animals should be taken into account, along with any other available signs, in attempting to forecast eruptions.

**Instrumentation**

The present tendency in observing volcanoes is toward elaborate and expensive instrumentation. Where this is not economically feasible, much can still be done with simpler means. Mechanical seismographs of moderate magnification are relatively inexpensive both in capital and in manning costs. These may often be adequate. Simple water-tube tiltmeters also are cheap; measuring the opening and closing of cracks in the summit region gives much the same information as geodometer measurements. Fumarole temperatures can be measured by an observer with an ordinary maximum thermometer. Telemetry saves footwork, but it is not indispensable.15

**Evacuation**

Timely evacuation from volcanic eruptions can eliminate the hazard to human life, even though destruction of buildings may still have to be accepted as inevitable. The real danger is from the more violent types of volcano in the less well-developed parts of the world where monitoring cannot be comprehensive. In this situation danger zoning is probably the only available defense—and even this is lamentably inadequate in many parts of the world. Programs of hazard zoning on many volcanoes in populated areas could be a worthwhile planning aid to be carried out well before the first rumblings of an impending eruption.

**Mitigation**

Certain characteristics of relatively thin and fluid basaltic lava flows make it possible to control their spread and at least partially to direct their courses. Well-established pahoehoe flows are fed by movement of the fluid lava through pipe-like lava tubes. If the tube can be clogged and its roof broken open, it may be possible to cause the liquid lava to spill out high on the flank of the volcano where it will do little or no harm. The reduction of the supply to the flow front stops the lava’s advance toward some threatened area, such as a city. The most practical means of breaking open the tube roof in many cases is by aerial bombardment or explosives. Clogging of the tube is partly by debris from the roof, but violent stirring of the liquid in the tube by bursting bombs may result in transforming it into more viscous lava, which moves through the tube less readily and may even clog it completely.
Success in diverting lava flows by bombing depends on several factors. Bombing may be ineffective until the flow has developed a well-established feeding tube, a channel confined between levees at a level above its surroundings, or a lava pool confined at a high level in a thin-walled cone. Even when one or more of these conditions exists, there must also be good visibility to permit selection of the best targets and accurate bombing. Very commonly, during eruptions visibility from the air is poor because of volcanic fume, smoke from burning vegetation, and ordinary clouds. Even if bombing can be accomplished, the successful diversion of the flow is dependent on favorable topography. If a flow is in a valley appreciably deeper than the flow is thick, there is no hope of directing the diverted lava out of the valley. The new lava stream will simply follow the margin of the old one, and it may actually flood over the old one and rejoin its feeding river downslope.

Although there does appear to be a considerable possibility of diverting fluid basaltic lava flows by bombing where conditions are favorable, it is not at all certain that the method would work on the more viscous block lava flows.

Diversion of lava flows from important areas may also be accomplished by means of artificial walls, designed not to act as dams but to turn the flow through a relatively small angle into a new course. The possibility depends on the fact that many flows exert a surprisingly small amount of thrust against objects in their path.

The diversion barriers can be constructed by bulldozers, using loose rock materials readily at hand, or ripped up from the substrata by the bulldozers. The height of wall that is necessary depends on the local topography and the size of the lava flow it is to divert.

Still another method of restricting and diverting lava flows has been the subject of half-joking conjecture for several decades. The idea, finally tried, was simply to spray water from fire hoses onto the edge of an advancing lava flow to chill it and retard its progress. It was given some credibility by the behavior of some lava flows on entering the ocean. For instance, when the 1911 flow of Matavanu, Samoa, entered the ocean it turned and advanced along shore, instead of continuing straight on into deep water. It seemed possible that the change of course was caused by chilling of the oceanward side of the flow, making it easier for the lava to spread laterally. It was also possible that the change was at least partly the result of the lava following the broad depression between the shoreline and the low ridge at the outer edge of the coral reef. However, in 1960 at Kilauea the flow behaved in the same way, and there was no depression parallel to the shoreline to guide it. Later in the 1960 eruption, on several occasions the Hawaii Fire Department tried spraying the flow margin to determine its effects. One example may be given. For several days the edge of the flow had been creeping slowly toward a wooden house. When the lava was about six meters (20 feet) from the house, volunteer firemen, who were not then otherwise occupied, turned two streams of water from 75 millimeters (three-inch) hoses onto the side of the flow. Within a few minutes the lava stopped moving, and it remained stationary for several hours. In short, it was found that even with rather small amounts of water the spread of the flow could locally be checked for periods long enough to remove the contents of buildings, or even to move entire buildings to safety.

The use of the spraying method depends, of course, on the availability of large amounts of water and of suitable pumps and other equipment. Its success depends on favorable topography and on the volume and rate of flow of the lava.
Volcanic Zoning and Risk Mapping

With most of the world’s volcanoes lying on plate boundaries, the nature of the boundary can give at least some indication of the type of volcano to be found there. The mid-Atlantic ridge is a divergent plate boundary where the two halves of the Atlantic are pulling apart and volcanoes are forming the new crust in the spreading zone. In this case the magma originates from the depths of the mantle and is therefore almost exclusively composed of basalt—the silica-deficient, highly fluid material that forms very mobile lava flows with relatively little explosive activity, typical of the Icelandic volcanoes. In complete contrast, convergent plate boundaries, which account for most of the Pacific Ocean rim, involve one plate being overrun and destroyed by another, with vast amounts of surface rocks being dragged down to great depths. At these depths the temperatures are high enough to cause melting and the generation of magma—which can on the convergent plate boundaries be of almost any composition. Most significant is the fact that these volcanoes can produce the viscous, gas-charged, silica-rich magmas that generate the more explosive types of eruptions. The island arc volcanoes situated very close to plate boundaries, such as in the East and West Indies, are characteristically rhyoites, or silica-rich volcanic rocks. With magmas of this nature the violence of Pelee or Krakatau is only to be expected.

The basis of risk evaluation lies in geological and historical studies of the exact nature of previous eruptions, inference of the likelihood of mudflows or the extent of lava flows, deduction from anticipated composition and viscosity, and consideration of the volcano’s topography.¹⁷

The delineation of areas of type and degree of hazard from volcanoes is generally known as volcanic zoning. In several parts of the world attempts are being made to identify which volcanoes are potentially dangerous and to indicate on maps the areas subject to different degrees and types of risk. Thus far work of this sort has been very limited. It is the only logical basis for deciding when an eruption starts or appears imminent, which areas should be evacuated, and for what periods.

The earliest zoning maps appear to have been made by the Volcanological Survey of the Netherlands Indies after the 1919 eruption of Kelud. The areas indicated as dangerous were chiefly those that had been previously devastated within historic time, and they show clearly the effects of topography on the flows. The work is being continued by the Geological Survey of Indonesia. In recent years similar maps have been prepared for some of the Kamchatkan volcanoes. In New Zealand, a general appraisal of volcanic risk has been made for the city of Auckland.¹⁸

Disaster Preparedness and Response

Response to a volcanic eruption must be swift and efficient. The initial response by local authorities usually includes evacuating the area and taking care of the victims by providing short-term feeding and emergency shelter. This initial response can be assisted by cash provided by foreign intervenors.

The secondary response by local authorities consists of relocating the victims if necessary, and providing all victims with credit and financial assistance. Special efforts must be made to restart the economy by providing the necessary assistance to agriculture and small business. The secondary response provided by foreign intervenors should parallel that of the local authorities. In general the appropriate types of aid to give to volcano victims include: cash, temporary lodging, short-term feeding of normal foods, surgical aid for the injured, loans or credit and agricultural assistance.
All of this requires pre-disaster contingency planning, not only for evacuation but also for a temporary community with all of the life-line and support services necessary to sustain the community.

Volcanoes are one of the few disaster types that may require evacuation to temporary shelters for a period of more than two or three days, although evacuation is seldom longer than two weeks. It becomes, therefore, one of the few times that tents may be an appropriate temporary shelter solution. Exceptions to this may be some of the Indonesian volcanoes where eruptions have lasted months. More permanent facilities may be necessary to house and provide services to these victims.

Notes
2 Ibid.
5 Fred M. Bullard, Volcanoes: In History, In Theory, In Eruption, p. 292-301.
6 Robert I. Tilling, "Volcanoes."
8 Tilling, "Volcanoes."
10 Tony Waltham, Catastrophe: The Violent Earth, p. 34.
12 Tony Waltham, Catastrophe: The Violent Earth, p. 35.
14 Tony Waltham, Catastrophe: The Violent Earth.
16 Ibid.
17 Tony Waltham, Catastrophe: The Violent Earth.
18 UNDRO, op. cit.

References


Volcano Disaster Overview

1. Environmental Effects

<table>
<thead>
<tr>
<th>Effects</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast</td>
<td>Destroys timber, crops, houses, bridges.</td>
</tr>
<tr>
<td>Lava flow</td>
<td>Inundates all in its path; causes fires; may force evacuation.</td>
</tr>
<tr>
<td></td>
<td>Damages structures if hit; may force evacuation.</td>
</tr>
<tr>
<td></td>
<td>Can destroy crops; damages machinery; can temporarily make croplands unusable (but restores nutrients); may force evacuation; may destroy animal habitat; creates respiratory problems; can clog waterways.</td>
</tr>
</tbody>
</table>

2. Patterns of Injury and Surgical Needs in Disasters

Deaths exceed injuries. Low surgical needs within the first 72 hours.

3. Patterns of Disease Resulting from Disasters

<table>
<thead>
<tr>
<th>Actual Immediate Epidemiological Threat</th>
<th>Secondary Epidemiological Threat</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

4. Immediate Social and Economic Consequences of Disasters

<table>
<thead>
<tr>
<th>Short-term mitigations</th>
<th>Disruption of marketing systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of housing</td>
<td>Loss of crops</td>
</tr>
</tbody>
</table>

5. Effects of Natural Hazards

<table>
<thead>
<tr>
<th>On Land</th>
<th>Structures</th>
<th>Agriculture</th>
<th>Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blast</td>
<td>Destroys or damages Building, other surface Structures</td>
<td>Minor damage</td>
<td>Widespread timber losses near eruption</td>
</tr>
<tr>
<td>Lava flow</td>
<td>Buries buildings, sets fires</td>
<td>Buries crops and renders land unusable</td>
<td>Destroys forest and starts forest fires</td>
</tr>
<tr>
<td>Ash deposits</td>
<td>No major effect</td>
<td>Destroys crops, makes Temporarily unusable, Pollutes water</td>
<td>Kills trees</td>
</tr>
<tr>
<td>Localized fissures</td>
<td>Damages structures</td>
<td>No major effect</td>
<td>No major effect</td>
</tr>
</tbody>
</table>

6. Response to Disasters (Ideal)

Initial Response:

By Local Authorities
Evacuation, search and rescue; short-term feeding, emergency shelter

By Foreign Intervenors
Cash

Secondary Response:

By Local Authorities
Relocation, credit, financial assistance to victims, assistance to assistance to agriculture and small business.

By Foreign Intervenors
Relocation, credit, financial assistance to victims, assistance to agriculture and small business.

7. Appropriate Aid

cash loans or credit blankets

temporary lodging agricultural assistance
Chapter 5
Tropical Cyclones

Introduction
Cyclones are among the most awesome events that nature can produce. They pose a major threat to lives and property in many parts of the world. Every year these sudden, unpredictable, violent storms bring widespread devastation to coastlines and islands lying in their erratic paths. A windstorm’s destructive work is done by the high wind, flood-producing rains and associated storm surges.1

Historical Examples

Tamil Nadu, India, November 1977

On November 12, 1977, a cyclone that originated in the Bay of Bengal developed winds of 90-110 kilometers per hour (60-70 miles per hour) and struck the central coast of Tamil Nadu State in southern India. Hardest hit by the resulting floods were the areas of West Tanjore, Dindigul, Vedasandur, and Chidambaram. Of particular concern was the Vedasandur Dam area, which had recently been transformed by irrigation from an arid, sheep-raising land to a three-crop-per-year area. The floods destroyed much of the irrigation system. The number of casualties in Tamil Nadu was limited, apparently by the fact that people had heeded early warnings and moved to higher ground.

On November 19, 1977, a second cyclone, which had been expected to hit Tamil Nadu, instead struck the central coast of Andhra Pradesh State in the Krishna Godavari Delta. Many people perished because advance warning was either too slowly or too narrowly disseminated. Damage in Andhra Pradesh was caused primarily by a storm surge that devastated some 65 villages, about 21 of which were completely washed away. The storm surge was reported to have been 5.7 meters (19 feet) high, 80 kilometers (50 miles) long, 16 kilometers (10 miles) wide, with a speed of 190 kilometers per hour (120 miles per hour). Many of the victims of the Andhra Pradesh cyclone were migrant laborers. This made identification of the dead difficult.

The factors that combined to form this dangerous tidal wave were the low-lying flatness of the delta area, the concavity of the coastline, the gentle slope of the land into the sea, and tide height - at 4:30 P.M., strike time, the tide was high. Normally, as at Tamil Nadu, cyclones cause flooding upstream, which brings topsoil to lower areas. In this case, however, intrusions of sea water and downstream flooding left saline silt in low areas. Sandcasting of fields and wells not only made agricultural reclamation necessary but also made housing reconstruction difficult because saline mud would not hold together.

On November 22-23, the cyclone that struck Tamil Nadu 10 days earlier crossed the southern peninsula into the Arabian Sea, gathered strength, and turned landward again. On November 23, it moved northward along the western coast, lashing northern Kerala State and the Lakshadweep Islands north of Mangalore. Damage and loss of life during this third, rejuvenated cyclone were less severe than in Tamil Nadu and Andhra Pradesh.
Altogether the combined disaster officially killed 9,796, with 4,258 missing; unofficial reports held that there were 25,800–31,000 dead, 5,462 million homeless, and millions more affected. Included in the impact was damage or destruction to over 1,400,000 houses, damage to irrigation works, roads, rail systems, public buildings and installations, and power and telecommunications networks, totaling U.S. $110,300,000. The fishing and weaving industries sustained damage valued at $22,705,881; 1,420,550 hectares (3,510,000 acres) of crops, 23,000 head of cattle and sheep, and 5,000 poultry birds were lost with an estimated value of over $353 million.²

Dominican Republic, August and September 1979

In August and September of 1979 two of the strongest and most destructive hurricanes of the twentieth century ripped through the Caribbean, causing terrible destruction to Dominica and more still to the Dominican Republic. The summary of the damage by sector is as follows: Electric Power. The hurricanes caused extensive damage to the Dominican Republic’s electric power system. Hydroelectric power plants at Valdesia and Tavera were damaged and knocked out of operation. The transmission system from Santo Domingo southwest to Azua was almost totally destroyed, while more than 35 percent of the distribution systems in the towns of Bani and San Cristobal were down. In general, 20-70 percent of the country’s power lines were down, depending on the particular area. The financial and other resources of the Dominican Electricity Corporation were not adequate to cope with the task of reestablishing and repairing the system, especially since such materials as poles, wire, and transformers were in very short supply.

Housing. Shelter needs in the wake of the storms were very high. Approximately 57,000 dwellings, housing some 350,000 people, (most of them poor) were severely damaged or destroyed. The heaviest damage was in the provinces west of Santo Domingo, often in isolated and mountainous rural locations. In one area of 160 square kilometers (100 square miles) between and to the north of Bani and San Cristobal, 75 percent of all housing was destroyed, apparently by wind. Most damage was to roofs, although in many cases doors and windows were also destroyed. The destruction of housing and other community infrastructure created serious health and refugee problems.

Agriculture. The total estimated value of losses of crops and chickens from the combined effect of wind and water damage was set at U.S. $266.5 million, about 25 percent of estimated agricultural Gross Domestic Product (GDP). Most of the damage was to small farms. Physical damage to irrigation, farm and poultry industry installations, and small marine fisheries was estimated at an additional $46.4 million. As a result of storm damage, there were considerable shortages of traditional low-income food crops, mainly plantains and root crops, necessitating greatly increased food imports. Lost exports, primarily coffee, were valued at about $100 million. The combined effect of increased food imports and lost export income was to significantly worsen the Dominican Republic’s already strained balance of payments situation. Dominican forests were savaged by the storms. Approximately 94,000 trees, mostly pine and primarily in public forests and parks, were felled. The fallen trees represented a potentially valuable resource in terms of the lumber that could be recovered from them. However, damage to the forests represented a serious environmental threat in terms of potential erosion, silting, flooding, etc.
The total number of dead was estimated at 1,400, with over 4,000 injured. The total number affected was 1.2 million (23 percent of total population). The total damaged was estimated at $830 million.

**Geographical Distribution**

Tropical cyclones are known around the world by various names: hurricanes in the Atlantic and Caribbean, typhoons in the West Pacific, baguios in the Philippines, cordonazos in Mexico, tainos in Haiti (see Table 5.1). A tropical cyclone is essentially a rotating storm in the tropical oceans. It is conventionally defined as a circular storm with rotating wind speeds in excess of 64 knots (32 meters per second). The life span of a tropical cyclone is, on average, about six to nine days until it enters land or recurses into temperate latitudes, but this may vary from a few hours to as much as three to four weeks. Tropical cyclones form in the oceans between 5 to 30 degrees north and south of the equator. They are found in all oceans of the world, with the probable exception of the South Atlantic and the South Pacific east of 140 deg. W longitude (See Fig. 5.1).

No two tropical cyclones follow the same track; some recurve, some do not; some loop; some slow to a standstill and some will accelerate. The movement of a tropical cyclone is generally 12 knots or less.

It is important to be aware of the regional names given in the above table so that, for example, what is described as a severe cyclone in the Bay of Bengal will be understood as essentially the same phenomenon as that which is called a hurricane when it occurs in the north Atlantic.

**Natural Preconditions for Disaster Occurrence**

Cyclones are born in the hot, humid late-summer environment of the tropics (June to August in the Caribbean, November to April in the South Pacific). As the sun warms the oceans, evaporation and conduction transfer heat to the atmosphere so rapidly that air and water temperatures seldom differ by more than 1 degree F. The water vapor generated by such evaporation is the fuel that drives a tropical storm, because as the vapor condenses into clouds and precipitation it pumps enormous amounts of heat into the cyclone. The fuel supply is controlled by the evaporation rate—which explains why cyclones cannot develop when the ocean temperature is below about 24 degrees Centigrade (76 degrees F).

The frequent products of this mix of heat and moisture are several thunderstorms that can become the seedling for a tropical cyclone—but it must be nurtured further. The trigger for most Atlantic hurricanes is an easterly wave, a westward-migrating low-pressure center that may have begun as an African thunderstorm. Typhoons in the Pacific and Indian oceans, and a few hurricanes in the Atlantic, emerge from waves in the equatorial trough, the calm, cloudy doldrums that separate the trade winds of the two hemispheres.

To develop and mature into a tropical storm, storm seedlings must overcome many obstacles. In fact only about nine of the more than 1000 seedlings tracked each year in the Atlantic will evolve into gale-force tropical storms or full-fledged cyclones.

The sole difference between harmless thunderstorms and a dangerous cyclone is the rotation that organizes weather systems. This spin, which meteorologists call vorticity, is ever-present in temperate latitudes, where the Coriolis effect of the earth’s rotation is pronounced. But in the tropics the weak Coriolis effect must be augmented by the wind itself. (The Coriolis effect is the
force caused by the earth’s rotation that deflects a moving body to the right in the Northern Hemisphere and to the left in the Southern Hemisphere.)

When two wind currents move side by side, the faster current tends to curl around the slower one. If the faster current is on the right (viewed from upwind), the curl is to the left, yielding positive vorticity in the Northern Hemisphere because it adds to the counterclockwise Coriolis effect; a right-hand curl creates negative vorticity. A curving wind also possesses vorticity—positive for a left-hand turn, negative for a right turn.

When positive vorticity becomes strong enough to spin a storm seedling, it starts a chain reaction. The thunderstorms, not revitalized by a steady influx of warm, moist air, organize around a deepening low-pressure center, called a tropical depression. This dramatically increases the likelihood of cyclone formation; fully 70 percent of these depressions develop into cyclones. (See Fig. 5.2.)

The depression becomes a tropical storm when its winds reach gale force, 62 kilometers per hour (40 miles per hour). The storm often already has as much total energy as a cyclone, but its winds are widely distributed and hence much slower; the ring of maximum wind may be as much as 320 kilometers (200 miles) across. The final step to cyclone status merely concentrates this energy. As pressure falls at the storm center, the ring of maximum wind contracts dramatically, until it is perhaps 50 kilometers (30 miles) in diameter. Outside this circle the velocity drops rapidly.

**Disaster Event**

When the cyclone-force winds move onto land the storm becomes the potential disaster. The lower the atmospheric pressure in the center of the storm, the more violent the action of wind, storm surge, and waves is likely to be. The storms can be classified by intensity, as is shown below.

The Beaufort scale (Table 5.2) is used to estimate the velocity of the wind by observing the effects of rising winds on the ocean surface and a variety of familiar objects. Another standard relating cyclone intensity to damage potential has been developed by the National Hurricane Center in the United States. It has been adapted from the Saffir/Simpson hurricane scale. This descriptive scale, over a range of categories 1 through 5, is shown in the following Table 5.3.

**Flooding**

High winds are, of course, only a part of the problems that are brought by the storm. Devastating floods from extremely heavy rainfall often accompany tropical cyclones. Flash floods of great volume and short duration may result from the cyclone’s rain, especially in hilly or mountainous terrain. Runoff from the intense rainfall accumulates quickly in restricted valleys and flows rapidly downstream, often as a large “wave.” Flood flows frequently contain large concentrations of sediment and debris.

The damage generated by these floods is increased where they cause mudslides that either cover or undercut roads, erode agricultural soil and contribute to long-term serious environmental degradation.

Tidal floods can also be caused by the combination of waves generated by cyclone winds and flood runoff resulting from the heavy rains that accompany cyclones. These floods may extend over large distances along a coastline. Their duration is usually short, being dependent upon the elevation of the tide, which rises and falls twice daily.
Tropical Storm Tracks

Figure 5.1

Areas of Occurrence of Intense Tropical Cyclones and Regional Descriptions

<table>
<thead>
<tr>
<th>Region</th>
<th>Range of maximum wind speeds (Meters per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>17-32</td>
</tr>
<tr>
<td></td>
<td>32-85</td>
</tr>
<tr>
<td>Western North Pacific Region</td>
<td>Tropical Cyclone</td>
</tr>
<tr>
<td>Bay of Bengal and Arabian Sea</td>
<td>Cyclone</td>
</tr>
<tr>
<td>South Indian Ocean</td>
<td>Tropical Depression</td>
</tr>
<tr>
<td>South Pacific Ocean</td>
<td>Tropical Depression</td>
</tr>
<tr>
<td>North Atlantic Ocean and eastern North Pacific Ocean</td>
<td>Tropical Storm</td>
</tr>
</tbody>
</table>


Table 5.1
An atmosphere disturbance forces warm moist air of the prevailing Easterlies to rise. As the air cools, water vapor condenses and falls as rain, heat energy is released, and winds intensify.

The storm grows as air spirals inward, rises, and is exhausted from the top by high level winds. Surface air converges at an increasing rate toward the low pressure at the storm center. High winds, heavy rain, and storm surges occur as the storm becomes a mature hurricane.


Figure 5.2
### The Beaufort Scale

<table>
<thead>
<tr>
<th>Beaufort Number</th>
<th>Wind Speed</th>
<th>Seaman’s Term</th>
<th>Estimating Wind Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Knots</td>
<td>mph</td>
<td>Effects observed at sea</td>
</tr>
<tr>
<td>0</td>
<td>under 1</td>
<td>under 1</td>
<td>Calm</td>
</tr>
<tr>
<td>1</td>
<td>1-3</td>
<td>1-3</td>
<td>Light air</td>
</tr>
<tr>
<td>2</td>
<td>4-6</td>
<td>4-7</td>
<td>Light breeze</td>
</tr>
<tr>
<td>3</td>
<td>7-10</td>
<td>8-12</td>
<td>Gentle breeze</td>
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<tr>
<td>4</td>
<td>11-16</td>
<td>13-18</td>
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<td>6</td>
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<td>Strong breeze</td>
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<td>7</td>
<td>28-33</td>
<td>32-38</td>
<td>Moderate gale</td>
</tr>
<tr>
<td>8</td>
<td>34-40</td>
<td>39-46</td>
<td>Fresh gale</td>
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<tr>
<td>9</td>
<td>41-47</td>
<td>47-54</td>
<td>Strong gale</td>
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<tr>
<td>10</td>
<td>48-55</td>
<td>55-63</td>
<td>Whole gale</td>
</tr>
<tr>
<td>11</td>
<td>56-63</td>
<td>64-72</td>
<td>Storm</td>
</tr>
<tr>
<td>12</td>
<td>64 or higher</td>
<td>73 or higher</td>
<td>Hurricane</td>
</tr>
</tbody>
</table>


*Table 5.2*
The Saffir / Simpson Hurricane Scale

**Scale No. 1:** Winds of 74 to 95 miles per hour. Damage primarily to shrubbery, trees, foliage, and unanchored mobile homes. No real damage to other structures. Some damage to poorly constructed signs. And/or: storm surge 4 to 5 feet above normal. Low-lying coastal roads inundated, minor pier damage, some small craft in exposed anchorage torn from moorings.

**Scale No. 2:** Winds of 96 to 110 miles per hour. Considerable damage to shrubbery and tree foliage; some trees blown down. Major damage to exposed mobile homes. Extensive damage to poorly constructed signs. Some damage to roofing materials of buildings; some window and door damage. No major damage to buildings. And/or: storm surge 6 to 8 feet above normal. Coastal roads and low-lying escape routes inland cut by rising water 2 to 4 hours before arrival of hurricane center. Considerable damage to piers. Marinas flooded. Small craft in unprotected anchorages torn from moorings. Evacuation of some shoreline residences and low-lying island areas required.

**Scale No. 3:** Winds of 111 to 130 miles per hour. Foliage torn from trees; large trees blown down. Practically all poorly constructed signs blown down. Some damage to roofing materials of buildings; some window and door damage. Some structural damage to small buildings. Mobile homes destroyed. And/or: storm surge of 9 to 12 feet above normal. Serious flooding at coast and many smaller structures near coast destroyed; larger structures near coast damaged by battering waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Flat terrain 5 feet or less above sea level flooded inland 8 miles or more. Evacuation of low-lying residences within several blocks of shoreline possibly required.

**Scale No. 4:** Winds of 131 to 155 miles per hour. Shrubs and trees blown down; all signs down. Extensive damage to roofing materials, windows and doors. Complete failure of roofs on many small residences. Complete destruction of mobile homes. And/or: storm surge 13 to 18 feet above normal. Flat terrain 10 feet or less above sea level flooded inland as far as 6 miles. Major damage to lower floors of structures near shore due to flooding and battering by waves and floating debris. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Major erosion of beaches. Massive evacuation of all residences within 500 yards of shore possibly required, and of single-story residences on low ground within 2 miles of shore.

**Scale No. 5:** Winds greater than 155 miles per hour. Shrubs and trees blown down; considerable damage to roofs of buildings; all signs down. Very severe and extensive damage to windows and doors. Complete failure of roofs on many residences and industrial buildings. Extensive shattering of glass in windows and doors. Some complete building failures. Small buildings overturned or blown away. Complete destruction of mobile homes. And/or storm surge greater than 18 feet above normal. Major damage to lower floors of all structures less than 15 feet above sea level within 500 yards of shore. Low-lying escape routes inland cut by rising water 3 to 5 hours before hurricane center arrives. Massive evacuation of all residential areas on low ground within 5 to 10 miles of shore possibly required.


**Table 5.3**
Storm Surges

In many major tropical cyclone disasters, storm surge (Fig. 5.3) is frequently a key factor. As the cyclone approaches the coastal area, strong on-shore winds can cause a rise of several meters in sea level; the result is water crossing the coast and flooding large areas of the interior. The factors that combine to cause a storm surge are partly meteorological and partly hydrographic, including the state and nature of the tide and the topography of the sea bed in the vicinity of the coast. The following are some major factors contributing to a storm surge:

- A fall in atmospheric pressure over the sea surface: in the center of a tropical cyclone the atmospheric pressure is much less than outside the storm. For each one millibar difference in air pressure, the mean water level in the storm will rise approximately one centimeter (less than 1/2 inch). Since the difference in atmospheric pressure rarely exceeds 100 millibars, the maximum rise in mean sea level due to this effect is about one meter (three feet).
- The effect of wind: as the winds strengthen they will have more effect on the water, causing waves, swells, and storm surges. While the storm is some distance from the coast, however, countercurrents beneath the ocean surface may offset any tendency for the winds to cause a storm surge or a net rise in the level of the sea.
- The influence of the sea bed: as the storm approaches a coast, especially one in which the sea bed slopes gradually, friction at the bottom of the sea will interfere with the return water currents and the wind effect will pile up water along the shore. This combination of strong winds and a gently sloping sea bed can result in very high storm surges, reaching sometimes as much as eight meters (25 feet) in very severe tropical cyclones.
- A funneling effect: a semienclosed bay in the path of the high water permits the storm’s winds to pump additional water into the bay and trap it there for extended periods until the water level inside the bay is considerably higher than along the open coast.
- The angle and speed at which the storm approaches the coast: this also affects the height of the surge. In general, the greater the forward speed and the more nearly perpendicular the track is to the coast, the higher the surge will be. However, the storm surge can also be dangerous in a severe storm that is moving either parallel to the coast or moving forward very slowly.
- The tides: in some countries the semi-diurnal tide has an amplitude of a few meters and shows some variation with the season of the year. In such regions there is a large difference in the maximum water height if the storm surge comes on the high tide rather than on the low tide. If landfall of a tropical cyclone coincides with the maximum of the “spring tides,” the resulting surge can be devastating, particularly if in the normal “high tide” the water is almost high enough to cover portions of the coast.

Countries most vulnerable to storm surges are those that experience the more severe tropical cyclones and have low-lying land along the closed and/or semi-enclosed bays facing the ocean. Such countries include Bangladesh, China, India, Japan, Mexico and the United States and, in the southern hemisphere, Australia. Storm surges also pose the threat of disaster in temperate zones, particularly in the North Sea where the strong winds of an intense depression may blow towards an exposed coastline. The North Sea is surrounded by land to the west, south and east. It has been the scene of storm surges that have caused heavy loss of life and extensive damage in the countries whose coastlines have been affected. These countries have therefore established elaborate protective measures (such as complex systems of dikes, flood gates, canals, reservoirs, etc), and warning systems for storm surge. Most of the disaster-prone developing countries have very limited financial resources. They cannot yet afford to build such extensive civil engineering structures and such alternative
measures as have to be devised and adopted. Improving forecasting and warnings of storm surge would greatly help to move the population to safety above the expected storm surge level. This may mean evacuating to higher ground wherever possible, or into specially built refuges. The construction of refuges may in themselves require considerable capital outlay and effort. However, they are comparatively less expensive, in the short run, than civil engineering works and they can save lives if built in sufficient numbers. Refuges may consist either of artificial earthen mounds (or “killas” as they are known in parts of Asia) large enough to protect entire village populations, or raised platforms built of reinforced concrete.8

**Frequency and Duration**

Tropical cyclones are a seasonal phenomenon with a frequency varying from an average of one per year in some areas to as many as 20 per year, a figure that is increasing as more storms are recorded through the use of satellite data. In most regions they are confined to a less-than-six-month period of the year when the ocean waters reach the required degree of warmth (Fig. 5.4), although they may occur in the western North Pacific at any time of year. Some storms last only a few hours, others as long as three weeks.9

**Forecasting/Forewarning**

**Forecasting Ability**

Attempts to forecast tropical cyclones date back into the nineteenth century. Criteria to indicate that a new cyclone is approaching include subnormal pressure in low latitudes and above-normal pressure in high latitudes, existing disturbance of some sort, and changeable winds. In addition, sea swells, erratic tides, and microseisms (a small quiver of the earth’s crust) may warn of the approaching storm.

International efforts under the leadership of the World Meteorological Organization have led to a system known as the World Weather Watch. The system includes some 8,500 land stations, 5,500 merchant ships, aircraft, several special ocean weather ships, automatic weather stations, and meteorological satellites. At present a tropical cyclone is usually first identified and then followed from satellite pictures. The detail in these pictures shows up anything more than three kilometers (two miles) across, so seedling cyclones show quite clearly. Observations from the network of stations on land and sea are exchanged by the complex Global Telecommunications System, and analyzed under the Global Data Processing System, as part of the World Weather Watch. There are three World Meteorological Centers (Melbourne, Moscow, and Washington, D.C.), some 20 regional centers, and more than 130 national centers where the data are analyzed and the results made available for use by forecasters. In addition the Global Atmospheric Research Program seeks to improve forecasting methods through meteorological research.10

The ultimate responsibilities for providing forecasts and warnings of tropical cyclones and their associated winds, rainfall, floods and storm surges fall upon the national services concerned with meteorology, hydrology, and hydrography.

**Forecasting Errors**

A number of investigations into forecasting errors have been carried out. These have indicated considerable variation from one year to another and from one region to another, the latter probably depending on the amount of data available and on the experience of the forecaster. Using over-all averages, the error in a 24-hour forecast of the position of a tropical cyclone’s
center is about 175 kilometers (110 miles). The probable error appears to be directly related to the forecast period; for example, the average error of a 48-hour forecast is about twice that of a 24-hour forecast.

Errors in forecasting the position of the center of a tropical cyclone are, of course, of immense practical importance. It is therefore encouraging that the verification statistics show an improving trend, a sign that additional data and intensive research are beginning to yield dividends.

**Forecasting Flooding**

In the forecasting and warning aspects of flood risk, there must be close coordination between the meteorological forecasters and the hydrologists who will be working with the water authorities and local officials. The meteorologist, besides forecasting the intensity, movement and evolution of the tropical cyclone, will also prepare forecasts of rainfall, its time of onset, duration and the amounts expected.

Rainfall is nearly always heavy in a tropical cyclone and may amount to a total between 75 and 300 millimeters during a period lasting from 12 to 48 hours. The rainfall varies considerably from one storm to another and is strongly influenced by the time required for the cyclone to pass. In mountainous countries the rainfall can be extremely heavy. For example, Japanese and Chinese weather records frequently show more than 600 millimeters of rain falling during the passage of a typhoon over large areas in the mountains.

The assessment of flood risks is based primarily on rainfall forecasts in those areas where the time interval between heavy rain and a flood is apt to be short. Examples of such areas are a city that is within the vicinity of a watershed and a small island that has mountains in the interior. In other areas where the water flows downstream for many hours or several days before doing any damage, flood forecasting is based mainly on an analysis of successive measurements of stream flow at various points along a river. Other important factors include the accumulated total of rain that has already fallen and the actual state of the rivers in relation to flood levels.

**Forecasting Storm Surges**

The forecasting of storm surges is at present largely based on empirical methods. Much promising research is now in progress in several countries. The object is to develop dynamic models that will provide numerical predictions to supplement those based on empirical formulae. One important preparatory step in the forecasting of storm surges consists of having available a considerable amount of background information. Among the items required are frequency charts of strong winds, the range of the diurnal tide for the months of the storm season, and the results of surveys of the topography of the continental shelf and of bays along the coast.

**Warning Systems**

Warning systems should be viewed as a combination of technical and social arrangements that allow individuals and groups affected by a storm to respond in ways most beneficial to them. On the technical side there needs to be a complex evaluation of meteorological data plus knowledge of coastal factors and engineering works that may modify the effects of the storm. On the social side the conditions for effective operation include organization for action to take place when the warning is received, issuance of the warning, directions for action transmitted as part of the warning, and evacuation where required. Assumptions often made about warning systems are that the message is not changed in transmission, that the recipients will understand it as intended by those who issued it, and that
Storm Surge

As a tropical storm forms, winds increase and atmospheric pressure drops.

Decreased atmospheric pressure causes the sea level to rise.

As the storm approaches land, winds pile up water to raise the sea level even higher, and the sea sweeps inland.


Figure 5.3
the recipients will know what to do in their own best interest when they get the message. Rarely are all these conditions fulfilled; in Bangladesh, for example, the radio may be off during critical hours of the night. In the United States warning systems are highly developed, with 1.9 million people put under the average warning. Despite repeated warnings, some coastal citizens in the Mississippi area hit by Hurricane Camille in 1969 did not evacuate, seriously underestimating the potential destructiveness of the storm.

With present forecasting methods for tropical cyclones, an overwarning affecting an area of roughly several hundred kilometers must be expected. This overwarned area is necessarily greater where there is less forecasting equipment available, as has been the case in the Pacific region.

The capacity for nations of communities to develop warning systems is affected by population size, financial or other resources, linkages with media, use of radio and TV, government-citizen relationships, frequency of extreme events, willingness of officials to risk false alarms, relationship among governmental units, and organizational capacity.12

The current international warning system recognizes two levels of warning. When the evaluation determines that a potential cyclone could make landfall within 48 hours, a “cyclone warning” is issued. For agencies involved in disaster preparedness, this signals the initiation of

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**Figure 5.4**

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The current international warning system recognizes two levels of warning. When the evaluation determines that a potential cyclone could make landfall within 48 hours, a “cyclone warning” is issued. For agencies involved in disaster preparedness, this signals the initiation of
a set of activities in anticipation that a cyclone will strike. When the cyclone is potentially within 24 hours of landfall, a “cyclone watch” is issued. This stage marks the emergency period when an advanced set of precautions are to be taken, including evacuation from vulnerable communities.

For many nations, however, the present international system of warning is inadequate. For example, some of the island nations of the South Pacific are spread out over enormous distances. The outer islands are without constant radio contact with a potential warning source.

For some people or industries, the 48-hour warning is also inadequate. The fishing industry may need 72 hours advanced warning for their fisherman and boats to reach safe harbor. Cement plants may need three to four days to shut down their operations and protect the equipment.

**Evacuation**

More than one-half the loss of life from tropical storms is due to drownings, either from the rise in sea water inundating the land or from floods induced by excessive rainfall. Evacuation has been a successful means of reducing the loss of life in the United States, as when 300,000 people were evacuated in advance of Hurricane Betsy in 1965. Only 75 lives were lost, despite damages of over $1.4 billion. Evacuation requires considerable prior planning and coordination of warning systems and evacuation plans. It has so far proved impracticable in areas like Bangladesh where communications are poor and local public awareness or motivation are not favorable.\(^{13}\)

**Impact on Built and Natural Environments**

**Immediate Impact of Cyclones**

The most serious immediate consequence of cyclones is the loss of human lives. It is estimated that between 1960-1970, 17 major storms in various parts of the world killed about 350,000 people, most from drowning. The death rate is significantly higher where communications are poor and warning systems and evacuation plans are inadequate. Furthermore, the number of deaths will increase as population pressures force people to inhabit more vulnerable areas, such as low-lying agricultural areas or overcrowded urban slums.

The most dramatic impact of cyclones is the damage they cause to houses and other physical structures. In addition to damaging homes and buildings, cyclones destroy or damage critical facilities, supply lines, crops, and/or food stocks. They disrupt economic activities and create financial burdens. They may destroy or damage facilities that are critical not only for responding to disasters, but also for maintaining a safe environment and public order. Among these are communications installations; electrical generating and transmission facilities; water storage, purification, and pumping facilities; sewage treatment facilities; hospitals; police stations; and various other public and private buildings.

Cyclones disrupt agriculture and destroy crops. High winds destroy some standing crops, especially grains, and damage orchards and forests. Flooding from intense rains damages certain crops, especially tubers, and may cause excessive erosion. Storm surges scour and erode topsoils, deposit salts on fields, and may increase salinity in subsurface water. Furthermore, access to markets for buying and selling agricultural produce may be impeded by damage to roads, bridges, railways, etc.
Cyclones disrupt economies. Consequences of the disaster include the loss of investments and jobs, for example, destruction of or damage to factories; production losses that result from the destruction of harvests or crops; the death of livestock; the closure of shops, small businesses, and industrial production units, etc. During the emergency, people must leave their jobs and devote their time to disaster-related activities such as search-and-rescue or caring for survivors. During this period, normal economic activities are severely curtailed even if the sources of employment are unaffected by the cyclone. Persons (such as subsistence farmers, urban squatters, fishermen, and others) who were participating only marginally in the economy before the cyclone will be affected most severely by the economic losses. After a cyclone, it is not uncommon for many small enterprises to fail.

In addition, the cost of relief and reconstruction creates a financial burden on the government. Increased expenditures for preventive and curative medicine, aid to the unemployed, and repair or replacement of housing are required, at a time when there is a decrease in public resources due to an overall decrease in economic activity and tax receipts.  

**Long-Term Impact of Hurricanes**

Cyclones also cause indirect and secondary effects that can have a far-reaching, long-term impact on a country. Fundamental changes may occur in the lifestyles of the people as well as in the basic direction in which the society had been moving prior to the disaster. Disaster-induced changes occur because disasters create a climate wherein changes in society (including land use, agricultural, economic, political, geographic and housing patterns) are more acceptable—or even demanded.

Cyclones can significantly retard the long-term economic growth of smaller countries. Indirect and secondary effects on the local and national economy may include reduction in family income, decline in production, inflation, unemployment, and decline in national income. In some cases, poorly-conceived relief efforts can recreate vulnerable conditions. For example, many relief agencies rush to initiate housing reconstruction projects after a cyclone. Yet many have no experience in the housing sector and do not know how to build safe houses. Scores of housing programs systematically rebuild each year thousands of structures that are more dangerous than the houses they replace.

Finally, relief and reconstruction efforts compete with development programs for available funds. In countries where cyclones occur frequently, they can create an enormous financial burden. Fiji provides a good example. In the 1970s, the country was repeatedly struck by cyclones, which forced the government to commit to reconstruction a large portion of the foreign aid received. In the early 1980s, roughly 20 percent of the foreign aid received was spent on overhead costs alone for reconstruction efforts from four separate cyclones.

**Vulnerable Communities**

The vulnerability of a human settlement to a cyclone is determined by its siting, the probability that a cyclone will occur, and the degree to which its structures can be damaged by it. Buildings are considered vulnerable if they cannot withstand the forces of high winds. Generally those most vulnerable to cyclones are light-weight structures with wood frames, especially older buildings where wood has deteriorated and weakened the walls. Houses made of unreinforced or poorly-constructed concrete block are also vulnerable.

Urban and rural communities on low islands or in unprotected, low-lying coastal areas or river floodplains are considered vulnerable to cyclones. Furthermore, the degree of exposure of land
and buildings will affect the velocity of the cyclone wind at ground level, with open country, seashore areas and rolling plains being the most vulnerable. Certain settlement patterns may create a “funnel effect” that increases the wind speed between buildings, leading to even greater damage.

**How High Winds Damage Buildings**

Contrary to popular belief, few houses are blown over. Instead, they are pulled apart by winds moving swiftly around and over the building. This lowers the pressure on the outside and creates suction on the walls and roof, effectively causing the equivalent of an explosion (see Fig. 5.5).

Whether or not a building will be able to resist the effects of wind is dependent not so much upon the materials that are used but the manner in which they are used. It is a common belief that heavier buildings, such as those made of concrete block, are safer, simply because the materials are stronger than other types of building materials. While it is true that a well-built and properly-engineered block house offers a better margin of safety than other types of buildings, safe housing can be and has been provided by a variety of other materials including wood, wattle-and-daub, and many others.

**Damage to Infrastructure**

Damage to infrastructure can also be widespread. Towers and transmission lines may fail as a result of resonance from high winds. Large buildings may also be damaged by wind resonance, flying debris, or erosion that undermines their foundations, leading to weakening or even failure of the building. Transportation facilities such as bridges, railways, airports, roads and ports are also vulnerable to damage by both high winds and flood waters.

**Disaster Mitigation**

Much of the potential impact of cyclones can be reduced or eliminated if certain precautions or mitigation measures are taken. The following are specific actions that can be taken to implement these improvements.

**Regulatory Controls and Their Relative Effectiveness**

Conventional land-use control measures regulate use, density and location as well as the rate of development and growth. Land-use planning and control for disaster prevention and mitigation purposes is designed to control land use so that low-risk activities can be placed in vulnerable areas.

In coastal areas exposed to cyclones and storm surges, zoning ordinances would regulate minimum building height, type of land-use according to the set-back for the shoreline and most vulnerable locations, and density occupancy of buildings. Land might be regulated so as to place residential development away from the coastline, reserving it for other uses.

Land-use control and regulation can be an effective tool for reducing vulnerability, but it is not a simple, universal cure. Controls must be relevant to local conditions, to the degree of physical hazard, to the existing local economy, and to the probable future socio-economic status of the area. Also involved are numerous human factors that have to do with the inhabitants’ perceptions of the hazard they face and the available means of altering the incidence of damage. The established way of life, existing land-use and ownership patterns, and pace of
social and economic change will determine to a greater or lesser extent what regulated uses are to be recommended.

Other needs or pressures are frequently so overwhelming that land-use policies for disaster prevention/mitigation are given little weight. Growth of population and land shortages have tended to push the poor further and further to marginal land such as ravines, steep slopes, or even riverbeds. Disaster prevention and mitigation controls may conflict with other interests such as employment and income opportunities. For example, rapid urbanization in many developing countries has produced large concentrations of urban squatters who have settled on unoccupied land (both public and private) in unattractive or undesirable locations, including marshes and the low-lying land exposed to periodic or seasonal flooding, but where they are close to employment opportunities and services. Squatter settlements in low-lying flood-prone areas are often caused by the high cost of suitable alternative locations and the extremely high per capita costs of new infrastructure and services.

Traditional and transitional economic systems are highly sensitive to regulation, and the economic costs (measured by employment or employment growth losses) of uprooting, relocating or inhibiting development can be very high. Land-use controls that do not respond to the economic forces they attempt to channel will be less effective. The cost of policing a body of unpopular or unworkable (for the poor) rules and regulations may exceed the capacity of the government.

Land-use policies must be supported by corresponding social and economic policies. Thus the reservation of new urban land for housing, especially where low-income families are concerned, should be linked to transportation and employment opportunities, education and other social services.

**Building Regulations**

Building codes establish minimum standards of design, construction and materials in order to avoid structural collapse. But like formal land-use controls, strict building regulations are unrealistic (and almost always unenforceable) for the majority of homes that typically receive no engineering input and are made from locally available, inexpensive materials.

A workable alternative to rigid building codes are more flexible building _performance standards_. Establishment of these policies and standards should be based on the degree to which a certain level of performance is desired. For example, it is probably not cost-effective (nor technically feasible) to build every house so that it is completely disaster-proof; yet it is possible to ensure that all houses have an increased level of safety. A primary objective of the standards, therefore, would be to encourage the development of more disaster-resistant houses (i.e., with a substantially increased level of safety) rather than to require that all houses be built to a very high engineering standard. This means that any type or size of house may be built, and any material may be used to build a house—whatever is appropriate to the economic situation of a homeowner—as long as the final structure is cyclone resistant and as long as it does not endanger the lives or property of neighbors or passersby.

Various economic, land and construction _incentives_ have been tried, with varying degrees of effectiveness in reducing vulnerability. Fiscal and financial incentives can be used to encourage proper, rational development in less vulnerable areas. They can also be used to avoid the undesirable location of infrastructure facilities, haphazard or irrational uses of land, over-developed land, and congestion of people and activities. Fiscal and financial incentives might
How High Winds Damage Buildings

Wind blowing into a building is slowed at the wind-ward face creating high pressure. The air flow separates as it spills around the building creating low pressure or suction at end walls, roof, and leeward walls.

The roof may lift off and the walls blow out without special reinforcement to the structure.

Figure 5.5
include subsidies and loans to landowners who comply with urban and land-use regulation
designed to reduce disaster risk. Taxes that penalize inappropriate use of land or construction
are most relevant to the modern or developed sectors of national economies. The marginal
(low-income) or traditional sectors are largely outside the tax system; therefore, “positive”
incentives in the form of housing and land subsidies are likely to be more effective and politically
more acceptable.

Positive incentives comprise various kinds of grants or low-interest loans for construction or for
the purchase of building materials to encourage new development on low-risk land. The
subsidies have to be sufficient to outweigh other concerns, such as access to transport,
proximity to work, etc., that are factors in perpetuating unplanned development in high-risk
zones.

Public development of urban infrastructure can be an effective measure to encourage
development in safe areas. Governments have traditionally provided roads, sewer systems,
water facilities and other public utilities, and often the actual construction of housing or sites and
services. This is an excellent opportunity for guiding growth away from hazardous lands and for
managing the impact of natural hazards. As a development strategy, the provision of
infrastructure may be used to curtail development by prohibiting public utilities, such as sewer
and water facilities, from being extended to disaster-prone areas. If services must be provided
in vulnerable areas, water supply networks, sewers and septic tanks should be located on lower-risk areas so as to minimize health hazards.

Measures to Reduce Economic Losses
Measures to reduce agricultural losses may include building ferrocement or other appropriate
strong grain silos to help protect harvests until they are sold; changing cropping patterns, if
possible, to avoid exposing crops during their most vulnerable stages (i.e. harvesting) to periods
of high risk (e.g., the flooding season); and introducing alternative crops or crop strains that are
more flood and wind resistant.

Measures to reduce losses to energy facilities include using power grids that allow continuation
of service to areas not damaged; diversification of generating capacity (i.e., oil, gas, coal, etc.);
and development of alternative energy sources (wind power, solar, biogas, etc.).

Public Awareness
Perhaps the biggest obstacle to vulnerability reduction is the lack of awareness of the existence
of a disaster threat and of basic disaster mitigation and preparedness measures that can
provide substantial and permanent benefits without necessarily causing governments or
individuals additional expenditure. Systematic methods are necessary to inform people about
the threat of disasters. Public awareness programs must explain some very basic and
frequently misunderstood issues on the nature of the disaster risks—the anticipated hazard, the
type of disaster impact, and the vulnerable condition to which the local population is exposed.

Disaster Preparedness and Response
Several important activities are necessary during the pre-disaster period. The following are the
most important measures that governments, communities or voluntary agencies need to
institute to be ready for the advent of a cyclone:

• developing a disaster preparedness plan to sequence the activities and responsibilities of
each participant
developing an effective forecasting system;
• developing warning and evacuation procedures for people threatened by floods
• training for first aid and trauma care, and maintaining stocks of necessary medical supplies
• establishing an emergency communication system as well as public service messages regarding evacuation, health, safety, and security.

The occurrence of a disaster is a critical time and the response must be quick and complete. Specific initial and secondary responses are listed below by the group responsible for them.

The initial response by local authorities after a cyclone includes:
• evacuation
• search-and-rescue
• medical assistance
• disaster assessment
• provision of short-term food and water
• water purification
• epidemiological surveillance
• provision of temporary lodging and, depending upon the climate, blankets.

The initial response by foreign aid organizations includes:
• cash
• assistance in reopening roads
• re-establishing communications contact with remote areas
• disaster assessment
• assistance with water purification.

The secondary response by local authorities after a cyclone includes:
• repair and/or reconstruction of infrastructure, housing and public buildings
• creation of jobs
• assistance to agricultural recovery (loans, seeds, farm equipment, animals) as well as to small businesses, fishermen, etc.

The secondary response by foreign agencies includes:
• repair and/or reconstruction of housing;
• creation of jobs
• provision of credit
• technical assistance
• assistance to recovery of agriculture, small businesses and institutions.

The many conclusions drawn and lessons learned from past cyclones can be used to mitigate and better respond to future occurrences. Some of the most helpful are listed below for easy reference.

• Outbreaks of cholera do not follow cyclones. Cholera must previously be endemic to a community.
• Waterborne diseases do not increase as a result of cyclones.
• Massive food aid is rarely required after a cyclone.
• Used clothing is almost never needed. It is usually culturally inappropriate. Though accepted by disaster victims, it is almost never worn.
• Blankets can be useful, but if they are needed they can be found locally and do not need to be imported.
• Assistance by outsiders is most effective in the reconstruction period, not the emergency phase.
• Most needs are met by the victims themselves or their local governments.
• In general, victims do not respond to disasters with abnormal behavior. Cyclones do not incite panic, hysteria or rioting.
• Cyclone relief and reconstruction programs should be integrated with long-term development programs.
• When properly executed, reconstruction assistance can provide a strong stimulus to recovery and a base for future development work.
• Reconstruction programs should seek to reduce vulnerability to future disaster.
• Re-establishment of the local economy, income security and agriculture are usually more important to cyclone victims than material assistance.
• Churches, schools and other large buildings that are often designated as cyclone shelters are usually not safe. The number of deaths attributed to destroyed or flooded shelters is alarming. Most experts agree that the best alternative is adequate warning and evacuation of the threatened areas.
Notes


2 OFDA Case Study Reports.

3 Ibid.


6 Ibid. p. 87.


10 Ibid.


13 Ibid.


15 INTERTEC, Briefing Papers, p. 28-32.

References


INTERTEC, Briefing Papers Prepared for Conference Held at Suva, Fiji, by PIDP, 1983.


OFDA Case Study Reports.


# Tropical Cyclone Disaster Overview

## 1. Environmental Effects

<table>
<thead>
<tr>
<th>Effects</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Winds</td>
<td>Damage structures; destroy some standing crops; damage orchards and trees</td>
</tr>
<tr>
<td>Intense Rains</td>
<td>Cause flooding that damages structures, may cause evacuations, landslides;</td>
</tr>
<tr>
<td></td>
<td>damage certain crops (tubers); erosion</td>
</tr>
<tr>
<td>Storm surge</td>
<td>Causes rapid flooding with above effects; scours and erodes topsoil; may</td>
</tr>
<tr>
<td></td>
<td>increase salinity in subsurface water; destroys most crops</td>
</tr>
</tbody>
</table>

## 2. Patterns of Injury and Surgical Needs in Disasters

- Without storm surges, injuries exceed deaths. Moderate surgical needs.
- With storm surges, deaths exceed injuries. Moderate surgical needs within first 72 hours.

## 3. Patterns of Disease Resulting from Disasters

<table>
<thead>
<tr>
<th>Actual Immediate Epidemiological Threat</th>
<th>Secondary Epidemiological Threat</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Waterborne diseases (except cholera), vectorborne diseases</td>
</tr>
</tbody>
</table>

## 4. Immediate Social and Economic Consequences of Disasters

- Loss of housing
- Loss of industrial production
- Loss of business production
- Damage to infrastructure
- Disruption of marketing systems
- Disruption of communications
- Looting

## 5. Effects of Natural Hazards

### On Land

<table>
<thead>
<tr>
<th>High Winds</th>
<th>Structures</th>
<th>Agriculture</th>
<th>Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Damages buildings, power lines, towers</td>
<td>Damage to standing crops such as grains</td>
<td>Widespread loss of timber</td>
</tr>
<tr>
<td>Flooding</td>
<td>Damages structures</td>
<td>Damage to standing crops in flood areas</td>
<td>Minor losses</td>
</tr>
<tr>
<td></td>
<td>Extensive damage to structures, roads, etc.</td>
<td>Extensive damage to crops, irrigation systems; leaves harmful salt deposits, scours topsoil, contaminates wells</td>
<td>Loss of trees</td>
</tr>
</tbody>
</table>

## 6. Response to Disasters (Ideal)

**Initial Response:**
- Evacuation; search and rescue; medical assistance; disaster assessment; provision of short-term food/water; water purification; epid. surveillance; provision of temporary lodging.

**Secondary Response:**
- Repair/reconstruction of infrastructure, housing, public buildings; jobs; assistance to agriculture, small business, fishermen.

**By Foreign Intervenors**
- Cash; assistance in reopening roads, re-establishing communications, contact with remote areas; disaster assessment; assistance with water purification.

**Appropriate Aid**
- cash, loans or credit, blankets
- temporary lodging, agricultural assistance, short-term feeding (normal foods)
Chapter 6
Floods

Introduction
People have long been attracted to floodplains. Here rivers deposit the topsoil picked up elsewhere, so the land is fertile. Floodplains are both flat and near water, so irrigation, ploughing and transport (usually aided by the river) are all made easier. The heavy settlement along the lower reaches of Egypt’s Nile, India’s Ganges, Bangladesh’s Brahmaputra-Padma, the Yellow River and Yangtze of China, and the Tigris and Euphrates of Iraq are all examples of floodplain civilizations.

Floodplains are desirable places to live, not only in agricultural societies, but also in industrial countries where the floodplains often host large capitals that use the river water for industry and its mouth as a harbor for shipping.

The floodplain of a river is a clearly definable physical feature of its valley. It is the almost flat area that borders the river. A floodplain is built up of layers of sediment deposited by the river when it periodically overflows its normal banks. Steep narrow valleys in mountain regions have no floodplains at all, but a large complex system of converging rivers in a lowland region may have a floodplain over a hundred kilometers wide. There is a natural tendency for a river to deposit sediment in its channel during times of low flow, so that an equilibrium is arrived at where the river comfortably fills its main channel under normal conditions. Therefore the river will spread out automatically onto its floodplain during periods of high flow—after all, floodplains are for floods.

But expansion of towns soon forces them to spread out—all too commonly onto the floodplains, where they were immediately in danger. In the United States alone there are currently an estimated 10 million people living in areas subject to flooding. A flood is too much water in the wrong place, whether it be an inundated city or a single street or a field flooded due to a blocked drain. Among the trigger mechanisms are dam or levee failures; more rain than the landscape can dispose of; the torrential rains of hurricanes; tsunamis; ocean storm surges; rapid snow melts; ice floes blocking a river; and burst water mains.

Flooding is generally defined as any abnormally high streamflow that overtops the natural or artificial banks of a stream. Flooding is a natural characteristic of rivers. The floodplains are normally dryland areas. They are an integral part of a river system that acts as a natural reservoir and temporary channel for flood waters. If more runoff is generated than the banks of a stream channel can accommodate, the water will overtop the stream banks and spread over the floodplain. The ultimate factor of damage, however, is not the quantity of water being discharged but how high the water goes above normal restraints or embankments. Furthermore, floods can form where there is no stream, as for example when abnormally heavy precipitation falls on flat terrain at such a rate that the soil cannot absorb the water or the water cannot run off as fast as it falls.

Of all the disasters except droughts, flood disasters affect the most people. But there are many more flood disasters than droughts, and the number affected by floods is increasing much more rapidly than those suffering droughts. In fact, flooding is one natural hazard that is becoming a greater threat rather than a constant or declining one. Floods are caused not only by rain but
also by human changes to the surface of the earth. Farming, deforestation, and urbanization increase the runoff from rains; thus storms that previously would have caused no flooding today inundate vast areas.

Not only do we contribute to the causes of floods, but reckless building in vulnerable areas, poor watershed management, and failure to control the flooding also help create the disaster condition. Ecologists have recently found evidence that human endeavors may directly be affecting the weather conditions that produce extensive and heavy rains. Irrigation of dry lands creates moisture conditions that contribute to increased humidity and evaporation, which in turn lead to increased rainfall. This is particularly heightened in desert areas where large lakes are built to provide water either for irrigation or for nearby settlements.

**Historical Examples**

**Bangladesh, 1974**

Bangladesh is a riverine country where recurrent flooding is both common and necessary. Every year large areas are submerged during the monsoon season and fertilized by deposits of fresh alluvium, i.e., the soil deposited by moving water. However, if the waters remain stagnant for too long, these beneficial floods become major disasters. Such was the case in the summer and fall of 1974 when flooding extended over nearly one-half of the country and stagnated for more than a month. At least 1,200 people died in the floods and another 27,500 died from subsequent disease and starvation. Approximately 425,000 houses were destroyed or severely damaged and the losses to agriculture were estimated at U.S. $325.9 million. A total of 36 million people suffered severe hardship and losses due to the disaster.

The devastation of the floods can be attributed to more than just a malicious act of nature. Neglect and lack of administrative control were also contributing factors. Under colonial rule regular dredging had helped to maintain adequate river depth. After independence, however, protective measures were lax and silting of rivers and deforestation resulted in gradually increasing flood levels. Slow environmental degradation left Bangladesh virtually defenseless against destructive flooding.

The most devastating effect of the floods was on the agricultural sector. Although agriculture accounts for 60 percent of the Gross Domestic Product (GDP) and employs 80 percent of the population, Bangladesh has not been able to feed itself. Ninety percent of the flooded 1.6 million hectare (four million acres) was rice lands, the country’s major crop. Little of this could be recuperated since the replanting season had already passed. Supply problems were compounded by the lack of a buffer stock, absence of foreign exchange to purchase food, and failure of food aid shipments to arrive in time. The longstanding foodgrain gap increased from 1973-74 to 1974-75. As a result, many people who escaped drowning died of starvation.

The country was already in the midst of a serious payments crisis when the floods increased the problem. A reduction in export revenue from the Bangladesh jute crop coincided with massive import requirements for food assistance after the disaster. The result was a severe trade imbalance and an increase in the current account deficit by U.S. $250 million. Per capita income and income distribution also suffered during this period. The countryside became increasingly impoverished as many small landholders lost both their crops and land.
The decline in agricultural output led to higher levels of unemployment and underemployment. Masses of destitute rural people migrated to urban areas where job opportunities proved equally scarce. Added to this was a 50 percent inflation rate fueled by escalating prices of essential commodities now in short supply. In sum, the flood directly caused deterioration in levels of output and combined with rising unemployment and inflation to disturb the once moderately equitable nature of Bangladesh society.³

Yellow River, China

China’s Yellow River has the dubious distinction of being responsible for more human deaths than any other individual feature of the world’s surface. The cause for this is the river’s unique form and configuration. For nearly 4,000 kilometers (2,500 miles) it flows through the mountains and plateaus of northern China, and on its route through the easily eroded loose soils it picks up an enormous quantity of silt. The flow of the river may be 40 percent yellow silt (which gives it its name) when it arrives at Kaifeng. From there it travels another 800 kilometers (500 miles) to the sea across the great Yellow Plain—essentially a massive alluvial fan, sloping more steeply than a true delta—which is also 800 kilometers wide and spreads around both sides of the mountains of Shantu. The river gradient across the plain is far higher than in a normal delta, but the Hwang Ho, as the Yellow River is known in Chinese, is still unable to carry its sediment load, and the plain is made of redeposited silt.

From Kaifeng, 15 channels radiate across the plain. Each time the Yellow River tops one of these, it causes enormous floods before resuming a single channel. The floods have drowned unbelievable numbers of people on the crowded plain, and the destruction of crops results in famine and yet more deaths. In only three floods since 1887 the Yellow River has killed over 6,000,000 people.

The levees, which were started over 2,500 years ago, have had to be constantly raised by the labour-intensive methods for which the Chinese are famous. There is nothing with which to build them except the silt. The constant raising means that the Yellow River now crosses its plain about 7.5 meters (25 feet) above the surrounding countryside, between inner and outer levees that form a belt 19 kilometers (12 miles) wide. The silt is the cause of the problem, for it is constantly deposited in the river channel. The river rises to yet higher levels and the Chinese are left with a literally never-ending task of building the levees higher still. Because of this the Yellow River now has no tributaries for over 640 kilometers (400 miles), and millions of people live below river level with the constant threat of flooding. There are no hills in the plain, no escape routes in the event of a flood. And the average area flooded each year is 8,200 square kilometers (3,000 square miles). Because the plain is below river level, it cannot drain. Regions stay flooded to the horizon for a year at a time. Once a major levee break lets the river completely escape, it occupies a braided course perhaps 24 kilometers (15 miles) wide for up to 10 years before it settles itself into a new channel.⁴

Geographical Distribution

Flooding is the most universal of natural hazards. It occurs on each continent and is a potential threat wherever there is rainfall or coastal hazards. With the exception where rainfall is never more than very light, every watershed is a potential site for flooding. Every coastline that is vulnerable to tropical cyclones or tsunamis is also at risk to flooding.
The most noted floods are associated with the world’s great rivers. However, the lesser floods on smaller rivers or upstream tributaries may cause cumulatively more damage, even though receiving less public attention.

**Natural Preconditions for Disasters**

All of the earth’s water (including the atmosphere) is part of a system referred to as the **hydrological cycle** (Fig. 6.1). Beginning with the moisture in the air, water vapor enters the atmosphere by evaporation from bodies of water and by transpiration (the giving off of water vapor) from plants and trees. Once aloft, the moisture cools and collects into clouds as it rises higher into the atmosphere. When temperature and moisture content reach the proper stage, the vapor in the clouds condenses, and the water in the clouds falls to the earth as rain or snow. Once returned to the surface, the water may evaporate again rapidly, or it may soak down into the earth and remain as groundwater for thousands of years until at last it again finds its way to an outlet. But regardless of where the precipitation falls, or how long it remains, eventually it is recycled.

At any given moment, only about .005 percent of the earth’s estimated 1,360 million cubic kilometers of water is actively involved in the hydrological cycle. But because of fluctuations in the cycle, the actual amount of water available to various regions of the world can vary dramatically, often bringing searing drought or devastating flood.

**Disaster Event**

**Flood Types**

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

Riverine floods are caused by precipitation over large areas or by melting of the winter’s accumulation of snow, or by both. These floods differ from flash floods in their extent and duration. Whereas flash floods are of short duration in small streams, riverine floods take place in river systems whose tributaries may drain large geographic areas and encompass many independent river basins (see Fig. 6.2). Floods on large river systems may continue for periods ranging from a few hours to many days. Flood flows in large river systems are the distribution of precipitation. The condition of the ground (amount of soil moisture, seasonal variations in vegetation, depth of snow cover, imperviousness due to urbanization, etc.) directly affects runoff.

In most cases the most devastating flooding from rainfall is that associated with tropical cyclones. Catastrophic flooding from rainfall is often aggravated by wind-induced surcharge along the coastline. Rainfall intensities are high and the area of the storm is broad-based; these
two factors together are capable of producing extreme flood discharges in both small and large river basins.

The size of catchment area usually governs the character of flooding. On very large rivers, such as the Nile and the Mekong, river flow is relatively slow to change in the downstream reaches. Flood waters are, therefore, mostly a combination of numerous and widespread rainfall events possibly with considerable snow-melt contribution. In large river basins, flooding is usually seasonal and of major significance. Peak discharges are maintained over a relatively long period of days or even weeks.

Flood-producing rainfall, with or without snow-melt, can also be of extratropical or weather frontal character. It may alternatively be the result of a large atmospheric depression with moisture-laden winds, moving from a marine environment onto and over a land mass. Rainfall in these events is generally widespread and can be heavy. Intensity can be high and is generally influenced by topographic relief. Coastal salt water flooding is usually caused by a combination of circumstances that may include astronomical tides, storm surges, or tsunamis. The latter two events are covered respectively in the lessons on tropical cyclones and tsunamis.

**Flood Characteristics**
The dangers of flood waters are associated with a number of different criteria, not necessarily independent of each other but creating different types of clearly recognizable hazards. A summary of the criteria and related hazards is given below.

*Depth of water*—Building stability against flotations and foundation failures, flood proofing, and vegetation survival have different degrees of tolerance to inundation. In each case these can usually be identified and the depth hazard established.

*Duration*—Time of inundation is of utmost importance since damage or degree of damage is often related to it. This applies to structural safety, the effect of interruption in communications, industrial activity and public services, and the life of plants.

*Velocity*—High velocities of flow create high erosive forces and hydrodynamic pressures. These features often result in complete or partial failure of structures by creating instability or destroying foundation support. Dangerously high velocities can occur on the floodplains as well as in the main river channel.

*Rate of rise* —The rate of rise of river level and discharge is important in its relation to the time available for giving flood warnings or making arrangements for evacuation and flood fighting arrangements. Rate of rise can therefore influence planning permission for floodplain occupation and its zoning.

*Frequency of occurrence*—Total potential damage in a floodplain relates to the cumulative effect of depth, duration and velocity hazards measured over a long period of time. This will very often, but not exclusively, influence decisions on planning permission, especially if the hazard can be measured in quantitative terms. Cumulative frequency of occurrence of the various hazards is a consideration that farming communities throughout the world have always taken into account, usually on the basis of experience and intuitive reasoning, as they decide the type and intensity of agricultural or livestock farming to employ in regions susceptible to floods.
The Hydrological Cycle

Magmatic Water

ATMOSPHERE

Precipitation → Evaporation from soil → Evapotranspiration → Evaporation

LAND

Infiltration → Groundwater Flow

Surface run-off

OCEAN

Figure 6.1
Flooding and Its Causes

Figure 6.2
Seasonality—Inundation of land during a growing season can have a completely destructive effect on agricultural production, as severe in fact as a prolonged drought. If flood waters occur during cold weather and if they derive predominantly from snow-melt with possible ice flows, general discomfort and subsistence levels of affected communities are also considerably influenced. Seasonality in large floods is therefore an important influence on severity of flood hazard.

Forecasting, Warning, and Monitoring Systems

Forecasting
The ability to forecast flooding is limited to the time during which changes in the hydrological conditions necessary for flooding to occur have begun to develop. The formulation of a forecast for flood conditions requires information on current hydrological conditions such as precipitation, river stage, water equivalent of snowpack, temperature, soil conditions over the entire drainage basin, as well as weather reports and forecasts.

In small headwater regions a forecast of crest height and time of occurrence is all the information required to initiate effective adjustments; the relatively rapid rate of rise and fall makes the period of time above flood stage relatively short. In lower reaches of large river systems where rates of rise and fall are slower, it is important to forecast the time when various critical stages of flow will be reached over the rise and fall. Reliability of forecasts for large downstream river systems is generally higher than for headwater systems.

Warning
Warning time for peak or overbank conditions can range from a few minutes in cloudburst conditions to a few hours in small headwater drainages to several days in the lower reaches of large river systems. As with forecasting, the time and reliability of the warning increase with distance downstream where adequate knowledge of upstream conditions exists. (Additional discussion on warning is found under the section, Disaster Mitigation Strategies.) Clearly the amount of information required, the data collection network necessary for collecting the information, the technical expertise required for interpretation, and the communication system needed to present timely information to potential victims are services that many poor and developing nations find difficult to provide. The World Meteorological Organization of the United Nations, through its World Weather Watch and Global Data Processing System, hopes to coordinate efforts to improve forecasting. This is especially important (and difficult) when conditions creating floods lie outside of the national boundaries of the downstream region.

Remote Sensing Monitoring
One of the most effective methods of monitoring floodplains is through remote sensing. Of the various techniques available Landsat is perhaps the most versatile. Landsat satellites (formally called Earth Resources Technology Satellites or ERTS) are used to map, inventory, and monitor earth features.

The major sensing instrument in Landsat is a multispectral scanner that produces images of the earth in green, red, and two wavelengths of infrared radiation. The products are black-and-white images, and images in digital form that can be processed by computers.
The following basic characteristics of the satellite system and its images are of importance in disaster planning, management, and mitigation:

- Each image covers an area 171 kilometers (110 miles) on a side.
- Each wavelength band has specific useful characteristics. For example, Band 7 (long wavelength infrared) always shows water as black, even if it has a high sediment load. This is most useful for mapping coastlines, lakes, rivers, and floods.
- The satellites pass over the same point every 16 or 18 days, thus providing repetitive and comparable observations over time. This is particularly important for detection of changes and monitoring of rates and extent of environmental change.
- Images are available for almost all areas of the world except within nine degrees of the north and south poles. Depending on cloud cover, images may be available in repetitive observations for all countries.

Further information on Landsat system capabilities and details of the methods of application of images is well-documented in the “Manual of Remote Sensing,” Second Edition, published by the American Society of Photogrammetry, 210 Little Falls Street, Falls Church, Virginia 22046, USA.

**Landsat Images of Floods**

Mapping of flooded areas with Landsat images is not difficult. There are advantages and disadvantages to the methods, but within their specific characteristics and limitations they can be highly useful. Several mapping image interpretation criteria are given below. They will be followed by a description of the most useful applications and limitations of the images.

**Interpretation Criteria**

- Floods are imaged best on Landsat Band 7 (long wavelength infrared) because water is always black in those images and is readily distinguished from lighter-toned areas.
- Landsat color composite images show floods as dark blue, light blue, or bluish white as the concentration of sediment in the water ranges respectively from very low, through medium, to high.
- Images taken before floods can be overlaid with images taken during floods; the resulting map of an inundated area will show the difference between the images.
- Digital processing of images may be necessary if the soils in and near flooded areas are very dark and difficult to distinguish from the flood water. This unusual situation is not often encountered.

**Limitations of Application**

- Since Landsat images have a resolution of about 0.45 hectare (one acre), details below that sizes are not readily visible unless they are of high contrast.
- Because of the resolution, images of floods are best for mapping at scales from 1/1,000,000 to about 1/100,000 but only rarely at scales larger than 1/100,000. Because of those limitations, the images are most suitable for broad area mapping at small scales and least suitable for mapping in urban areas where delineation of a flood boundary is required at much higher precision.
• Since Landsat images are taken at regular intervals that cannot be changed, it is not possible to image a flood at its peak, except by chance. It is, however, possible to map areas that have been inundated by a flood up to about two weeks after the flood has receded, because the wet ground left after flood recession can be mapped.
• Areas undergoing flooding may often be cloud covered during the time of a Landsat overpass, thus preventing acquisition of usable images. 

Impact on Built and Natural Environments

Flooding can have any of the following effects on housing or other small buildings.
• Houses washed away due to the impact of the water under high stream velocity. The houses are commonly destroyed or dislocated so severely that their reconstruction is not feasible.
• Flotation of houses caused by rising waters. This occurs when light-weight, typically wood houses are not securely anchored. They can be removed too far from their foundations for relocation and repair.
• Damage caused by inundation of house. The house may remain intact and on its foundation, but the water damage to materials may be severe. Repair is often feasible but may require special procedures to dry out properly.
• Undercutting of house. The velocity of the water may scour and erode the house’s foundation or the earth under the foundation. This may result in the collapse of the house or require substantial repair.
• Damage caused by debris. Massive floating objects such as trees and other houses may impact on standing houses and cause significant damage.

Health-Related Effects

In floods, deaths usually exceed injuries. Surgical needs are low and are generally only during the first 72 hours. Floods may create conditions that promote secondary threats of waterborne and vectorborne diseases. A slight increase in deaths from venomous snake bites has been reported but not fully substantiated.

Impact on Agriculture

In most flood prone countries where economies are based on agriculture, the largest economic flood-related losses are in the agricultural sector. Even in the industrialized United States 48 percent of flood losses in 1975 were in agriculture.

Obviously most losses to agriculture result from the drowning of crops. Susceptibility to drowning depends on the type of crop and duration of flooding. Some are quickly killed by a relatively small amount of superfluous water. Others can resist as much as a few days of submersion. Even crops that thrive on large amounts of standing water will be killed if the water stagnates as in the Bangladesh example. Other agricultural losses occur in the submersion of crop storage facilities. Grains and other crops will quickly spoil if saturated with water, even for a short time.

An additional negative impact on the agricultural sector is the erosion of topsoil by the floods. Here the impact is indeed long term, resulting in the reduced productivity of the land and possibly eventual abandonment.

Flooding, however, is not all bad. For some agricultural areas flooding is a positive and necessary event. These lands depend on the periodic silt deposits for added nutrients to the soil. Flooding also serves other advantages including the filtering or dilution of pollutants that
enter the waterways, flushing of nutrients in river systems, preserving of wetlands, recharging of groundwater, and maintaining of river ecosystems by providing breeding, nesting, feeding and nursery areas for fish, shell fish, migrating waterfowl, and others.\textsuperscript{11}

**Impact on Development**

Widespread floods can have a significant effect on the long-term economic growth of the affected region. Indirect and secondary effects on the local and national economy may include reduction in family income, decline in the production of business and industrial enterprises, inflation, unemployment, increase in income disparities, and decline in national income. In addition, relief and reconstruction efforts often compete with development programs for available funds. In countries where flooding occurs frequently, floods can create an enormous financial burden.

The loss of crops and the need to find alternate sources of income have often caused small-scale migrations of farmers and skilled workers from rural areas to cities. Once established in a city, few return to their homes or farms.

Small marginal farms usually cannot survive economically following a major flood. Farmers are often forced to sell their land because they cannot afford to rehabilitate it. This may result in a substantial increase in the number of people migrating to urban areas, and thus a related housing shortage.

**International Implications**

In many of the great river basins, significant portions of their watersheds lie upstream within another nation’s boundaries. The causes of the flooding may well be created outside of the affected country in those upstream areas. This has occurred where deforestation, erosion, overgrazing, desertification and other environmental degradations have increased the runoff from previously normal rainfalls. The upstream country may be suffering environmental degradation but may not experience the effects of the flood. The downstream country may have little control over protecting itself from these recurrent floods.

**Disaster Mitigation Strategies**

The majority of the deaths and much of the destruction created by floods are largely preventable. A great deal can be done to lessen the impact of a disaster. First, though, the general public as well as engineers, planners, politicians and others need to understand the nature of the hazard. Based on that understanding, a decision and a commitment needs to be made to provide mitigation measures to reduce flood damage. Reducing the harmful effects of a flood requires actions on three fronts: reducing the vulnerability of the physical settlements and structures in which people live; reducing the vulnerability of the economy; and strengthening the social structure of a community so that community coping mechanisms can help absorb the impact of a disaster and promote rapid recovery.

The first step in vulnerability reduction for human settlements is to identify the high-risk areas. This is done by relating a natural hazard, such as a flood, to the terrain and to the probability that such an event will occur. This activity is known as risk mapping. Flood risk mapping, for example, would indicate the areas likely to be covered by water during floods of given magnitude.
The second step in vulnerability reduction is to identify those communities that are particularly susceptible to damage or destruction. This is done by relating risk to human settlements and their structures.

The third step is the selection of a vulnerability reduction strategy consisting of a comprehensive floodplain management program. The objective of such a program should be the absolute reduction of flood damage potential. This can be accomplished only by: (1) preventing an increase in flood damage potential resulting from new development in floodplains, and (2) reducing the flood damage potential in already developed floodplains. Both approaches must be used if the objective of reduced flood damage potential within a community is to be realized.

**Preventive Approaches**

Preventive floodplain management approaches usually consist of land use controls, such as floodplain regulations and subdivision regulations, which are applied to the 100-year floodplain. Briefly, the procedure is to define the 100-year water surface elevations, flood outlines and floodway. The floodway is the channel and the portion of the adjacent floodplain required to pass the 100-year flood without significantly increasing the water surface elevation, assuming the remainder of the floodplain is not available to convey flood water.

Once the floodplain and floodway are defined, potential development agencies have the options, which are subject to regulation, of leaving the floodplain in open space (perhaps as public or private park and recreation areas), developing the fringe area, or modifying the floodplain or floodway (using options such as channelization) to remove areas from the floodplain. Development that occurs under any of these options will essentially be free from major flood damage up to and including the 100-year flood event.

It is important to work with development agencies to make them aware of the flood hazard, the need for addressing the hazard and the options available to them as noted above. Experience has shown that these agencies have recognized the need to address the flood hazards and have exercised the options available to them to build quality developments safe from flooding during the 100-year event.

Other preventive approaches include:

- the acquisition of floodplain land, or at least the development rights to the land, by the overseeing agency. This could take the form of land swaps that provide alternatives to development of the site;
- establishment of incentives to encourage future development on safer sites and safer methods of construction (such as favorable taxation, loans or subsidies to those qualifying in terms of building methods or sites);
- diversification of agricultural production; identification and planting of flood-resistant crops or adjustment of planting season, if possible, to avoid coinciding with the flood season; establishment of cash and food reserves;
- reforestation, range management and animal grazing controls to increase absorption and reduce rapid runoff;
- construction of raised areas or buildings specified as refuge areas if evacuation is impossible.  

**Remedial Approaches**

In developed floodplain areas, where a high flood damage potential already exists, simply applying land use controls to defined floodplains will not have an immediate impact on the flood
damage potential. Additional actions must be implemented if the goal is to reduce a community’s flood damage potential. Remedial floodplain management involves the planning, design, construction and maintenance of facilities to reduce the flood damage potential in an already developed floodplain. The remedial options available include construction of flood control works (such as improved channels and detention facilities), retrofit floodproofing of existing buildings, flood detection and warning systems, acquisition and relocation or demolition of structures, and public awareness programs.

For the intensively utilized floodplains of urban centers in Third World countries, the application of these approaches will require considerable political will and cooperation by the users of these lands. Brief discussions of the most commonly used remedial options, including advantages and disadvantages, are given below.

Channelization

The construction of open channels is a commonly used method of reducing the size of a floodplain or floodway. To prevent erosion, channels can be lined with grass, wire-enclosed rock, concrete, riprap or cobblestones placed a few layers deep. Open channels allow water to enter them at almost any point, thus compensating for inadequate tributary collection systems. Different types of channels may be more appropriate in different locations, such as urban, industrial or rural areas. The design of channels should include continuous adjacent maintenance trails and maintenance access points that can provide an additional link in the ground transportation network, thereby providing a multiple-use benefit.

Grass-lined channels near population centers provide additional multiple-use possibilities such as playgrounds, soccer fields and open space. These channels require the largest amount of right-of-way. In hilly terrain they may also require flow restrictors to control the longitudinal channel slope and hence the velocity of the flood waters.

Riprap or wire-enclosed, rock-lined channels can withstand higher velocities, thus requiring less right-of-way. The higher velocities can pose a greater hazard to anyone caught in them. These channels have limited multiple-use potential beyond the maintenance trail.

Concrete-lined channels generally require the least amount of right-of-way and the least amount of routine maintenance. They are also the most expensive. Concrete-lined channels are the least aesthetically pleasing, usually providing no multiple-use opportunities beyond the maintenance trail. Because they present the greatest velocity hazard, they sometimes have to be fenced for safety reasons. Great care must be exercised in the design and construction of these channels.

Detention Facilities

Major on-stream detention facilities have their greatest value when placed immediately above already developed floodplain areas. Detention facilities, such as dams, store flood waters and release them at lower rates, thus reducing or eliminating the need for major downstream flood control facilities, the construction of which would disrupt the developed areas.

Perhaps the greatest disadvantage of detention facilities, assuming a structurally sound facility, is the false sense of security that such structures create among the general public. These facilities are almost never designed to contain the probable maximum flood. Thus they require a spillway to pass discharges in excess of the design flood. Oftentimes the design flood is the
100-year flood, since this frequency has become the standard for floodplain management, as noted earlier. Unfortunately, the public assumes the detention facility has eliminated any flood hazard; that they are consequently totally unprepared for the possibility of a flood that exceeds the design capacity of the facility.

Detention facilities built above undeveloped floodplain areas can actually induce increased flood damages. The 100-year floodplain immediately downstream from such a facility will be quite small, and normal floodplain management activities will allow for intense development of the pre-detention floodplain. Then when a flood larger than the design capacity of the facility occurs, extensive damage can result. This damage would not have occurred if the detention had not been built, and if the pre-detention floodplain had been managed to control development. In such cases, downstream capacity for the routed discharge from a flood in the 250- to 500-year frequency range should be reserved as an integral part of the detention facility design.

Detention facilities offer many opportunities for multiple use. Dry flood pools can be used for athletic fields, playgrounds and open space.

*Floodproofing*

Retrofit floodproofing of existing buildings is sometimes a viable solution, depending upon the location of the structure within the floodplain and its structural integrity. There are two basic types of floodproofing: active and passive. Active floodproofing is temporary, requiring some positive action on the part of building owners and/or occupants immediately before a flood event. It will not be effective if personnel are not available to perform the necessary functions when the flood occurs. Passive floodproofing is permanent and does not require any action at the time of the flood.

Active floodproofing requires some type of flood detection and warning system to give time for the personnel to install the floodproofing devices. In flash flood situations the personnel may not be available to respond in time. Therefore active floodproofing is most effective in areas with long warning lead times; it should not be relied upon, if possible, in flash flood areas.

*Flood Detection and Warning Systems*

Flood detection and warning systems can be effective in reducing loss of life and property damage. In flash flood locations the major benefit will be reduction in loss of life. The short lead times limit the amount of active floodproofing that can be accomplished. In slow-rising flood situations major savings from reductions in flood damage can be accomplished.

Flood detection systems can range from inexpensive networks of volunteer rainfall and stream stage observers and simple rule curves to sophisticated networks of telemetered gauges and computer models. An example of low technology flood detection is an informal system of observers who use the existing infrastructure of telephones to send progressive flood information downstream.

Methods for warning the public should be well thought out, documented, and practiced on an annual basis. Ways to disseminate warnings include radio, television, warning sirens and public address systems. Users of detection and warning systems should be aware that all members of the public will not respond in the desired manner to warnings. An understanding of how and why people respond to warnings is an essential ingredient in any warning system.
**Acquisition**

Remedial acquisition consists of the acquisition and relocation or demolition of high-risk structures in the floodplain. The cost of this alternative is high because full value must be paid for the structure and the land. Occasionally some money can be recouped by selling the structure to someone willing to move it or salvage materials from it. Acquisition can be better justified if the land can be put to some beneficial public use compatible with the flood hazard. In these cases funding assistance from a source such as an open space or recreation fund may be available. Following a flood disaster, funding assistance for acquisition of damaged properties may be available through disaster response agencies.

**Public Awareness Programs**

Appropriate public awareness programs should be implemented for the following purposes:

- to make floodplain occupants and/or owners aware of identified flood hazards;
- to encourage individuals to take actions such as floodproofing and developing escape plans, to mitigate their flood potential;
- to make individuals aware of the existence and operation of flood warning plans;
- to encourage individuals to keep drainageways clean and to report potential maintenance problems.

**Master Plans**

The basic guide, or road map, that provides local community officials, land owners, and developers with the information necessary to manage the floodplain is the master plan. The master plan documents the floodplain, floodway, discharges and proposed preventive and remedial actions to be taken to reduce the flood damage potential.

Each drainageway should be master planned for its entire length through the urban area as well as adjacent areas where future urbanization is anticipated. All local jurisdictions affected by the drainageway should be actively involved in the planning process, and the final product should be one that is acceptable to all jurisdictions. A regional agency can be very helpful in coordinating the formulation of a multijurisdictional master plan.

- The master planning process consists of the following steps:
  - Obtain good mapping of the study area.
  - Develop hydrology for several frequencies including the 100-year (the other frequencies are used in the benefit-cost analysis).
  - Delineate floodplains for the frequencies for which hydrology was developed, using existing channel and floodplain conditions.
  - Estimate flood damages for the various frequencies and develop flood damage-frequency curves and average annual damages (assume that floodplain regulations will prevent new flood damage potential from being introduced into the floodplain).
  - Conduct a review of all possible flood damage reduction alternatives, such as dams, channels, conduits, floodproofing, acquisition, etc., to attempt to eliminate from consideration those alternatives that are obviously inappropriate.
  - Prepare preliminary designs and cost estimates for the remaining alternatives and delineate residual floodplains for the frequencies being used.
  - Determine residual flood damages for each alternative.
  - Complete a benefit-cost analysis for each alternative.
  - Review each alternative for other factors such as political considerations, multiple-use opportunities, environmental factors, etc.
  - Select an alternative or combination of alternatives acceptable to each affected jurisdiction.
• Publish a master plan report with sufficient documentation of the above process, a preliminary design of the selected alternative, cost estimates, and the existing and proposed 100-year floodplains.

Formulation of a master plan can take from one to two years depending on the complexity of the problems and the number of local jurisdictions involved. On the other hand, the delineation of the 100-year floodplain is a straightforward process that can be accomplished relatively quickly. As soon as the floodplain and floodway have been defined, separate publication of a flood hazard area delineation report is often desirable. Early publication of the floodplain delineation report allows local jurisdictions to begin their preventive floodplain management activities before the master plan is complete.

The elements that should be a part of every master plan are land-use controls (floodplain regulations) governing the development of a 100-year floodplain, and a public information program.

Using the Master Plan

Once a master plan and/or a flood hazard area delineation report is completed, it should be adopted by the local governments as an integral part of the communities’ land-use planning and development review processes. Every development proposal in or near the floodplain should be required to conform to the master plan. Utilization of the master plan is further described below.

Preventive Use

Implementation of the preventive aspects of the master plan involves adoption of the floodplain and the imposition of floodplain regulations as described earlier. Then every development proposal within the floodplain must either conform to the requirements of the floodplain regulation (elevating, floodproofing, etc.) or the development agency may want to revise the floodplain by structural means, such as channelization. It is important that a staff with expertise be available to review development proposals.

If the master plan calls for acquisition of floodplain land, that land will be identified in the plan, and a review of a proposed development in relationship to the master plan will allow for identification of a potential conflict. The government can then proceed to acquire the land.

The master plan can also be used to prevent proposed development from creating new obstructions to implementation of remedial works. Here again, the review of the proposed development in relationship to the master plan can identify conflicts between the two, and steps can be taken to prevent the conflict from being constructed.

Remedial Use

The master plan forms the basis for the design and construction of remedial facilities to correct existing problems. Once a preliminary design has been agreed upon by all agencies involved, the process of implementation can begin.

One technique is to complete the construction design for the entire project, and then to divide the project into several schedules that are financially manageable. The schedules are then constructed over a period of years as funding permits. Construction of the initial schedules may not provide the ultimate degree of protection, but at least the community is progressing toward the total solution.
Funding

Funding for floodplain management programs and facilities typically has low priority. Floodplain management must compete for funds from the same limited resources that fund a myriad of other services. It behooves the professionals in this field to convince the funding sources that floodplain management is an integral and important part of community services. Floodplain management facilities need to be planned, designed, constructed and maintained. Inadequate funding of floodplain management compromises its effectiveness, often creating greater long-term costs.

Floodplain management programs provide the linkage between the planning documents and the actual implementation of the plans. These management programs need funds to develop information on floodplains, to document drainage problems, to monitor development activities, to review development proposals, to meet with involved parties, and to provide all other services that significantly reduce the potential of past mistakes being repeated. Economies of scale can be achieved if technical review assistance and criteria guidance are provided on a regional basis.

Much of the responsibility for implementing these activities lies with the public sector. However, nongovernment organizations can also play important roles. They can take the lead in organizing the communities affected by floodplain management, assisting individuals in either relocation or in flood protection of their property, or facilitating the master planning to accommodate the particular needs of the affected community.

Summary

The most important point to remember is this: floodplain management must consist of several actions that, when taken in concert, effectively reduce flood damage potential. A vast array of individual actions can be taken. These can be categorized as preventive or remedial. The common denominator of any floodplain management program, however, is floodplain regulation. It is important to combine both remedial and preventive actions in developing a floodplain management program. The specific actions that are implemented and the approach to their implementation will vary from community to community. Each community must identify its needs, resources, and objectives and develop accordingly a floodplain management program. (See Fig. 6.3)

The basic guide that enables local government to implement a comprehensive floodplain program is a drainage master plan. A master plan provides documentation for identifying the problems, defining the limits of the floodplain, and outlining proposed preventive and remedial actions to be taken to reduce the flood damage potential. Without a master plan it is difficult to achieve consistency of action and to solve the problems.13

The following are lessons learned from past flood disasters:

- Floods do not cause outbreaks of cholera. Cholera must be endemic to the community before the flood strikes.
- Massive long-term food aid is rarely required after a flood, although food distribution systems may need to be set up immediately after a flood in the affected area.
- Used clothing is almost never needed; it is usually culturally inappropriate. Though accepted by disaster victims, it is almost never worn.
• Blankets can be useful, but if they are needed they can be found locally and do not need to be imported.
• Flood mitigation and reconstruction programs must be integrated with long-term development programs.
• Reconstruction assistance in agriculture can provide a strong stimulus to recovery and a base for positive changes.
• Reconstruction programs should seek to reduce the vulnerability of communities.
• Re-establishment of the local agricultural economy and of job security is more important to flood victims than material assistance.

See also Table 6.1 and 6.2 for summary of preparedness and post-disaster activities for floods.
## Basic Flood Preparedness Measures

<table>
<thead>
<tr>
<th>Planning</th>
<th>A disaster preparedness plan that sets out the sequence of activities and responsibilities of response personnel must be developed.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warning</td>
<td>Warning and evacuation procedures in vulnerable areas must be developed.</td>
</tr>
<tr>
<td>Medical</td>
<td>Train personnel in first aid and trauma care, and stock necessary medical supplies.</td>
</tr>
<tr>
<td>Communication</td>
<td>Systems and messages must be developed to inform the public of health, safety, and security matters.</td>
</tr>
<tr>
<td>Essential Services</td>
<td>Hospitals, government buildings, communication systems, etc. must be sited for continued operation during an emergency.</td>
</tr>
</tbody>
</table>

Source: INTERTECT

Table 6.1
Typical Post-Disaster Activities

Initial Response

By Local Authorities:

- evaluation
- search and rescue
- medical assistance
- disaster assessment
- short-term food and water provision
- water purification
- epidemiological surveillance
- temporary lodging provision and blankets if needed

Secondary Response

By Local Authorities:

- repair and/or reconstruct infrastructure, housing and public buildings
- create jobs
- assist recovery of agriculture (through loans, seed, farm equipment, animals), small businesses, fishermen, etc.

By Foreign Agencies:

- give credit
- create jobs
- repair and/or reconstruct housing
- provide technical assistance
- assist recovery of agriculture, small businesses and institutions, etc.

Source: Intertect, p. 85-87

Table 6.2
Conclusions
Considering the preceding information the following conclusions can be drawn.

Floods are not subject to complete control but their damaging effects can be mitigated.

The upward flood cost trend can be moderated through comprehensive floodplain, stormwater, and coastal zone management measures that are economically, environmentally, and socially cost effective.

Potential benefits from flood control measures are often lost through subsequent, unwise development in supposedly protected areas.

All levels of governments should persuasively support the designation of flood-prone areas for open space uses.
Notes

6. INTERTECT, p. 80-82.
11. Ibid. p. 17.

References


White, Gilbert, Editor, Natural Hazards, Local, National Global, Oxford University Press, New York, 1974.
Flood Disaster Overview

1. Environmental Effects

<table>
<thead>
<tr>
<th>Effects</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inundation</td>
<td>Damages structures, forces evacuation, erodes topsoil, may change course of streams, rivers; destroys most crops; deposits silt in some downstream areas that may not be beneficial</td>
</tr>
</tbody>
</table>

2. Patterns of Injury and Surgical Needs in Disasters

Deaths exceed injuries. Low surgical needs within the first 72 hours.

3. Patterns of Disease Resulting from Disasters

<table>
<thead>
<tr>
<th>Actual Immediate Epidemiological Threat</th>
<th>Secondary Epidemiological Threat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waterborne diseases</td>
<td>Waterborne, vectorborne diseases</td>
</tr>
</tbody>
</table>

4. Immediate Social and Economic Consequences of Disasters

<table>
<thead>
<tr>
<th>Short-term mitigations</th>
<th>Loss of crops</th>
<th>Loss of business production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of housing</td>
<td>Damage to infrastructure</td>
<td>Disruption of marketing systems</td>
</tr>
<tr>
<td>Loss of industrial production</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. Effects of Natural Hazards

<table>
<thead>
<tr>
<th>On Land</th>
<th>Structures</th>
<th>Agriculture</th>
<th>Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erosion</td>
<td>Undercuts foundations</td>
<td>Destroys crops, changes cropping patterns</td>
<td>Reduces forests</td>
</tr>
<tr>
<td>Mudslides</td>
<td>Buries structures</td>
<td>Localized crops losses</td>
<td>Localized timber losses</td>
</tr>
<tr>
<td>Silting</td>
<td>No major effect</td>
<td>Improves soil</td>
<td>No major effect</td>
</tr>
</tbody>
</table>

6. Response to Disasters (Ideal)

**Initial Response:**

**By Local Authorities**
Evacuation; search and rescue; medical assistance; disaster assessment; provision of short-term food/water/water purification; epidemiological surveillance; provision of temporary lodging.

**By Foreign Intervenors**
Cash; assistance in re-opening roads, re-establishing communications, contact with remote areas; disaster assessment; assistance with water purification.

**Secondary Response:**
Repair/reconstruction of infrastructure, housing, public buildings; jobs; assistance to agriculture, small business, fishermen.
Repair/reconstruction of housing, jobs; credit; technical assistance to agriculture, small business, institutions.

7. Appropriate Aid

<table>
<thead>
<tr>
<th>cash</th>
<th>short-term feeding (normal foods)</th>
<th>loans or credit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>temporary lodging</td>
<td>blankets</td>
</tr>
</tbody>
</table>
Chapter 7
Drought

Introduction
Drought has long been recognized as one of the most insidious causes of human misery. It has today the unfortunate distinction of being the natural disaster that annually claims the most victims. Its ability to cause widespread misery is actually increasing. While generally associated with semiarid climates, drought can occur in areas that normally enjoy adequate rainfall and moisture levels. In the broadest sense, any lack of water for the normal needs of agriculture, livestock, industry, or human population may be termed a drought. The cause may be lack of supply, contamination of supply, inadequate storage or conveyance facilities, or abnormal demand. Drought, as commonly understood, is a condition of climatic dryness that is severe enough to reduce soil moisture and water below the minimums necessary for sustaining plant, animal, and human life. Drought is usually accompanied by hot, dry winds and may be followed by damaging floods. More socially relevant than technically correct is the definition used by Ari Toubo Eibrahim, the minister of agriculture in Niger, who has said that a drought is “Not as much water as the people need.”

Historical Examples

Chad, 1970s

Chad, the largest landlocked country of the African Sahel region, suffered greatly from the prolonged drought of the 1970s. Based on a 60 percent reduction in cereal grain output and 50 percent loss in the livestock herd, the dollar damage was assessed at more than U.S. $84 million. Because of inadequate data, the actual number of starvation victims and displaced persons is unknown. However, it is estimated that more than 900,000 people were severely affected by the drought.

Contributing to the problems created by the drought, the growing populations of humans and livestock put excessive pressure on the already barren land. This led to overgrazing, continuous cropping, and lowering of the groundwater table. Thus, the sharply lower rainfall of 1972 and 1973 served to increase a degenerative process that was already underway.

While attention has been focused on the magnitude of human suffering, the drought’s impact on the economy has been equally profound. In real terms, the Gross Domestic Product (GDP) of Chad was down nine percent in 1973, the worst year of the drought. The loss in real economic growth was a devastating setback for Chad; its 1975 per capita Gross National Product (GNP) of $120 ranked Chad as one of the lowest income countries in the world.

One of the greatest effects of the drought was on livestock production, an important source of income, employment, and exports in Chad. The national herd of 4.7 million cattle, goats, and sheep was reduced by one half, and the remaining animals suffered from malnutrition and disease. Because of the importance livestock played as a foreign exchange earner, the losses had a severe impact on the budgetary and balance of payments situations.
Population and employment also registered the effects of the disaster. About half of the population of four million lived in the Sahelian zone. As the drought persisted, many people migrated in search of relief. Some followed their herds into neighboring Cameroon, Niger, and the Central African Empire, while others settled in urban centers within Chad, particularly the capital city of N'Djamena. Squatter settlements grew; urban overcrowding and unemployment increased; additional burdens were placed on limited social services; and political instability intensified.  

**Bolivia, 1983**

As a result of a severe and prolonged drought during 1983 that affected large areas of seven of Bolivia's nine departments, an estimated 80 percent of the normal fall harvest of staple crops was lost. Approximately 35 percent of Bolivia's total land area was directly affected; 90 percent of the altiplano, 70 percent of the valleys, and 10 percent of the lowlands. The drought deprived nearly 1.6 million peasant farmers of their source of income and food supply. The city of Potosi, with 104,000 inhabitants, was totally without normal sources of water.

A reported food crop deficit of over 1,000,000 metric tons, half of which was potatoes, was largely attributed to the drought. Severe livestock losses further depleted the meager resources of the rural population. These losses included over 200,000 cattle, 3,000,000 sheep, and 660,000 llamas and alpacas.

Although small, isolated droughts are not uncommon in the altiplano, this drought was considered a major disaster because of the large geographical area involved; because the traditional alternative source of foodstuffs, the eastern lowlands, had been flooded; and because the transportation structure had been seriously damaged by floods.

The consequences of the drought, for both the people and the economy, were expected to be far-reaching. Migration to urban areas, a common response to drought in the altiplano, accelerated noticeably in 1983; increasing demands for goods and services pressured already overburdened municipalities and added to the large number of urban unemployed. The shutdown of several industries dependent on agricultural production further aggravated the unemployment situation and added to Bolivia's economic problems. The country's GDP growth rate for 1983, earlier projected at four percent, was expected to be less than one percent, or possibly even negative, as a result of the drought and earlier flood.

Total agricultural losses were estimated at U.S. $417.2 million: $277.7 million in crop losses and $139.5 million in livestock losses. (Please note: Figures are based on a conversion rate from local currency to U.S. dollars of 400:1. If the official exchange rate of about 200:1 were used, reported damage would be about double the above.) Lost food crop production, resulting mainly from drought but also including flood losses, exceeded 1,000,000 metric tons.

**Geographical Distribution**

Droughts occur in all of the world's continents. In recent decades the most severe and devastating to human populations have been in Africa, perhaps giving the impression that droughts are principally an African problem. In fact devastating droughts have occurred in virtually all of the major semiarid regions of the world as well as in many zones that are normally temperate climates with significant annual rainfalls.
In addition to the droughts in the African Sahel, there have recently been major droughts in northeast Brazil, Chile, Ethiopia, the Philippines, the Bolivian altiplano, and India. Near-drought conditions in the grain-producing regions of the United States and the Soviet Union have also occurred, affecting greatly the international food supply and demand. Trends in the occurrence of droughts indicate they are becoming more frequent on the edges of desert lands and where agricultural, lumbering, and livestock grazing practices are changing.

**Natural Preconditions for Drought**

Drought differs from other natural disasters in its slowness of onset and its commonly lengthy duration. Before the rise of modern water-consuming cities, drought was an agricultural disaster. Now, with cities having expanded faster than water supplies can be made available, the specter of drought faces both the farmer and the urban dweller. Shifts in atmospheric circulation, which cause drought, may extend for time scales of a month, a season, several years or even a century. The latter might be termed a climatic shift, but the effect on humans and their environment is equally great. Because of the economic and environmental importance of drought, determined efforts are being made to solve the problem of prediction of the atmospheric circulation patterns that produce droughts.

The following are main causes of drought:

- Widespread and persistent atmospheric calm areas called subsidence, which do not cause precipitation. These areas result from the present-day atmospheric circulation, which tends to create subsidence in the subtropical latitudes of both hemispheres.
- Localized subsidence induced by mountain barriers or other physiographic features. Most such areas lie in the lee of mountains across the westerly belts. They are hence in midlatitudes. The dryness is caused by the warming of westerly currents as they descend east of the summits. This allows them to hold moisture and carry it away.
- Absence of rainmaking disturbances causes dry weather even in areas of moist air. In general, rain is caused by the travel of organized disturbances across a region—i.e., systems that involve actual uplift of humid air. Thus the aridity of the Mediterranean summer, though in part due to subsidence, arises mainly from the absence of cyclonic disturbances that bring the rains of winter. There is plenty of water in the air, but nothing to bring it down as rain.
- Absence of humid airstreams. The relationship between the water available for precipitation (precipitable water) and the precipitation that actually falls is by no means simple. As we have just seen, dry weather may be prolonged in areas of high humidity. In addition to having rainmaking atmospheric disturbances, regions of abundant rainfall must have access to humid airstreams. Some innercontinental regions are quite remote from such sources.

These four causes are interdependent, but their relative effect depends on season and locality. One can broadly distinguish between:

1. Almost continuously dry climates, leading to desert surface conditions, in which there is no season of appreciable rainfall;
2. Semi-arid or subhumid climates with a short wet season in which humid airstreams or rainmaking disturbances penetrate;
3. The rare subhumid areas in which rainfall is infrequent but not confined to a special season.
Human activities also contribute to the development of drought conditions. Overgrazing, poor cropping methods and improper soil conservation techniques often contribute to creating the drought.  (See Fig. 7.1.)

**Recurrence Interval**

Climatologists debate whether drought is a short-term aberration in the climate or the result of long-term climatic changes. Some argue that drought feeds upon itself; that as vegetation is stripped from the land, the surface dries out and reflects more of the sun’s heat. This would alter the thermal dynamics of the atmosphere and suppress rainfall, which would, in turn, dry out more land. This process is discussed in the chapter on desertification.

Historically, droughts have tended to occur at regular intervals. Many scientists have noted that in areas where long-term droughts have been prevalent, surges of dry periods apparently occur at relatively predictable intervals. With this in mind, climatologists are seeking to compile historical records of drought so that drought forecasting can be made more accurate.

Whether precisely predictable or not, the historical trends can give an indication as to when drought periods might be expected. For this reason, it is important that persons living in marginal or semiarid areas try to learn about the history of drought in a particular region and use this knowledge as a rule of thumb in predicting future drought periods.

**Impact of Droughts on Built and Natural Environments**

The effects of droughts can be divided according to the primary or immediate effects, and the secondary or resulting effects.

**Primary Effects**

Primary effects of drought result from a lack of water. As a dry period progresses and water supplies dwindle, existing water supplies are overtaxed and finally dry up. The primary losses are loss of crops, loss of livestock and other animals, and loss of water for hygienic use and drinking.

**Secondary Effects of Drought**

The secondary effects of drought follow and result from the primary effects. As water supplies dwindle and crops and fodder are depleted, families begin to migrate in search of better grazing lands for their herds or move to the cities to seek jobs and alternative sources of income. If the dwindling supplies of food are not replaced, famine can occur, further accelerating the migration out of the stricken areas to less affected zones. The migration may, in itself, contribute to spreading the scope of the disaster, especially if grazing animals are moved with the people. If drought is long term, it may result in permanent changes of settlement, social, and living patterns. For example, before the 1968 drought, 65 percent of Mauritania's population were nomads. By 1976 that figure was down to 36 percent. The town of Nouakchott grew from 12,300 in 1964 to approximately 135,000 20 years later.

Secondary effects of droughts also include major ecological changes, such as increased scrub growth, increased flash flooding and increased wind erosion of soils. Of these, desertification is the most concern.
The Drought Cycle

**Normal Hydrological Balance:** Water supply is adequate to meet demand. The community grows and land use intensifies.

**Drought:** Meteorological changes reduce rainfall, while urbanization, overgrazing, reforestation, and farming reduce water retention of the soil. The normal hydrological balance is broken. The topsoil erodes and the water table is lowered making recovery difficult. Food production and drinking water are reduced and people migrate out of the area.

Figure 7.1
The Impact of Droughts on Development

If a drought is allowed to continue without response, the impact on development can be severe. Food shortages may become chronic. The country urban growth may be accelerated. To respond to this, the government must borrow heavily and must divert money from other development schemes in order to meet these needs. All serve to undermine the potential for economic development.

If drought response is treated as only a relief operation, it may wipe out years of development work, especially in rural areas. Agricultural projects in particular are most likely to be affected by droughts. For those in agricultural development, droughts or the threat of droughts should be considered a part of the overall development equation. A balanced agricultural program that develops good water resources, addresses the problems of soil erosion, adopts realistic limits on the expansion of animal herds, or accompanies herd expansion with comprehensive range management will contribute to the mitigation of drought impact.

The same philosophy is used for reconstruction in the aftermath of a drought. Reconstruction should be viewed as an opportunity to accelerate development work. It is an ideal time to introduce improved animal husbandry techniques, rangeland management, water resource development schemes and erosion control measures.

Famine

The most serious impact of droughts can be that of creating famine. Its importance requires separate discussion within this lesson. It should be regarded as a parallel disaster that will have parallel implications for preparedness, mitigation, and relief activities.

Famine is a disaster that occurs as the result primarily of drought, but it can also follow pestilence, windstorm, and human-induced catastrophes such as war and civil strife. Starvation is the result of food shortage. Famine and food emergencies are common events particularly in Africa and Asia, despite many intense and continuing efforts to address the problems. Drought-related famines appear to occur with cyclical frequency in many parts of Africa, both along the edges of deserts and in certain rain forest regions.

Famines rarely occur unexpectedly. Food stocks are not often depleted or destroyed suddenly and simultaneously in large communities. Crops in the fields may be destroyed quickly by pests such as locusts, but grain stocks may be rendered totally unfit for human consumption only as a result of moisture damage, infestation or contamination. Nongrain commodities are more vulnerable to damage and loss, especially those that cannot be stored without modern technology such as refrigeration.

More frequently, famine is predictable. In other words, the creeping onset of crop failure or food emergency is predictable from a series of meteorologic, agricultural, political and/or economic indicators that may be monitored continuously. This process of famine preparedness through surveillance is a major function of the Food & Agriculture Organization (FAO) headquartered in Rome. Where international concern is not hampered by political constraints, the early warning system has begun to work relatively well in recent years, and international appeals for food assistance have been mounted successfully on many occasions. However, the bureaucracy is somewhat cumbersome, and bulk shipments by sea and by land are subject to many delays, so that international response to famine has often been a slow process. Thus, it is extremely important that:

- indicators of an impending famine be closely monitored and measures taken quickly if it appears that a food shortage is developing;
priority be given to developing strong food and agricultural systems that provide an adequate fall-back resource in threatened areas.

**Relief Operations for Famine and Food Emergencies**

The primary purpose of relief operations during famine is to provide food to inhibit the occurrence of malnutrition. This objective is most effectively achieved through programs that provide the essential nutrition to maintain health. The nutrition component of relief operations in times of famine and food emergency may be divided into two broad groups of interrelated activities dealing with general food rations and selective feeding programs. Often the provision of food assistance to disaster victims is accompanied by public health programs, particularly immunization campaigns and primary health care services.

**General food rations.** The provision of general food rations to a hungry population involves the complex interaction of nutritional planning, agency appeal and procurement, donor pledging, international shipping, national logistics, warehousing, inventory and distribution. The principal UN coordinating body with responsibility for this component of disaster relief is the World Food Program (WFP) of the Food & Agriculture Organization. The mechanics of food distribution systems appropriate for famine victims, refugees or displaced persons may vary according to the specific location, population dependence on food aid, logistic conditions and local procurement opportunities.

**Selective feeding programs.** The provision of selective feeding programs, while constituting a part of many development programs in general, is of particular importance in famine relief operations. The purposes of selective feeding programs are to provide complete protection to population groups with increased vulnerability to nutritional deficiencies and to recuperate those already suffering from malnutrition. Selective feeding programs for disaster victims are usually divided into two distinct operations.

**Supplementary feeding programs** are designed to protect vulnerable groups against malnutrition and to rehabilitate those individuals currently suffering from moderate protein-energy malnutrition (PEM).

**Intensive feeding programs** (also called therapeutic feeding) are curative operations designed to reduce mortality among cases of severe PEM. These are most effective when organized as an inpatient operation using several feedings per day.

**Disaster Mitigation Strategies**

**Risk Identification**

To reduce the threat of droughts and to lessen their impact should they occur, a number of measures can be taken. The first step in disaster mitigation is to identify areas that are at risk to a drought. In recent years, a large number of studies have identified drought-prone areas.

To establish whether an area is drought-prone, individuals can analyze historical records to determine whether or not droughts have previously occurred. For extremely remote areas where no information exists locally, the Office of U.S. Foreign Disaster Assistance can be queried to obtain satellite data, which can provide an indicator of whether or not the area is vulnerable.
Once vulnerable areas have been identified, priority zones should be established. These zones are normally the most marginal settlements, those most at risk from a drought. Once the priority zones have been identified, comprehensive and integrated rural development programs should be initiated. Among the usual activities are:

* **Agricultural improvements** including modifying cropping patterns and introduction of drought-resistant varieties of crops;
* **Rangeland management** including improvement of grazing lands, and grazing patterns, introduction of feedlots, and protection of shrubs and trees;

**Water resource development** including improved irrigation, and water storage facilities, protection of surface water from evaporation, introduction of drip irrigation systems, and water containment methods such as retention dams and subsurface dams.

Small storm retention dams can be built across drainage depressions or dry riverbeds to trap water from occasional flash floods. Some of the water can be diverted into nearby depressions to form temporary reservoirs. These provide temporary water for drinking and irrigation, and seepage into the soil will replenish soil moisture and groundwater.

Subsurface dams are used to trap water in the sandy bottoms of dry riverbeds. A trench is dug across the streambed down to a layer of impervious clay. The trench is then filled and packed with clay to form an underground dam. When flash floods occur, a portion of the water will be trapped in the sand behind the dam. Small wells can be dug by hand to reach the water.

* **Animal husbandry** activities including maintaining smaller herds, eliminating unproductive animals, and upgrading the quality and productivity of stock through improved breeding practices.

**Land-Use Planning**

Another approach to reduce the impact of droughts on human settlements (including nomadic communities) is to employ land-use planning techniques. Land-use planning in drought-prone areas builds upon the information collected in the risk assessment.

Those lands identified as drought prone will benefit from controlled or restricted use. This requires the assessment of such land to describe the degree of its drought-prone condition, its present land use, the cyclical patterns of its land use, and land ownership. Land-use controls similar to zoning regulations could be created and adopted by governing bodies. These controls can include:

- numbers of livestock per unit area;
- maximum population density;
- limits on amounts of water taken from public water supplies for agricultural or industrial use;
- authority to declare a state of emergency during which time animal herds are required to be depleted or transported to nonemergency areas, more stringent water usage allowances are imposed, etc.

Creating land-use planning recommendations or controls has typically been easier than implementing them. Their implementation becomes feasible only when there is a political authority and will to enforce the controls. Even then, public acceptance of the controls is necessary for success in their implementation. Consequently, a set of land-use planning recommendations needs to be linked to a program of public information to make the users of the
land aware of the issues. Planning recommendations should also be linked to incentives that will encourage the land users to comply with the controls.

**Disaster Preparedness**

Several preparedness activities will decrease the impact of droughts on human settlements.

*Establishment a monitoring system.* The first step in drought preparedness is to establish a monitoring system to provide warning if a drought is imminent. A monitoring system should be based on simple information that nontechnical observers can easily acquire and transmit. Such a system is usually based on indicators. Among the normal indicators of the onset of a drought are:

- an unusual dry period;
- an increased number of wind storms;
- an increased number of dust storms;
- diminishing water supplies;
- an increase in the death rate of animals;
- changes in the migratory patterns of nomads;
- changes in vegetation, especially the introduction of desert plants such as scrub brushes;
- unusual, that is, unseasonal, changes in the prevalence rates of specific communicable diseases associated with personal and environmental hygiene, principally nonvenerereal skin diseases and diarrheal diseases, indicating the diminished use of water for washing.

*Identify and stockpile seeds for alternative drought-resistant crops.* Once a drought begins, some attempts must be made to stimulate alternative agricultural activities. A number of crops can survive mild droughts. Seeds should be kept on hand so that farmers will not lose everything in a drought.

*Identify and stockpile feeds for cattle or other livestock.* Once a drought begins it is important that the needs of cattle and other livestock be recognized. Losses can be greatly reduced if herds are penned up and fed in feedlots. This will save the animals, take pressure off the land, and let vegetation regenerate.

*Determine human nutritional requirements and develop an on-site relief distribution plan.* As a drought develops, people must receive relief supplies as near to their homes as possible. While this puts a great burden on the relief agency, it will ensure that people do not leave their homes and migrate to other areas. If they leave, the relief period will be prolonged and there will be fewer people in the area to take action to reduce the impact of the drought.

*Identify and select appropriate action to fight desertification.* If desertification is a potential threat, measures should be taken to identify suitable approaches that could be employed to prevent the creation of deserts during a drought period. Plans should be developed to implement programs to prevent further desertification, and the necessary equipment and material should be acquired and strategically placed. (See Chapter 8 on desertification.)

**Emergency Response**

Once a drought has commenced, the emergency response must be swift and comprehensive. If action is quickly taken, the following activities normally occur in the affected area:

- distribution of supplementary food for vulnerable population groups in the affected zones
- distribution of fodder for animals in the affected zones
- provision of water supplies to the communities (water supplies must be constant and people must be sure of this constant supply; otherwise they will leave the area.)
distribution of seeds for alternative crops.

If desertification is accelerated during a drought, several activities are normally taken to reclaim the land and develop water resources. These are discussed in the chapter on desertification.

If emergency measures are not immediately instituted at the beginning of a drought, large populations will inevitably begin migrating from the drought-stricken area. Once this has happened, the emergency response becomes a famine response, and emergency relief measures must be initiated.

**Post-disaster Activities**

Once the drought has abated or the flow of displaced persons has been stemmed, permanent recovery activities are initiated. Usually the victims and the government must decide on one of two courses of action: re-establishment of communities in the drought-stricken area, or resettlement of the drought victims to unaffected areas. As a general rule, resettlement is not favored except in extreme circumstances or where desertification has made return to the original communities impossible.

If the drought victims return to their homes, the focus is on re-establishing, and hopefully improving, normal economic and agricultural activities. Typical programs include:

- economic assistance;
- agricultural extension;
- animal husbandry;
- rangeland management;
- water resource development;
- agricultural engineering works including development of windbreaks and crop protection devices, installation of improved irrigation systems and introduction of drip irrigation.

The reader should note that the reconstruction activities are virtually identical to the disaster mitigation activities; they require the same type of skills and technical inputs as the former.

**Myths and Lessons Learned**

The most important myth concerning droughts is that nothing can be done to prevent them or to respond effectively once they have started. In fact, small-scale measures can have a significant impact, and with proper forethought the ravaging effects of droughts can often be substantially reduced. The experience of relief agencies in the serious Sahelian drought of the 1970s provided many useful lessons on how to respond to disasters and how not to operate in these conditions. These include:

*The importance of early warning.* Droughts do not occur without warning. Indicators can be monitored and interpreted, giving adequate notice in order to begin response and reduce the severity of the drought.

*The importance of water allocation and rationing.* At the beginning of a drought water supplies must be used wisely. Priorities should be established and measures to protect water supplies should be taken immediately. In some cases, researchers have noted that if water supplies had been rationed and allocated so that the high-priority areas had received sufficient water, the effects of the droughts would have been minimal, and shortages could have been met through supplies from outside the affected area.
The importance of responding to the disaster where it is occurring. If early warning signs are not recognized and a drought reaches advanced stages, migrations of people and animals normally occur. In the past there was a tendency to supply relief to the drought victims at the terminus of their migration, and not at its origin. This served to draw more people out of the affected areas, increasing the problem. The lesson was that relief supplies should be provided at the point where the drought is occurring. This would enable people to stay in the area, thus providing a work force to respond to the drought.

The importance of encouraging an early return of migrants. Relief operations for persons displaced by droughts should be of limited duration. Such operations should attempt to encourage these people to return as soon as possible to their homes. Experience has shown that if they do not return within several months, they will probably never return.

The need to focus on agriculture, animals and water supply. Past operations have overemphasized relief. Relief operations must be balanced by immediate and wide-spread attacks on the causes of the drought and by measures to reduce the impact. Emphasis must be placed on improving agriculture, saving herds, and improving and expanding water resources.

The need to avoid camps. For most relief agencies, the easiest way to distribute a variety of aid is by centralizing the distribution and establishing a refugee camp. Too often, however, these camps become permanent settlements. As the primary goal is to encourage people to return, relief efforts should be focused on providing the relief to the people in their own communities. This means that a great deal of sophistication is required in the relief logistics system.8

Notes
5 INTERTECT, The Potential Contribution of Peace Corps to Disaster Preparedness in Africa, INTERTECT, Dallas, Texas, 1983, p. 54-56
6 Ibid. p. 69-72
7 Ibid.
8 Ibid. p. 59-60.

References


Drought Disaster Overview

1. Environmental Effects

<table>
<thead>
<tr>
<th>Effects</th>
<th>Consequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced cloud cover; increased daytime</td>
<td>Dramatic reduction of surface water; severe crop</td>
</tr>
<tr>
<td>temperatures; increased evaporation rates</td>
<td>losses; soil erosion</td>
</tr>
<tr>
<td>Increasing likelihood of dust and sandstorms</td>
<td>Food shortages; increased hunger and malnutrition</td>
</tr>
<tr>
<td></td>
<td>Losses to livestock</td>
</tr>
<tr>
<td></td>
<td>Population shifts and migration</td>
</tr>
</tbody>
</table>

2. Patterns of Injury and Surgical Needs in Disasters

Few or no surgical needs.

3. Patterns of Disease Resulting from Disasters

<table>
<thead>
<tr>
<th>Actual Immediate Epidemiological Threat</th>
<th>Secondary Epidemiological Threat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malnutrition</td>
<td>Malnutrition increases susceptibility to all diseases, but particularly measles, diarrhea.</td>
</tr>
</tbody>
</table>

4. Immediate Social and Economic Consequences of Disasters

<table>
<thead>
<tr>
<th>Short-term migrations</th>
<th>Long-term migration</th>
<th>Loss of crops</th>
</tr>
</thead>
</table>

5. Effects of Natural Hazards

<table>
<thead>
<tr>
<th>On Land</th>
<th>Structures</th>
<th>Agriculture</th>
<th>Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry soils</td>
<td>No major damage</td>
<td>Kills crops</td>
<td>Kills some trees</td>
</tr>
<tr>
<td>Windstorms</td>
<td>Minor damage</td>
<td>Erodes topsoil</td>
<td>Minor damage</td>
</tr>
<tr>
<td>Desertification</td>
<td>No major damage</td>
<td>Covers farmland with sand</td>
<td>Kills trees, increases shrub growth</td>
</tr>
</tbody>
</table>

6. Response to Disasters (Ideal)

**Initial Response:**

- **By Local Authorities**
  - Medical, nutritional services, water (on site if possible); epidemiological surveillance

- **By Foreign Intervenors**
  - Medical, nutritional services, water (on site if possible); epidemiological surveillance

**Secondary Response:**

- Re-establishment of agricultural sector (loans, seeds, farm equipment, animals); technical assistance, nutritional surveillance
- Re-establishment of agricultural sector (loans, seeds, farm equipment, animals); technical assistance, nutritional surveillance

7. Appropriate Aid

- cash
- immunizations
- intensive feeding
- medical supplies
- agricultural assistance
- short- and long-term food aid (normal foods)
- loans or credit
Chapter 8
Desertification

Introduction and Definition

Although deserts are not without life, they can be viewed as areas with extremely limited agricultural potential. Deserts occur in a variety of types, hot and cold, stony and sandy, but all are characterized by rainfall deficiencies so marked that cultivation or stock-rearing are possible only with special adaptations, as, for example, by the development of irrigation. Desertification, as the extension or intensification of desert conditions, involves a decline in the productivity of the land. Desertification, especially in developing countries, worsens conditions of poverty, brings malnutrition and disease, erodes the basis of the national economy and then brings deterioration of social services already hampered by remoteness and lack of funds. All this affects the ability of dryland communities to respond to succeeding droughts, each of which would then tend to advance further the deterioration of living standards, which represents the human aspect of desertification.

Desertification, as part of the cycle of agriculturally good and bad years, is a slow-onset disaster. Signs of its approach are in evidence well before the situation becomes catastrophic. Desertification arises from the interaction between a difficult, unreliable and sensitive dryland environment and the human use and occupation of it in an effort to make a living. For this reason people who live in susceptible areas must learn how to live and work in harmony with the constant threat of desertification.

If desertification were allowed to develop uncontrolled, almost the entire population of the earth’s drylands could be said to face eventual risk. These drylands contain between 600 and 700 million people, and in terms of broad areas and livelihood systems their numbers are as shown in Table 8.1.1

The number of people immediately threatened, their general location and livelihood systems, are shown in Table 8.2.2 Of the 78 million people threatened, about a third may be in a position, because of high income or other advantages, to avoid the worst consequences of desertification. This still leaves about 50 million people who are immediately menaced through the destruction of their livelihoods. These people face the grim prospect of uprooting themselves from everything familiar and migrating to other areas frequently ill-equipped to receive them.

Historical Examples

The Sahara

In Arabic sahara means “desert.” Sahara is plural. Indeed, the Sahara is not one but many deserts. It contains half the desert surface of the world.

In the past 65 million years the borders of the Sahara have expanded and retreated many times. Oak and cedar trees once grew in the Saharan highlands, and rock paintings portray abundant wildlife. But about 3000 B.C. the current drying trend began setting in, and humans, relative newcomers to north Africa, had to contend with desertification of the worst degree.
# Estimates of Drylands\textsuperscript{a} Populations by Region\textsuperscript{b} and Livelihood (in thousands)

<table>
<thead>
<tr>
<th>Region</th>
<th>Dry lands total pop.\textsuperscript{c}</th>
<th>Urban based</th>
<th>Cropping based</th>
<th>Animal based</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mediterranean Basin</td>
<td>106,800</td>
<td>42,000</td>
<td>60,000</td>
<td>42,044</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(39%)</td>
<td>(57%)</td>
<td>(4%)</td>
</tr>
<tr>
<td>Sub-saharan Africa</td>
<td>75,500</td>
<td>11,700</td>
<td>46,800</td>
<td>17,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(15%)</td>
<td>(62%)</td>
<td>(23%)</td>
</tr>
<tr>
<td>Asia and the Pacific</td>
<td>378,000</td>
<td>106,800</td>
<td>260,400</td>
<td>10,300</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(26%)</td>
<td>(69%)</td>
<td>(3%)</td>
</tr>
<tr>
<td>Americas</td>
<td>68,100</td>
<td>33,700</td>
<td>29,300</td>
<td>5,100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(50%)</td>
<td>(43%)</td>
<td>(7%)</td>
</tr>
<tr>
<td></td>
<td><strong>628,400</strong></td>
<td><strong>194,200</strong></td>
<td><strong>397,100</strong></td>
<td><strong>37,100</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(31%)</td>
<td>(63%)</td>
<td>(6%)</td>
</tr>
</tbody>
</table>

\textsuperscript{a} Meigs classification (1953) including extremely arid, arid, and semi-arid area.

\textsuperscript{b} Groupings as designated by UNEP Governing Council for regional meetings.

\textsuperscript{c} Total world population was estimated to be 3.85 billion in 1974.


Table 8.1
<table>
<thead>
<tr>
<th>Region</th>
<th>Total Pop.</th>
<th>Urban based</th>
<th>Cropping based</th>
<th>Animal based</th>
<th>Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mediterranean Basin</td>
<td>9,820</td>
<td>2,995 (31%)</td>
<td>5,900 (60%)</td>
<td>925 (9%)</td>
<td>1,320,000</td>
</tr>
<tr>
<td>Sub-Saharan Africa</td>
<td>16,165</td>
<td>3,072 (19%)</td>
<td>6,014 (37%)</td>
<td>7,079 (44%)</td>
<td>6,850,000</td>
</tr>
<tr>
<td>Asia and the Pacific</td>
<td>28,482</td>
<td>7,740 (27%)</td>
<td>14,311 (54%)</td>
<td>6,431 (19%)</td>
<td>4,361,000</td>
</tr>
<tr>
<td>Americas</td>
<td>20,079</td>
<td>7,683 (32%)</td>
<td>13,417 (56%)</td>
<td>2,979 (12%)</td>
<td>17,545,000</td>
</tr>
<tr>
<td></td>
<td>78,546</td>
<td>21,490 (27%)</td>
<td>39,642 (51%)</td>
<td>17,414 (22%)</td>
<td>30,076,000</td>
</tr>
</tbody>
</table>

\(^a\) Meigs classification (1953) including extremely arid, arid, and semi-arid area.
\(^b\) Groupings as designated by UNEP Governing Council for regional meetings.
\(^c\) Total world population was estimated to be 3.85 billion in 1974.


Table 8.2
Yet in only a few places is the desert advancing like an army of sand. The war is being lost in patchwork battles from within. A piece of land goes here, another dies there. The enemy is no longer just the climate. It is ourselves and our animals, chopping trees for fuel, clearing marginal lands and cultivating away their fertility, and grazing grasslands to death. In 1968 severe drought struck the southern frontier of the Sahara, a region called the Sahel. As many as 250,000 people and millions of animals died over the next six years.

Climatologists are debating whether drought in the Sahel is a short-term climatic change. Many argue that the drought feeds on itself, that as vegetation is stripped from the land, the surface dries out and reflects more of the sun’s heat. This would alter the thermal dynamics of the atmosphere in ways that suppress rainfall. Others suspect that increased dust or other atmospheric pollutants could be causing desertifying changes in the climate. The northern part of the Sahel has always been a desert, but now the southern quarter too is turning into one. Foraging animals are wiping out even the thorn trees.

The real problem was an overgrowth of livestock in the 1950s. But rain fell abundantly then. No one was aware that the land could not support so many animals.

According to the government’s director for the protection of nature: “Now there is a wood and charcoal shortage too. Still the people cut and cut. They think that Allah will provide the rain, the trees. We hope to save whatever’s left by persuading the people that they are responsible for their own environment, and then trying to reforest it. Time is running short. We should have started ten years ago.”

The Sahel is etched with barren gullies, dug by the flash floods common during the brief rainy season. Some fields have eroded to bedrock. Everywhere there are butchered trees, their branches hacked down so that livestock can reach the leaves.

Before the drought nomads built up their herds to devastating levels. Previously the cattle moved continually, following the water and giving the grasses time to recover. But Western aid organizations financed many wells in the Sahel. These encouraged cattle herds to linger and thus overgraze land nearby.

Cattle symbolize wealth in the Sahel. The nomads do not want to limit their herds. Besides, more cattle means more might survive the next drought.

The problems of the Sahel seem overwhelming. So much land has been ruined, so many trees felled. There are so many hungry mouths. 4

**Upper Volta (Yatenga)**

The Mossi agrarian system of northern Upper Volta is an example of a system having attained its limits, that is, it no longer responds to the primary demand of feeding the human communities that are responsible for its existence. Over the last 20 years this impasse has worsened and recently reached its pinnacle following a series of disastrous harvests.

Between 1970 and 1973, the harvests were so catastrophic that hundreds of peasant families left their villages to seek a better life in southwest Upper Volta or the Ivory Coast. The same year international aid in the form of 11,000 tons of grain was sent to this district. The Yatenga region is located in northern Upper Volta, in the center between 13 and 14 degrees north latitude. About 250,000 people lived in the Yatenga region in 1925; 415,000 in
In 1975, in the heart of the region, where the heaviest concentrations of villages are found, the population density reached 70-100 inhabitants per square kilometer. Twenty-five percent of the regional space contained more than 50 inhabitants per square kilometer.

The climate of the region is characterized by a totally dry period from November to March and an annual rainfall of about 700-710 millimeters (after 50 years of observation), occurring almost solely from June to September. The rainfall is subject to considerable interannual fluctuation, and its timing is irregular during the wet season. Spread out over a short time span, these rains play a decisive role in the volume of crops. This is particularly true of the frequency and abundance of the precipitation that falls at season’s end, especially since the unabsorbent and unfertile soils cannot cope with these irregular rainfalls.

Cotton growing evolved briskly, supplying what was then the mother country. The cultivation of this crop has left a dismal souvenir; deforestation occurred as growers searched for new land to cultivate. The yield of these cash crops fell considerably during the 1960s. Yatenga, which supplied the market with 420 tons of raw cotton in 1930, 800 tons of groundnut and 270 tons of raw cotton in 1939, delivered in 1970 fewer than five tons of cotton and marketed only a few dozen tons of groundnuts.

Stockbreeding also played a role in the effort to make Yatenga participate in an exchange economy. At the beginning of the century, the region was considered rich in cattle and horses. These were the products sold in the southern regions, of Upper Volta, Ghana, and the Ivory Coast, thus bringing into Yatenga the money needed for the payment of taxes and new duties.\(^5\)

**Geographical Distribution**

It is important to delineate the world distribution of deserts and to define the meaning of aridity. Figure 8.1 illustrates not only the true deserts but the widespread semidesert areas of the world, all of which can be categorized as the arid zone. Neglecting the very cold drylands and the extreme deserts themselves, the latter not subject to further degradation, there remains an area of potentially productive but threatened drylands covering 45 million square kilometers or 30 percent of the world’s land surface. These occur so widely that two-thirds of the 150 nations of the world are affected. For statistical convenience the true climatic desert has been defined cartographically by the 100 millimeters (c. four inches) annual precipitation line (termed an isohyet). Calculations have shown that within this zone there is a permanent water deficit, because potential evapotranspiration, the combination of water evaporation and water used by plants and finally given off in water vapor, is so high that it exceeds the total rainfall by a factor of at least 10. The coastal deserts of Chile/Peru and of Namibia (southwest Africa) are exceptions to the general 100 millimeters rule; because of high humidity of the air in certain seasons, the desert margin is marked by the 50 millimeters (c. two inches) isohyet.

The world’s semidesert can be defined as those areas lying between the 100-400 millimeters (c. 4-12 inches) isohyets, again with the exceptions of north Chile and Namibia, where the limits of 50-300 millimeters apply. These slightly moister parts of the arid zone include not only large stretches of the Middle East and the notorious Sahel belt to the south of the Sahara, but also the Kalahari, central Australia, much of inner Asia, Patagonia and the southwest portion of the United States. The widespread range of the arid zone (from 50 degrees latitude to within some 10 degrees of the equator) is sufficient to demonstrate that the lack of precipitation is the dominant climatic element, not the temperature. Thus we can distinguish between the hot
deserts of the Sahara and Arabia, on the one hand, and the mid-latitude deserts of central Australia or the Gobi of central Asia, on the other.

The dearth of rainfall in the arid zone may be caused by one or more factors. First, aridity may result from location within a continental interior far removed from the moisture-laden oceanic winds, as in the case of central Asia. Second, the region may lie in the rain shadow of a major mountain range, so that much of the precipitation from the moist airstream is removed in passage across the mountain zone. The Kalahari and parts of Patagonia fall into this category. Third, coastal deserts such as the Atacama of Chile exist because winds, having blown across a cool ocean current onto a heated land, do not condense their moisture into anything more than mist. Last, but most important, are the major tropical deserts that coincide with large, permanent high-pressure systems in which air is slowly subsiding before blowing outwards at the surface. In this way rain-bearing cyclones are virtually excluded and precipitation totals are practically nil in wide areas of the central Sahara and Arabia. The driest place in the world, however, occurs near Calama, in Chile’s Atacama Desert, where no rain has fallen for over 400 years.6

Natural and Human Preconditions for Disaster Occurrence

Factors Leading to Desertification

Vulnerability to desertification and the severity of its impact are partly governed by climate, in that the lower and more uncertain the rainfall, the greater the potential for desertification. Other natural factors include the seasonal occurrence of rainfall, as between hot season, when it is quickly evaporated, and cool season. Also important are nonclimatic factors such as the structure and texture of the soil, topography, and types of vegetation. Above all, susceptibility to desertification is a function of pressure of land use, as reflected in density of population or livestock or in the extent of agricultural mechanization.

Background: The Soil-Water Energy Balance

To see precisely what happens when desertification occurs, attention should be focused on that shallow meeting place, between soil and atmosphere, where plants thrive and where a balance is maintained between incoming and outgoing energy and between water received and lost.

When rain falls, some of the water is directly taken up by plants. Some filters into the soil, where it may remain in storage. The rest evaporates or runs off. Some soil moisture, being intercepted by plants, is put back into the atmosphere by the transpiration of plants. Some of the moisture may seep into deeper layers, collecting in underground reservoirs or aquifers, where it may remain for thousands of years. Or it may migrate slowly from plateau to depression or back to the ocean itself.

The soil-air meeting place participates in an energy balance activated by the rays of the sun or by atmospheric heating. The surface layer reflects some of this energy back into the atmosphere and into space. Some is held in storage by the soil, thereby warming the earth. This energy as well as that directly from the sun is used by plants to carry out the processes of photosynthesis and growth. Some of the plants are eaten by grazers or browsers, and these animals in turn may be eaten by carnivores. Through respiration all animals return energy and moisture to the atmosphere. They also return humus to the soil. The excreta of animals, their decomposing carcasses, and the decomposition of plants supply the soil with organic nutrients that are most dense in the topmost layers and thinner below. This balance is lost when land is denuded by desertification.
Adaptation of the Hydrological Cycle in Arid Climates
In arid situations the cycling of water and energy takes on special characteristics because of infrequent rainfall and abundant solar energy from cloudless skies. Vegetation is generally sparser than in humid areas, providing less cover to the ground surface and returning less organic matter to the topsoil. During occasional intense rainfalls flash floods may occur. However, this surface water is rapidly lost through evaporation, and in the long intervening dry spells the soil is parched and heated by the sun.

Vegetation in Arid Environments
However scanty it may be, the dryland vegetation constitutes a fundamental resource that transforms solar energy into food and protects and stabilizes the surface of the ground.

Part of the plant population consists of short-lived ephemerals, plants that germinate and complete their life cycles rapidly after rain, remaining as seed through intervening dry periods. Such plants are commonly fleshy and palatable; they are preferred by grazing animals. Other plants, such as perennial grasses, wither during dry spells and die back to the root stock or to bulbs; with fresh rains they shoot forth anew. These plants form more durable pastures. When green, they are attractive and palatable to stock. They may provide valuable hay, although when thoroughly dried they have little pastoral value. Nevertheless, their extensive, fine root systems remain to bind the topsoil and to contribute to its organic content. Last are the longer-lived perennial plants that resist water loss by such adaptations as woody stems and leathery leaves. These include the larger plants, such as shrubs and trees, which remain nutritious during the dry periods when they can provide an important food source to grazing animals. However, their adaptations may reduce for some stock their palatability and attractiveness. These plants have the additional role of protecting the ground surface, providing shade and preserving an environment that favors the response of important shorter-lived plants.

Dryland Mismanagement
Misuse and eventual desertification arise through any use of drylands that does not take into account their limitations and the patchwork contrasts in productivity and vulnerability that accompany them. The problem is compounded by fluctuating climate and land conditions, and a tendency toward over-optimistic assessments of the potential of drylands for sustained production. Such assessments are often made on the basis of remembered best years. Optimism is often a response to external pressures to which the users of drylands are increasingly subjected—from commercial markets, from their own rising expectations, and from population growth. Optimism is often associated with the introduction of inappropriate technology in the hope of short-term gains, for instance deep ploughing of croplands or excessive pulverization through mechanical tillage of topsoils.

Positive and Negative Land Use
Traditional systems of land use have met these environmental challenges in various ways in order to maintain flexibility and spread the risks. For instance, pastoralists may herd several kinds of animals, each capable of profiting from different parts of the ecosystem, or they may range widely as nomads to spread and lighten the grazing load. But with increasing technological inputs arising from the push towards higher productivity, there is a trend towards diminished flexibility. For instance, as dryland farmers extend towards the climatic limits of cropping, they must depend increasingly on the hardiest cereals, wheat and barley, and fallowing to conserve soil moisture. Lack of flexibility is particularly evident in large-scale commercial ranching and farming operations, which tend to be highly specialized; nevertheless,
it may also exist in traditional cropping systems through inequitable systems of land ownership and land tenure.

**Inappropriate Technology**
Technical innovations are often brought in from more humid environments without full regard for the particular equilibrium of dryland ecosystems. For instance, introduction of deep wells has improved the availability of water while increasing herd size and decreasing herd mobility, leading to local overgrazing and excessive trampling around the new watering points. Technological changes can give rise to desertification through excessive demands on limited natural resources.

**Non-agricultural Threats to Drylands**
The concept of proper land use must be extended beyond agricultural practices. Modern society is threading the drylands with roads and highways, exploring them for mineral resources, opening mines, sinking oil wells, constructing pipelines and canals, establishing factories, and building cities. People are increasingly intruding into arid lands for purposes of health and recreation. These new activities are important because they diversify the bases of human occupation of the drylands and provide an important additional source of revenue. However, they must be undertaken with a full regard for the delicate natural balance that prevails there. For example, dryland soil surfaces disturbed by earthmoving machinery will take longer to rejuvenate and stabilize, and they may become subject to wind drifting. Many of the new activities in the drylands have been made possible by advanced technology, but it is this same ever-growing technological capacity that so strengthens people’s ability to disrupt and damage a sensitive environment.

**The Failure of Natural Dryland Restoration**
Failure of the dryland to heal itself usually arises from sudden and severe disturbance, and such disturbances, in the present world, are almost always the work of people. Human activities may have a less pronounced impact in more richly endowed environments where a greater richness of land and life aids the process of restoration; but these human activities have more drastic consequences in the drylands, and desertification is a common outcome.

If people are the chief instrument of desertification, the process should not be viewed exclusively from the human side. Desertification results from the interaction between people and a difficult, changing environment. It occurs when people penetrate such environments and act there—often out of the need for survival—without an understanding of or proper regard for their sensitivities and limitations.

**Initial Stages of Desertification**
In its initial stages desertification may merely involve a shift to a more desertlike and less productive ecosystem, with water, energy and nutritional balances less favorable to plant growth than before. But land use in arid regions poses problems that continually menace the prevailing equilibrium. This is at least partly because of fluctuations in rainfall between drought years and good years. Not yet predictable, these fluctuations are difficult for the land user to respond to effectively.

**Herd Growth**
In dryland pastoral economies, large numbers of stock tend to build up during runs of good years, too many to be supported through the inevitable ensuing drought. There is a natural
reluctance to cut back on stock numbers in the first dry year, and a tendency to hang on until drought is seen to be established. Unfortunately by this time dryland pastures are probably being overgrazed toward a state that threatens eventual regeneration. By this time, too, prices for surplus stock will probably have shrunk because of a glutted market, and destocking through sale of surplus numbers will be opposed by economic forces. For the same reasons, destocking may be prevented during the periods critical to the regeneration of pastures, that is, those periods following the rains that end drought.

**Extending Farming in Marginal Areas**

Dryland farmers, too, have a tendency after a period of good years to extend their cropping onto ever more marginal lands. Moving into areas of higher climatic risks, they push back the pastoralists. This is especially prevalent when pressure on the land is increased by population growth, restrictive systems of land tenure or shortsighted introduction of mechanization. The expectable but unpredictable onset of drought will find the marginal land prepared for planting, stripped of its protective natural vegetation and vulnerable to erosion. Such land enters a run of dry years without defenses and may emerge in too degraded a condition to support even livestock.

Thus, the delayed response of the land user through cycles of good and insufficient rainfall may convert periodic drought into an engine of long-term desertification. But this need not be so. Land-use practices should combine with efficient marketing systems to make possible an appropriate response to drought, which is a natural and inevitable factor of dryland agriculture and a recurring event that must be taken into account. Land users should also take advantage equally of the rainier years, employing them to replenish the ultimate agricultural resources, the fertility of the soil and the production of vegetation.

**Climatic Preconditions for Desertification**

What is certain is that the direct physical consequences of changes on the local, effective climate, such as the adverse effects of surface denudation on the soil-water balance, are many times more important than any indirect large-scale climatic effects.

However, the climatic effects can not be ignored since the climatic boundaries in the drylands are subject to short-term shifts corresponding to sequences of lean years and fat years. In general, the drier the climate, the greater the rainfall variability and the higher the drought risk. Such fluctuations are expressed geographically in expansions and contractions of the dryland belts, such that a semiarid region may experience arid conditions at one time, and subhumid conditions at another.

These fluctuations, although not so regular as to be predictable, can be divided into short-period, two- to four-year changes that introduce periodic stress into livelihood systems, and those of greater amplitude and duration that can lead to significant changes in the patterns and structure of land use, such as the extension of cultivation in good years or large build-ups in stock numbers in runs of good years. It may not be possible to adjust these expansions promptly when drought inevitably follows. When drought strikes land-use systems that are stretched beyond their usual limits, the consequences can be disastrous and of their maximum, and long-lasting degradation can occur. Recovery from such degradation will be slow at best, and if land-use pressures continue unabated, recovery may be partial only, to a lower plane of productivity than formerly. Desertification will then have occurred.
The Disaster and its Impact on the Natural Environment

Impact of Land Use on Dryland Equilibrium

Under natural conditions and through appropriate conservation strategies, the dryland ecosystems maintain a balanced exchange between water and energy. Unfortunately this favorable equilibrium is readily disturbed when people unwisely use the land. For example, where meager vegetation is reduced to expose the ground surface, the organic portion of the soil will be mineralized by exposure to the sun, and the soil structure will be broken down by rain falling directly on the soil. In addition, the sun will bake the top layer of soil into a thin crust that prevents infiltration of additional water. As the equilibrium of subsurface water deteriorates, the level of groundwater in nearby wells may fall. The water lost to the soil store now contributes to over-rapid runoff. Where the surface has been loosened or disturbed as by the trampling of animals, the topmost soil layer, that with the best structure and containing the bulk of plant food, may be washed away, or blown away in dust storms. The denuded soil is essentially infertile, with poor structure and water relations. All these changes constitute a shift towards a more hostile environment for plants, with the result that the vegetation responds less well to rain and produces less biomass. Many plants tend to die off at an increasingly early stage of drought. Such changes are typical of desertification.

Process and Stages of Desertification

The main process and stages of desertification can be summarized as follows. In pastoral rangelands, there is an initial deterioration in the composition of pastures subject to excessive grazing in dry periods, particularly a reduction in the proportion of edible perennial plants and an increase in the proportion of annual and inedible species. The thinning and death of vegetation in dry seasons increases the extent of bare ground. This is followed in turn by a deterioration of the surface conditions that are vital to plant growth. Impoverishment of plant-water relations is especially pronounced, and ephemerals now respond poorly to rain. With consequent increase in runoff, sheet and gully erosion set in on sloping ground, and the topsoil and its store are lost. These changes result in an environment inhospitable to plant growth and less suitable as pasture. With continuing erosion, formerly productive lands may be lost through soil stripping and gully extension. These changes are even more drastic where devegetation occurs in strategic areas, as on watershed uplands, and the processes are advanced where soils are exposed and disturbed in dryland cultivation.

Water and Wind Erosion

In areas of rainfed farming, desertification often originates on fallow land or on land cleared for cultivation. Removal of the original ground cover exposes the soil to accelerated wind and water erosion. The beating action of rain on naked soil puddles the surface, which crusts when the sun comes out, reducing infiltration of water into the soil and further increasing runoff. This in turn leads to increased soil erosion, which, unless halted by protective measures, ultimately strips away the fertile surface soil and exposes infertile subsoils. Gullies may form on the lower parts of slopes, impeding or preventing farming operations. Sediment deposited at the foot of slopes covers plants, fills waterways and aggravates flooding in low-lying areas. The flooding follows increased runoff from the slopes above.

Water and wind erosion work together, as redeposited silts from surfaces stripped by water erosion are particularly vulnerable to wind transport. Wind erosion starts with the movement of coarse soil particles in one part of a field, then progresses downwind with increasing severity as bouncing soil particles knock other particles into the air in a kind of progressive, increasing
effect. Finer materials are lifted as dust into the air and carried away over long distances; coarser sandy materials drift over the surface until they are trapped by plants in accumulations of low, rounded hills and small dunes. Removal of fine topsoil materials means the loss of the most productive and nutritious portions of the soil complex, while sterile sand accumulations cover plants and good soil. In addition, the blasting impact of moving sand harms young crops. Fine airborne particles may carry soil-borne diseases, irritate respiratory tracts of humans and animals, cause wear on machinery parts and reduce visibility.

**Salinization and Alkalization of Soils**

The principal manifestations of desertification on irrigated lands are soil salinization or alkalization occurring with inadequate leaching of salts contained in the soil or added in irrigation water. Salinization and water logging commonly occur together. Where the soil is waterlogged, the upward movement of saline groundwater leaves salts on the surface where water evaporates. On soils that are not waterlogged, salinization can still occur when water containing soluble salts moves from irrigation furrows into the ridges where crops are planted or to high spots in poorly leveled land. Underirrigation of weakly permeable soils can also lead to salinization if the irrigation water is salty.

**Desertification as Patchy Destruction**

Desertification breaks out in areas of naturally vulnerable land subject to pressures of land use. These degraded patches link up to carry the process over extended areas. It is generally incorrect to envision the process as an advance of the desert frontier engulfing usable land on its perimeter: the advancing sand dune is in fact a very special and localized case. Desertification, as a patchy destruction that may be far removed from any nebulous front line, is a more subtle and insidious process.

**Hazard Analysis and Prediction**

Experiences indicate that the long-term progressive deterioration that constitutes desertification may not be readily identifiable against the background of short-term environmental fluctuations that spring periodic shifts in rainfall. There is a consequent need for regular monitoring of the status of dryland ecosystems. Such monitoring can provide early warning of trends, identify areas in which change is taking place, and provide a basis for the investigation of causes and processes. It is in terms of such information that measures for prevention or reclamation will ultimately be designed.

Global surveillance of the status of dryland ecosystems and of the land use can be achieved most economically through the remote sensing powers of specialized orbiting satellites. The Landsat system, already in operation, has this capacity. Landsat now provides imagery with a resolution of at least 50 meters (165 feet), and there are prospects of higher resolutions.

Studies of the relationship between agriculture and climate, such as those carried out by the World Meteorological Organization in western Asia and Saharan Africa, have done much to determine the connections between climate and the water needs of cereal crops. This has enabled them to use climatic records as a basis for determining when suitable growing seasons will occur. These studies should be extended and improved through additional meteorological recording and investigations into the water requirements of crops at different stages of growth and under a range of soil conditions. By providing good estimates of climatic risk, such studies will support policies of land zoning, and measures should be taken to discourage the extension of cropping beyond certain environmental limits.
Recovery, Mitigation Problems and Strategies

Solutions: General Considerations

Must Have Human and Social Objectives
Because desertification is a slow-onset disaster that is part of a constant climatic cyclical trend, the response must be synthesized into the values and routines of daily life. Measures to combat it must ultimately be directed toward people, toward sustaining and improving their livelihoods. Thus, measures to combat desertification must be seen as having human and social objectives. They must be inspired by an acknowledgement of dryland people’s rights to acceptable standards of health, nutrition, education, livelihood and social well-being, consistent with human dignity.

Respect for Lifestyles
Traditional social values must be recognized, and the life styles and ancient knowledge developed through long adaptation to the dryland environment must be respected.

The approach should be an integrated one, in which proposals involving technological or environmental change are linked with social and economic measures undertaken to advance development.

Community Involvement
Measures to combat desertification will not succeed without the willing participation of local communities. The need to work through existing livelihood systems and established local patterns must be recognized. The involvement of the community must be sought, as by enlisting the example of community leaders. It may be necessary to create incentives toward community participation. The practicality and advantages of proposed measures should be demonstrated at the earliest stage through realistic pilot projects. The enlistment of community participation should not be thought of exclusively in terms of outside experts persuading people to do what the experts think is good for them. Local knowledge should also be enlisted. Sometimes the best procedure would be the elimination of obstacles to the good land-use practices that local people would otherwise prefer to carry out.

Interdependence of Land Types
Plans for the reclamation and improved use of rainfed croplands should be a part of integrated schemes for the use of functional areas such as drainage catchments. The interdependence of uplands, foothills, and valleys, with their associated land use, must be recognized.

Using Maps in Planning
A first step in formulating a plan is to map land types and land use at a scale appropriate to cropping (using a scale of 1:50,000 to 1:250,000, depending on conditions). The land units mapped should be classified according to potential use as determined by the existence of hazards, such as steepness and length of slope, the presence of stones or rocks, the risk of flooding, the quality of the drainage and vulnerability to wind erosion.

Planning Strategies
Recommendations as to how the various parts of the land should be used will constitute the plan, which must recognize appropriate limits to rainfed cropping, as determined by rainfall, terrain, soils, and relationships with adjacent land uses such as forestry or grazing. The marginal lands outside these limits should be removed from cropping by acquisition, by financial inducements or by the establishment of forest, grazing or water-catchment reserves. When
such measures involve the disruption of traditional livelihood systems, they are unlikely to succeed unless they form part of larger schemes of rural reconstruction involving appropriate changes in land tenure, the consolidation of holdings, or resettlement programs offering alternative livelihoods.

Balancing Human and Environmental Needs
The ideal objective is the recovery and maintenance of ecological balance in the drylands in order to sustain productivity, but this must be reconciled with the needs of local populations. Some degree of environmental disturbance, as determined by pressing human needs, must be tolerated in land management. On the other hand, it must be recognized that land-use pressures have been the major factor in the advance of desertification. Accordingly, changes in land use will be required, and these bring with them a need for corresponding social changes. Some policing of affected lands may be required, but it will not succeed without a sympathetic community response.

Priorities and Enforcement
Priorities in programs to combat desertification should be influenced by the severity of its impact on the populations concerned and by the degree of their vulnerability, rather than by the severity of its impact on the land alone. When the situation has been made clear, decisions can be made on priorities, which might include abandonment of lands most severely affected, and a reclamation program designed in terms of the availability of water, labor and capital. After the program has been implemented, reclaimed lands can be re-allocated, but not without clear regulations on what can be done with them. Reclamation provides an occasion for the enforcement of practices that will prevent desertification from recurring.

Specific Actions
Grazing
To combat desertification in pastoral systems means to adopt grazing practices that will allow vegetation to recuperate. In areas too dry for rainfed cropping, the natural vegetation usually forms the most efficient pasture in terms of upkeep, grazing returns and protection of the soil surface. The maintenance of a plant cover that will sustain the pastoral system under most conditions is the obvious goal of land-use planning. Anything more—intensive reclamation, for example, by planting programs or mechanical controls—will be feasible only in restricted areas where the physical process of desertification threaten installations, communications, settlements or valuable cropland.

Experience indicates that the death of livestock is chiefly due to the failure of pastures rather than of water supplies. Accordingly, conservation measures should be introduced for the control of grazing access to dryland ranges where such control does not exist, including fencing where necessary and economically feasible.

Using Surveys. As a first step, surveys should be initiated to determine the useful productivity of the main varieties of dryland pasture under differing seasonal conditions, the requirements of pasture plants for successful regeneration under grazing, and the dimensions of the grazing impact of a proposed system composed of certain animals in certain numbers. Surveys must take into account the dual role of perennials as surface protectors and as fodder during drought. A logical first step in the assessment of dryland pastures is to map them, indicating their distinct topographic, soil and water conditions.
Surveys lead to preliminary assessments of carrying capacity under a variety of conditions, and these in turn form the basis for appropriate grazing strategies. “Carrying capacity” is an overworked but poorly understood term, and research should be employed to clarify and quantify it. Meanwhile, reasonable estimates must be used to support grazing strategies incorporating a number of elements.

These strategies should incorporate possibilities for deferred or rotational grazing and for the establishment of protected reserves as seed reservoirs, grazing reserves in the event of drought, and plant and wildlife refuges in which genetic variety can be conserved. As far as possible, they should preserve the mobility, flexibility, diversity and low stocking rates traditional in dryland grazing systems. Consideration should be given to fencing rangeland areas subject to concentrated stock movements, pastures that are particularly vulnerable because of the soil or the land formation, or sensitive areas such as town perimeters.

*Pasture and Land Management.* Opportunity should be taken locally to enrich natural pastures by developing simple water-harvesting schemes, such as through the use of trenches and flood banks in areas of natural flooding. These areas should generally be treated as controlled reserves, available for the breeding of animals, as a resource against drought and for harvesting forage. Controlled reserves can also be established in the form of green belts, as suggested in the feasibility studies concerned with the establishment of such protected reserves on the northern and southern borders of the Sahara. Consideration should be given to using such areas for subsistence cropping. They should be fenced off from the open range and their use integrated into the general grazing scheme. Range conditions should periodically be surveyed to determine what grazing pressures are doing to the land and vegetation. The grazing system can thus be adjusted as required, and the herds can be guided to ephemeral vegetation.

Pastoral systems will need help in coping with recurrent drought stress. A number of measures can be taken to provide this help, such as the setting aside of grazing and forage reserves, the provision of transport facilities for the movement of stock, financial assistance to restore herd numbers following drought, and insurance against drought losses.

*Farming.* Because cropping represents a more productive use of the land, attempts should be made to expand the safely cropped areas by introducing crops that are more resistant to extreme conditions and by improving methods of cultivation and water conservation. Such actions should be supported by demonstration projects and extension services. In selecting drought-resistant or salt-resistant crops, attention should be paid to the genetic qualities of local plants whether they have already been domesticated or not.

*Clean Fallowing.* Allowing a field to rest while stripped of vegetation provides a way of conserving the moisture in the soil. Like several such techniques, clean fallowing happens to increase the land’s vulnerability to erosion. Safeguards can be erected by improved methods of rainfed cropping and by measures that maintain ground cover and improve soil structure.

*Crop Rotation.* Crop rotation, including cover crops to be ploughed back into soil, should also be introduced into mechanized systems of rainfed monocropping. Such systems should restrict the burning or removal of litter, and livestock should be introduced to graze on feed crop residues. Strip cropping should be encouraged, as should the planting of shelter belts on open plains. To combat salinization on valley floors, deep-rooted plant varieties or salt-tolerant pasture can be planted.
Slash-and-Burn Agriculture. This method of cultivation is typical of rainfed cropping in drylands; with summer rain, the farmer will return to a particular plot after its vigor has been restored by extended fallow, often as long as 20 years. Shortening the cycle, coming back too soon, can have adverse effects on plant recovery and regrowth and on soil fertility. When this happens, measures should be taken to restore the cycle to its older rhythm, perhaps by expanding the area available to cultivation or by removing population pressures through resettlement or the development of alternative livelihoods.

Making Fallow Periods Economically Feasible. In these systems, valuable substances, such as gum arabic, can sometimes be extracted from the natural regrowth during the fallow part of the cycle. Steps can be taken to increase the value of regrowth by introducing new trees or by adopting good forestry practices.

Land Management
Once rainfed cropland has been degraded, efforts to rehabilitate it should form part of larger actions directed toward water management, improved land use and the control of erosion. Within broader plans, specific actions to be taken will depend on the course that desertification has followed.

Gullying. This particularly unsightly form of erosion can be arrested by planting trees in upper catchments and along gully margins and by planting grass in areas that feed the gullies with flows. Also helpful are the construction of diversion banks and furrows across gully heads, and the installation of check dams and silt traps along gully courses. Under favorable conditions, gullies can simply be filled in and their banks replanted.

Sheet Erosion. This form of erosion, which scour soil from wide areas, can be countered with contour banks and ditches, grass-covered contour strips, and terraces.

Wind Erosion. This form of erosion blows soil away from rainfed cropland and causes sand drift and dune encroachment. It can be countered by planting shrubs and trees in shelter belts (at a spacing four times as far apart as their eventual height). Fences can be constructed or lines of resistant shrubs and trees planted as barriers against oncoming sand, upwind of threatened areas. Bare sand can be covered with matting, bituminous coating or mulches of vegetation litter.

Stabilizing Sand Surfaces. Sand surfaces can be stabilized by seeding and planting proper successions of vegetation, including plants that thrive in sand in association with shrubs and trees. This can be done easily by establishing greenbasins, a technique developed in Australia. Greenbelts are created by building or ploughing small circular banks in a field to form a series of basins. These trap windblown seeds and nourish them by trapping moisture and water to form small temporary ponds. The embankments protect the seeds from dust storms, and the moisture provides the nourishment to enable them to sprout. Greenbelts several kilometers wide and hundreds of kilometers long are often built as a line-of-defense, much like a firebreak, to prevent further encroachment of the desert. In addition dunes can be leveled or reshaped to remove slip faces while acting to prevent their reappearance.

Irrigation
Desertification of Irrigated Land. The amount of irrigated land lost annually to desertification (some hundreds of thousands of hectares) is about equal to the amount of land newly brought under irrigation each year. Large investments are involved in the breakdown and abandonment of such intensive, highly capitalized agricultural projects. Irrigable land is scarce, and new
enterprises are enormously expensive. Such considerations stress the importance of maintaining existing irrigation schemes by countering desertification with preventive action whenever it affects them.

**Salinization.** The most prevalent form of desertification in irrigated cropping systems occurs when waterlogging causes salts and alkali to infect soils, particularly where drainage is poor and leaching inadequate. It is a problem that emphasizes the importance of preliminary surveys and testing of proposed irrigation projects to assure adequate design. Most salinization problems arise from irrigation system design deficiencies.

**Irrigation System Design.** Good design should be based on an understanding of how much water is available for irrigation and on the knowledge of its silt and salt loads, including seasonal variations. A close study of the soils must be made in the area embraced by a land-use project. Such study must consider their texture and salinity, and especially their water properties, as these will determine drainage requirements and water availability to crops. Water requirements for proposed cropping systems should be determined. The position and salt content of the groundwater table should also be determined, as there are seasonal fluctuations in both. This will require some understanding of the hydraulic properties of the soil’s lower layers, and of how these layers store and transmit water.

**Field Test Results.** These investigations should yield a map showing salt hazards and how they might restrict the proposed cropping system. On the basis of the map and the surveys, design work can continue with particular emphasis on the distribution of the water and on effective drainage systems and the subdivisions of the system as determined by estimated water needs. Finally, design should take account of the services and communications the system will require and the settlements that serve and are served by it.

**Maintaining Balance of Groundwater Supplies.** Irrigation projects based on groundwater supplies encounter special difficulties because groundwater quality is usually lower than that of surface waters and the threat of salinization is generally higher. Limitations in groundwater supplies may hinder proper leaching. Groundwater supplies must be kept in balance with the requirements of land use, and enough water must be provided for both irrigation and leaching. Generally, discipline applied to water use must be stricter when irrigation is based on groundwater rather than surface water.

**Reclamation of Salinized Lands.** When irrigated lands have suffered salinization or other forms of desertification, they should be surveyed as a first step to reclamation. By determining what topographic changes have occurred and the degree of salinization of soil and groundwater levels, an individual can estimate what is needed to leach and drain affected lands and what else might be required to restore the system—by releveling of ground surfaces, for example, or renewal of irrigation channels. How drainage will be carried out—whether by tubewells, tile drainage or open ditches—will depend on groundwater conditions, soil properties and costs of land and labor. To decide among alternatives, a cost-benefit analysis may be needed.

**Secondary Physical Effects**

It must also be borne in mind that desertification has an impact beyond the lands immediately affected. Dust storms can move soil great distances, and increased flooding may occur far downstream due to overly rapid runoff from lands denuded of trees and plants in upstream catchments undergoing desertification.
**Issues in Reconstruction Peculiar to Desertification**

When working to prevent, mitigate, or recover from the results of desertification, an individual should keep in mind the following information that can make reconstruction efforts more successful.

**Desertification Feeds on Itself**

The need for action to combat desertification is all the more urgent because the process is a dynamic one. Desertification can feed on itself and become self-accelerating. With delay, rehabilitation becomes increasingly lengthy and expensive, and degradation may reach a threshold beyond which it is irreversible in practical and economic terms. Fundamental preventive measures should be introduced as soon as possible. These should be in the form of socio-economically appropriate land-use practices that improve the fertility of microclimates and soils and prevent desertification from making further encroachments.

**Monitoring Dryland Conditions**

Apart from limitations set by climate, dryland ecosystems will remain sensitive to land-use pressure because their soils and dynamics are delicately balanced. The best-designed dryland livelihood system will still require constant surveillance if balance is to be sustained. It is therefore essential that campaigns against desertification must incorporate systems of monitoring that will indicate how campaigns are proceeding and when people should be alerted about pending problems. This requirement strongly underlines the need to develop indigenous science and technology, so that assessment, monitoring and planning will not be added to the list of imported items.

**A Flexible Plan of Action**

A geographical spread as immense as the drylands comprises a vast variety of biophysical, economic and social settings. Desertification processes and problems are correspondingly varied and complex. Any plan of action to combat desertification will recognize this, and with it that there can be no single set of remedies. Recommendations must take account of different situations and be flexible enough to encompass a wide range of conditions.

**The Problem of Applying Current Knowledge**

A review of the desertification problem strongly supports the contention that past failures to maintain balanced livelihood systems in the drylands are the outcome of an inability to apply existing knowledge of physical processes rather than lack of understanding of what those processes are. The same is true of the design of measures to combat desertification. Accordingly, plans of action should address, first of all, the application of existing knowledge, the adaptation of existing knowledge to local situations in the social and physical spheres, and problems of acceptance and participation among local communities.

**Desertification and Government Goals**

It should not be take for granted that action to combat desertification will take first place among national commitments. A plan of action to combat desertification should not appear to pre-empt already-established national priorities. Nevertheless, it should be kept in mind that action on the ground will largely be carried out by national organizations, and presentation of the plan should accordingly aim to influence governmental attitudes toward the problem of desertification and should seek to secure the active commitment of governments. This is most likely to occur when combative measures, linked to broad national plans for development, appear to be consistent with national goals.
**Assistance Programs and Community Development**

**Accommodating Settled Pastoralists**

Recent years have shown an increased tendency for pastoral nomads to settle down in fixed habitations. This happens because of changing personal goals or attitudes, because of drought disaster, or because of government programs. Nomadic herding is then left to part of the former community, which comes increasingly to resemble more settled pastoral systems. These changes will continue, and assistance should be given to accommodate them.

**Plight of Pastoralists**

Over recent years, nomadic pastoralists have been increasingly at a disadvantage relative to adjacent farmers, particularly during periods of above-average rainfall when cropping tends to encroach on pasture lands. Care should be taken to preserve by legislation or taxation policies if necessary, the traditional access of pastoralists to rangelands and watering points.

**Conclusion**

Desertification is accelerating with devastating consequences for both humans and the environment. Desertification and the associated problems of bankruptcy, poverty and famine make immediate implementation of mitigation measures imperative. Yet to be effective, these measures can meet human needs only while maintaining the dryland’s fragile ecology. In the simplest terms this means that all dryland residents must incorporate respect for the dryland ecology into the routine of their daily lives.  

**Notes**

2. Ibid., p. 10.

**References**


Chapter 9
Deforestation

Introduction and Definition
Deforestation is the removal or damage of vegetation in a forest to the extent that it no longer supports its natural flora and fauna. It is most frequently caused by humans taking care of immediate needs while not being aware of the long-term effects of their actions. Deforestation is a slow-onset disaster that may contribute to other, cataclysmic disasters. It reaches catastrophic proportions after large areas of vegetation in a forest are damaged or removed. By changing an area’s natural flora and fauna, it removes the land’s protective and regenerative properties.

The rapid rate of deforestation in the tropics is a key driving force in the yearly increase of flood disasters. According to a Food and Agriculture Organization and United Nations Environmental Program (FAO/UNEP) study in 1981, tropical forests are disappearing at the rate of 7.3 million hectares (18 million acres) per year:

- 4.2 million hectares (10.4 million acres) a year in Latin America
- 1.8 million hectares (4.4 million acres) a year in Asia
- 1.3 million hectares (3.2 million acres) a year in Africa.

Historical Examples

Deforestation in Africa
In Africa, for example, 2.3 million hectares of open woodlands are cleared each year, and the vegetation of other vast areas of woodlands is declining with severe consequences for land and people. Also, the survival of extensive forests in one region provides little comfort to residents of areas experiencing wholesale forest destruction. The dense forests of West Africa and a few other areas in the continent (especially Madagascar, Rwanda, and Burundi) are disappearing fast, while rain forests in parts of Central Africa are little touched as yet. The Ivory Coast has lost 70 percent of the forest with which it began the twentieth century; there and in Nigeria some 10 percent of the accessible forest was cleared each year in the second half of the 1970s. The U.N. assessment of Africa concludes: “In the long run there is a real ecological threat to the whole continent.”

Deforestation in Asia
The formerly dominant timber exporters of Southeast Asia are fast approaching their days of reckoning for past forestry exploitation. In late 1977, while pressing for the adoption of a new forestry policy, the deputy premier of Malaysia shocked his compatriots by projecting that peninsular Malaysia’s once-lush forests would be severely depleted in just 12 years. He predicted that by 1990 the rate of timber production would not be adequate to meet domestic, let alone foreign, demand. Stringent new logging controls are being imposed in Thailand following the National Forestry Department’s estimate that the country’s forests will be virtually gone in 25 years if present logging and farming practices continue. Thailand has a special problem with poachers of valuable tropical hardwoods; in some recent years 30 or more forest guards have been killed in gun battles.
Recent satellite pictures of the Philippines, traditionally a major timber exporter, indicate that forests now cover only 30 percent of the country, though the government feels a forest cover of 46 percent is desirable for economic and environmental reasons. If existing logging patterns prevail, a consortium of Philippine research organizations has concluded, all original old-growth forests will have been cut down by the year 2000, and projected timber supplies from second-growth forests and plantations will not suffice to meet even domestic needs. Destructive increases in flooding and sedimentation have already been registered. Indonesia, which emerged in the 1970s as the world’s leading tropical-timber exporter, retains extensive and rich forests on its outer islands—yet most of them have been slated for logging in the years ahead.

Geographical Distribution
According to a world survey conducted in the early 1970s by Reidar Persson, about one-fifth of the earth’s land is covered by closed forests (where tree crowns cover 20 percent or more of the ground when viewed from above). Roughly another 12 percent of the land is covered by open woodlands (where scattered trees provide a crown cover of 5-19 percent). Forests are not, of course, distributed uniformly among continents or countries. North America, the Soviet Union, Northern Europe, and the humid tropical belt across Central Africa, South America, and Southeast Asia are rich in forest. Most of Africa and Asia and parts of Central and South America are forest-poor.

Among less-developed countries, China and South Korea stand out for having substantially increased their forested areas in recent times. Throughout most of Africa, Asia, and Latin America, the forest area is shrinking, and usually not according to any rational plan. Areas that were densely settled long ago—such as the Middle East, parts of North Africa, the Andean region of South America, and most of China and South Asia—lost the bulk of their forests in ages past, though the depletion of tree cover generally continues. But many developing countries in other areas are now experiencing unprecedented forest destruction.

Many of the most severe human impacts of the decline in tree cover are unfolding in drier, lightly wooded areas of the Third World where devegetation helps create desert-like conditions and acute fuel-wood shortages. But what most people think of as deforestation—the conversion of closed forests to other uses or to scrubland—today occurs mainly in the humid tropics.

As of the mid-1970s, according to a U.N. study, tropical moist forests covered about 935 million hectares, a 40 percent reduction from their natural areas. Estimates of the rate at which tropical forests are disappearing have varied considerably. The differing estimates reflect both the inadequacies in the data and different definitions of deforestation. The natural balance of large areas is being disrupted by logging even where permanent clearance does not occur.

The global story of tropical forest depletion is mixed but on the whole somber. Many areas are undergoing rapid and wasteful destruction, while a few—mainly parts of Amazonia and Central Africa—enjoy a reprieve from the ax for the time being. As forests are razed in the absence of sound land-use plans, priceless biological resources are eliminated, crucial ecological services disrupted, and future economic potentials lost. The statement that all the world’s rain forests will be gone by century’s end is clearly exaggerated. But a continuation of recent trends will be costly.

Economic and Social Conditions Leading to Deforestation
The spread of agriculture, firewood collection, and unregulated timber harvesting are the principal immediate causes of forest losses. But behind these lurk more basic failures. Usually,
uncontrolled deforestation is a symptom of a society’s inability to get a grip on other fundamental development problems: agricultural stagnation, grossly unequal land tenure, rising unemployment, rapid population growth, and the incapacity to regulate private enterprise to protect the public interest.

**Farming**

The spread of farming in one form or another is by far the major cause of outright forest loss today, as it has been through most of human history. Although its extent is often exaggerated, some potentially arable land yet remains under forest in parts of Africa, Latin America, and Southeast Asia. Given the population increases in store for these regions, the conversion of much of this land to agriculture over the coming decades will be necessary. However, the spread of agriculture is often characterized more by chaos and ecological destruction than by rationality, even when it is “planned” by governments.

**Farming and Rain Forest Soil**

In the tropical rain forests, where little is known about soil conditions and potentials, both legal and illegal colonists are trying to carve farms out of the jungle. Much tropical land colonization, as U.N. analysts have observed, “is indiscriminate...an ill-advised use of the land. It is merely a process of trial and error. Very often the chosen forest land cannot support permanent agriculture. When soil fertility is lost, cultivation is abandoned and the land is often grazed. The bare soil will frequently return to forest, unless, as is often the case, it is first destroyed by erosion.” By now even the most ecologically illiterate economic planners realize what biologists have long said: the apparent fertility of lush jungle soils is often illusory.

**Slash-and-Burn Farming**

Much of the blame for tropical forest destruction is often laid on the shoulders of shifting cultivators—those who slash and burn a clearing in the forest, grow crops for a few years until soil fertility dissipates, and then move on to clear a new patch. However, while itinerant farmers are indeed major agents of deforestation, it is important to differentiate among the various sorts of shifting cultivators and the soundness of their methods.

Traditional systems of shifting cultivation entail lengthy fallow periods during which soil fertility is restored and trees regrow on the cultivated plots. Today many traditional peoples in the Amazon Basin, Central Africa, and Southeast Asia are still practicing shifting cultivation in harmony with nature. It is when such farmers get hemmed in by logging companies, the spread of plantations, or other incursions of modern society that they can become enemies of the forest. In addition, as human numbers in a given region rise and the free forest area about them shrinks, fallow cycles are shortened to the point where trees have no chance to regrow.

Many of the “shifting cultivators” causing the greatest forest destruction today are not traditional practitioners of this art. They are rootless, landless people struggling to make what living they can amid unfamiliar ecological conditions. In Indonesia, for instance, many of those who have migrated from crowded Java to the outer islands have found continuous cultivation of the land unworkable, either because the soils are not appropriate or because promised technical assistance has not materialized. Many migrants have become new shifting cultivators who damage the timber and wildlife resources of the areas over which they spread. In Venezuela, which has a high rate of unemployment and rising numbers of landless peasants, 30,000 families, most of them practicing shifting cultivation, are living within national parks, forest reserves, and other supposedly protected areas. An influx of shifting cultivators in the
watershed above the Panama Canal is causing increased siltation of a crucial reservoir, thereby jeopardizing both the canal’s future utility and Panama City’s water supply.

**Grazing**

In Central and South America large areas of tropical forest have been cleared to create grazing lands, a transition that is sometimes unsustainable and frequently of dubious social value. The Brazilian government has granted huge concessions to both domestic and foreign corporations wanting to raise cattle in the Amazon region. Large tax incentives have attracted investors to grazing enterprises that would otherwise be uneconomical and will probably be short-lived.⁵

Large landowners in Venezuela too are transforming forest into pasture, while in Central America, virgin forest is giving way to pastures created by ranchers anxious to cash in on the lucrative beef-export market to the United States. Pointing to massive soil erosion on denuded slopes and to the widespread deterioration of soil structure, ecologist Joseph Tosi has estimated that more than half of the pasture land in Costa Rica is not suited to grazing.⁶

**Firewood Collection**

Firewood collection can contribute to the depletion of tree cover, especially in areas that were only lightly wooded to begin with. Where the balance between tree growth and human numbers permits, peasants can make do with dead wood and scraps from trees cut for other purposes. Dense forests can produce a lot of burnable material without any live trees being felled.

The outright destruction of living trees to meet fuel need occurs most commonly around cities and towns, where commercial markets for firewood and charcoal exist. Well-organized syndicates bring fuel by truck, camel, and donkey cart into cities like Ouagadougou in Upper Volta and Niamey in Niger, damaging the landscape in a widening circle.

Firewood scarcity is often most serious in areas far removed from designated forests. The increase in tree planting required just to meet projected fuel needs, let alone wood for other uses, is awesome; according to World Bank calculations, the rate of firewood planting (now perhaps 500,000 hectares a year in the Third World, excluding China) must jump fivefold if enormous ecological and economic costs are to be avoided.

**Logging**

Logging in humid tropical forests—much of which has been done by multinational corporations—usually involves not clear-cutting but the “creaming” of the forest’s small proportion of commercially valued species. However, the process of cutting and removing selected trees amid dense foliage and on delicate soils usually causes far more destruction of vegetation and wildlife than the bare statistics of extracted timber would suggest. One Indonesian study revealed that logging operations damaged or destroyed about 40 percent of the trees left behind.

Even when practiced responsibly, logging in many tropical forest areas leads to the permanent loss of forests. Wherever loggers build roads and settlements, other people follow. With or without government approval, cultivators move along new logging roads and into cut-over areas, hoping to put down roots. The clearings and smoke plumes of slash-and-burn cultivation are normal sights around new roads throughout the humid tropics. When these farms fail, they are sometimes replaced by cattle pastures or by useless, tenacious grasses.
Related Disasters

**Description of Physical Events**

The greatest and most immediate danger of deforestation is that gradually diminishing forested areas contribute to or worsen other disasters. For example, by removing vegetation that retains water, deforestation can lead to flooding, drought and desertification. By removing vegetation that stabilizes the soil, desertification can lead to erosion, siltation and an increased chance of landslides during earthquakes.

“In view of the likelihood that much of the vast area of the world’s surface still forested will be deforested in coming decades, the consequence of this in leading to disastrous floods cannot be over-emphasized,” wrote Professor L.D. Pryor in his 1982 report “Ecological Mismanagement in Natural Disasters” for the International Union for Conservation of Nature and Natural Resources (IUCN).7

Decades of research have proved that the deforestation of watersheds, especially around smaller rivers and streams, can increase the severity of flooding, reduce streamflows and dry up springs during dry seasons, and increase the load of sediment entering waterways. Yet most efforts to combat such problems have entailed engineering measures—dams, embankments, dredging—that address symptoms but not their causes.

**Deforestation and Floods**

The exact contribution of deforestation to flood trends is probably impossible to pinpoint, but as flooding worsens in country after country, new attention is being given to the protection of watersheds. In the fall of 1978 India suffered some of the worst flooding in its history. Following two days of concentrated rainfall, 66,000 villages were inundated, more than 2,000 people drowned, and 40,000 cattle were swept away. Two states, West Bengal and Uttar Pradesh, lost a total of $750 million in crops. Many Indian officials are beginning to wonder whether their chronic flood problems can be reduced without a restoration of forest cover in the increasingly denuded hills of northern India and Nepal. According to the country’s National Commission on Floods, the area annually affected by floods now averages 40 million hectares, compared to 25 million hectares three decades ago. Perhaps more important, rising numbers of people live in flood-prone areas. Indian expenditures to offset flood damages averaged $250 million a year between 1953 and 1978.

**Deforestation on Mountains**

Outside the humid tropical zones the last extensive forests in many Third World countries are on the steep slopes and more remote reaches of mountains. Agriculture nearly everywhere has traditionally been concentrated on the plains and valley floors, and with good reason, for severe erosion and other ecological calamities often occur when slopes are left unprotected by vegetation. Yet today, pushed by the lack of access to land or jobs, cultivators are moving up mountainsides in many parts of Africa, Asia, and Latin America, clearing forests as they go.

Frequently a precarious and futile business, mountainside farming and the associated deforestation can also affect the welfare of those in farms and cities downstream by increasing flooding and the siltation of rivers, reservoirs, and harbors.

**Hazard Analysis and Prediction**

Analyzing a locality to determine deforestation damage can be difficult because deforestation is an overall trend. In general it is difficult to know whether a piece of farmland is unhealthy in its
present state and would be better off as forest. Therefore, it is necessary to gather information on overall forest trends. In much of the world this data on forest trends has generally been unreliable or altogether lacking. But recently a large number of surveys have been initiated, many of them making use of satellite photography, and the quality of forest data is improving fast. Discussions of forest trends are plagued by definitional problems. How many trees, how close together, make a forest? At what point does selective logging become deforestation? If the clearing of a slash-and-burn farmer will be left for natural regrowth, has deforestation occurred? Even statistics on tree planting can be confusing. A eucalyptus plantation established on former cropland should not be lumped together with a restored hillside forest of mixed native species. And “reforestation” often means clearing standing forests to make room for tree plantations.

**Impact on Built and Natural Environments**

**Impact on Buildings**
Deforestation and timber scarcity have an especially harmful impact on housing in poor countries. Even if Third World governments were to make a serious effort to meet the housing problem, adequate wood supplies would not be available in many cases. For example, in the late 1970s the Indian state of Gujarat conceived of an ambitious plan to construct huts for landless laborers. The plan was derailed by the lack of raw materials. The program called for 25 million wood poles, but only 400,000 of these became available each year; and only four million bamboo stalks were produced a year although 765 million were needed.

**Impact on Agriculture and Ecology**
Deforestation's impact on food supply follows this chain of events:
1. deforestation
2. erosion
3. collapse of hillsides
4. loss of topsoil and agricultural land.

Deforestation also unbalances the water supply by contributing to drought and flood.

**Impact on Economy**
What are the economic consequences of uncontrolled deforestation and forest-product scarcity? One outcome of a nation’s forestry shortcomings can be a rising dependence on imported forest products. Already most Third World countries are net importers of forest products, particularly paper (the production of which requires both wood-fiber and manufacturing plants).

Trade-deficit figures do not come close to capturing the negative impacts of tree scarcity, some of which are acutely felt by low-income citizens even in timber-exporting countries. For one thing the major forest products used by most Third World residents never enter the market economy; when fruits or firewood become scarce, people either do without or switch to noncommercial alternatives rather than to imported goods. In addition, foreign exchange shortages and high prices can hold a nation’s wood and paper consumption well below the levels at which basic needs are satisfied.

Acute scarcities of firewood and timber plague wide areas of Africa, Asia, and Latin America. But a continuation of the last quarter-century’s trends of deforestation, inadequate forest renewal, and growth in wood demand would have worldwide repercussions. The amount of
exploitable timber available per person in the world is falling; in the words of the U.S. government’s *Global 2000* study, we face a “transition from a period of global forest wealth to a period of global forest poverty.” Real prices of commercial wood products are certain to rise, choking off projected consumption increases, fueling inflation, and denying low-income people everywhere many of the benefits that forest products provide.

Soaring firewood prices are also another inflation source. Almost everywhere that commercial firewood markets exist, prices over the last decade have multiplied. In one town in Upper Volta, a donkey cartload of wood that sold for 350 Central African francs in 1970 cost 1000 francs in 1975 and 1750 francs in 1979. In parts of West Africa and Central America urban families spend one-fourth of their income on wood or charcoal for cooking. As market prices have outpaced the purchasing power of the urban poor, many state governments in India have had to establish special firewood depots that sell low-priced fuel to the poorest groups. Subsidized firewood has joined subsidized food as a measure necessary to prevent starvation in India.

**Recovery Strategies and Problems**

Forestry planning must incorporate both a long-term horizon and a humane social vision. One of the most positive developments in the global environmental scene over the last decade has been the new recognition of the importance of forestry among aid agencies and Third World governments. But the sources of deforestation are deep.

**The Role of Foresters**

Meeting the forestry challenge requires radical changes in the roles of foresters and national forest agencies. Their traditional mandates have been to protect and manage the exploitation of forest reserves. Good foresters have always been concerned as well with protecting environmentally crucial forest areas and sustaining the long-term output of the forests in their care. But even these desirable traits are not enough. Today foresters need to move outside the forests and help people meet their basic forest needs.

As an alternative to large plantations, integrating trees and wood production into small-farm systems holds great potential in both semiarid and humid areas. Spatially-dispersed forestry practiced by many farmers can often provide far greater environmental benefits than a woodlot concentrated in one place.

**Impact on Communities**

To an outsider, prompting rural communities to grow some badly needed trees may not seem like such a tall order. But the experience of countries such as China and South Korea, which have already implemented participatory forestry on a wide scale, demonstrates that actually doing so requires changes in the attitudes and activities of governments and aid agencies, and reforms in villagers’ social organization and land use.

Foresters, and development planners in general, are used to running things from above. What contact they have had with villagers has usually been in their roles as policemen, denying destitute people access to protected lands and wood.

Yet experience has shown that tree planting cannot be imposed from above and carried out in the face of a hostile population. New forms of land use impinge upon the daily activities of everyone. When the local people are not active supporters, saplings have a way of disappearing overnight. With fodder usually as scarce as firewood, uncontrolled goats or cattle
can quickly ruin a new plantation. Community involvement then is not just an ideologically appealing goal; it is a practical necessity if rural forest needs are to be met. Popular participation is important for economic reasons too, for in most countries the costs of the needed plantings and upkeep would be prohibitive if local residents did not pitch in generously with their labor.

**Issues in Reforestation**

Another major need is for the improved management of natural woodlands in order to increase their output of useful products. Recent “reforestation” schemes in semiarid West Africa have sometimes been a mixed blessing, entailing the clearing of rich and diverse woodlands to make room for plantations of fast-growing exotic species. The multitude of nonwood products that local people glean from the forest are thus lost—and the productivity of exotic plantations in the Sahel has often turned out to be far lower than expected.

But simply increasing the area planted with trees will not necessarily do justice to social and environmental concerns. With forestry, as with all development activities, who does the producing and who gets the benefits are as crucial as what gets produced. The management of a village woodlot can be designed in ways that help or hurt the rural poor.

Another issue in reforestation is that it can become a multijurisdictional problem, i.e. deforestation in one area may produce flooding downstream in another area of the country or perhaps in another country, thereby requiring both national and international efforts.

**Disaster Mitigation**

To reduce the damage done by areas already denuded, mitigation procedures such as catch dams and terraces can be implemented. For more information see the chapters on floods and desertification.

**Conclusion**

Desirable approaches to forestry differ from place to place. But probably no country lacks the physical resources to meet its most urgent rural forestry needs. Villages virtually everywhere have unused or misused lands on which fast-growing woodlots can be planted. Individual farmers are often willing and able to grow more trees in and around their fields when given the means to do so. In watersheds, the raising of crops, trees, and livestock can be integrated in new ways that protect soils as they provide extra benefits for people. Agroforestry systems can give shifting cultivators a stable, productive life. Idle lands along roads and canals and around fields can be planted to trees that produce food, fodder, timber, traditional medicines, and industrial raw materials as well as a more hospitable environment. Cheap, efficient cooking stoves that cut family woodfuel needs in half can be distributed.

Community forestry, as the new approach is known, has begun to catch on over the last decade. U.N. agencies have begun promoting the concept, and the world’s major aid institution, the World Bank, announced in 1978 a marked shift in its forestry program, with emphasis on fuelwood and small-scale activities replacing the former preoccupation with large-scale timber. Having lent nothing for firewood projects in the early 1970s, the World Bank loaned $1 billion for this purpose in the first five years of the 1980s. Other aid agencies have also shown new interest in people-oriented forestry.

Whether the issue is the maintenance of timber output, the protection of ecological stability, or the growing of fuel, a host of workable forestry technologies are known and await wider
implementation. But essential as they are, forestry measures alone will not be enough to solve
the deforestation problem. Many of the underlying sources of deforestation originate outside the
scope of forestry per se. In order to halt the destructive spread of cultivation, national
development patterns must provide the destroyers with alternative ways to feed themselves; in
particular, crop yields and employment must be boosted on the lands best suited to farming.
Sound forestry policies can contribute to these efforts, but broader decisions on investment
priorities, land tenure, and the choice of technologies will be even more critical. Woodland
depletion by firewood gatherers can be greatly mitigated by tree planting, but broader attention
to rural energy needs, alternative energy sources, and national energy priorities is also
necessary. Of course, human population growth underlies all the sources of deforestation. A
vast amount of tree planting is essential over the coming decades, but its benefits will be
undercut if the deeper roots of deforestation are not eradicated.9

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Appendix I

Glossary of International Disaster Assistance Terms

This glossary is intended as an aid to generalists working in the disaster assistance field. It has been prepared with the hope that terms common in the disaster assistance vocabulary will be rendered more comprehensible to all interested individuals, whether they be disaster relief specialists or specialists in related fields.

It is also hoped that this glossary will help standardize terms frequently used in international seminars on disaster preparedness. The glossary will be revised and updated as needs dictate. Anyone wishing to offer a term for inclusion should feel free to do so.

— A —

**Acceleration** — a change in velocity due to gravity; in earthquake hazard analysis, it is expressed as a fraction of gravity pull (g).

**Adjustments** — any physical or structural rearrangement of the environment to safeguard human life and property, such as the building of dams or windbreaks, or the strengthening of buildings.

**Aerial reconnaissance** — the survey of a disaster area by air to determine extent and type of destruction.

**Afforestation** — establishment of a tree crop in an area where trees have always or long been absent.

**Aftershock** — a tremor that follows the main shock of an earthquake and originates at or near the focus of the primary earthquake. Generally, major earthquakes are followed by a large number of aftershocks that decrease in frequency over time.

**Agroclimatic region** — identification of a region on the basis of homogeneous climate, physical features, and crop types; used to determine crop calendars, forecast crop yields, and conduct drought assessments.

**Agroforestry** — the growing of crops and trees together, or the use of special crops or trees to supplement or complement normal field crops.

**Agrometeorology** — the study and application of meteorology and climatology to specific problems in agriculture such as crop-yield modeling and forecasting.

**Alert signals** — a commonly recognized siren, flag, or other device sounded or raised on the authority of local officials to indicate an emergency, human-made or natural. The use of such a signal may also activate specified emergency procedures, such as mobilization or evacuation.

**Amplitude** — the maximum displacement from zero level of any wave such as a seismic wave.
Analogue modeling — the application of a specific set of historic agronomic and climatic data of a given area to another area for which no such data exist; used to estimate crop conditions and potential yields.

Array — in seismology, an ordered arrangement of seismometers/geophones, the data from which feed into a central receiver.

Arrival time — the time at which a particular seismic wave phase arrives at a detector and triggers recording or alert devices.

Aseismic — nonseismic; used to designate structures that can withstand earthquakes or areas that are relatively free from seismic activity.

Ash flow — in eruptions of gas-charged magma, a relatively small proportion of the material may be thrown high into the atmosphere by explosion. Much of the resulting ash remains suspended in a cloud that spreads rapidly outward close to the ground.

Assessment — survey of a disaster area to make estimates of damages and recommendations for necessary relief action.

Atmospheric pollution — contamination of the atmosphere by gases and solids produced by the burning of natural and artificial fuels in chemical and some industrial processes, and in nuclear explosions; the term may also include contamination produced by accumulation of cosmic dust, raising of surface dust by wind, volcanic eruptions, vegetation decay, sea spray evaporation, and natural radioactivity.

Avalanche — the rapid and sudden sliding and flowage of masses of usually incoherent and unsorted mixtures of snow/ice/rock material.

Barometric pressure — the pressure exerted by the atmosphere as a consequence of the gravitational attraction exerted upon a “column” of air lying directly above any given point on the earth’s surface.

Beaufort scale — scale of wind and rain conditions and speed, measured from zero when the sea is calm like a mirror and winds are less than one mile per hour, to 12 for hurricanes, when the air is filled with foam and spray and wind speeds are greater than 72 miles per hour.

Body wave — a seismic wave that travels through the interior of the earth and is not related to a boundary surface.

Buffer strip — (also called a filter strip) a strip of trees or vegetation left intact along streams to protect against erosion, or to keep runoff from washing sediment or debris into streams.

Carrying capacity — the number or weight of any species that can survive in a given ecosystem without causing its deterioration. A more narrow definition is the maximum stocking possible on
a given range or wildlife area, without diminishing the forage yields or damaging the watershed; the ability of a community to sustain growth.

*Catastrophe theory* — a coherent group of general propositions used as principles to explain sudden, violent disturbances on the earth’s surface.

*Change detection* — the application of satellite or airborne imagery (via computer discernment) to analyze temporal changes on the earth’s surface.

*Civil defense* — a government agency that serves to coordinate, organize, and direct in time of emergency, the government, voluntary agency and private emergency response systems. It also acts to prevent, mitigate, and prepare for disasters. The civil defense agency provides relief and life support after a disaster strikes; it also initiates recovery and rehabilitation action and programs. In some countries similar functions may be performed by civil protection, emergency preparedness, emergency services, civil preparedness, or disaster assistance agencies.

*Clear cutting* — clean felling or complete cutting that removes an entire standing crop of trees.

*Climatic anomaly* — unusual or exceptional climatic conditions within a particular region or area.

*Climatology* — the branch of meteorology concerned with the mean physical state of the atmosphere together with its statistical variations in both space and time, as reflected in the totality of weather behavior over a period of many years. Climatology encompasses not only the description of climate but also the physical origins and wide-range practical consequences of climate and climatic change.

*Communications* — in disaster preparedness and assistance, the interconnected network for transmitting information about potential disasters to the population. Orbiting satellites, seismographic meters and other equipment that monitors changes on the earth form a part of this network. Public awareness and education programs designed to inform the population of the likelihood of a disaster and recommended actions to take in such an event, and warning signals alerting the community to a disaster are also part of this network. Information transmitted between the disaster site and the emergency operations center, heads of government, voluntary agencies, and international relief coordinators via telephone, radio, telegraph, or other media (television, newspaper, magazines, ham radio operators), is also a vital part of the communications network.

*Contingency planning* — a series of assessments and evaluations followed by the development of proposed plans of action in anticipation of a natural or human-made disaster. This involves: 1) identification of the potential threat, e.g., proximity to an active volcano, settlements on seismic faults or flood plains, history of drought, food shortages, or epidemics, etc.; 2) identification of likely impact of disaster, e.g., number of people potentially affected, disruption of food or water supply, transportation system, or communication channels, damage to property, roads, health facilities, duration of disaster and its effects; 3) anticipating and developing optimum response to such a threat, e.g., educate/alert population to potential risk, develop notification and evacuation plans, provide means of transporting people, food and medical supplies; 4) identification of existing resources, e.g., areas where shelters could be established, sources of food, water and medical supplies, communication and transportation systems, location of reconstruction equipment.
Crater — a bowl-shaped depression, as at the mouth of a volcano or geyser (or any pit resembling this), especially when formed by a subterranean explosion or by the impact of a meteor.

Creep — the gradual and more or less continuous, permanent deformation process sustained by ice and rock materials under gravitational stresses; also called mass move.

Creeping disaster — a disaster of slow onset, such as drought, health deterioration, or famine, which may not have an easily identifiable beginning.

Crop calendar — seasonal timetable of a region’s standard crops giving dates of sowing and various stages of growth under different weather conditions.

Crop moisture index (CMI) — a modified Palmer index representing those aspects of soil moisture that affect vegetation and field operations (see Palmer index).

Crop moisture ratio — the ratio of precipitation to the potential evapotranspiration (PET) for key stages in crop development. It measures the proportion of water supply-to-demand under rainfed conditions for successive growth stages of specific crops.

Crop yield — the amount of a crop harvested over a given period of time or at a given moment in its cycle.

CSB — Corn-Soya Blend, precooked blend of corn, defatted soy flour, vitamins and minerals.

CSM — Corn-Soya Milk, precooked corn, defatted soy flour, dry skim milk, vitamins and minerals

Cumulative precipitation — a procedure for comparing meteorological and agricultural droughts by relating drought stages to a percentage of normal precipitation.

Curriculum development — when used in connection with disaster preparedness, relates to the inclusion of public awareness information in school education program (see public awareness).

Cyclone — a large-scale closed circulation system in the earth’s atmosphere with relatively low barometric pressure and winds that blow counterclockwise around the center in the northern hemisphere and clockwise in the southern hemisphere. See also hurricane, typhoon, and tropical cyclone. Called “cyclone” in Indian Ocean and South Pacific; “hurricane” in Western Atlantic and Eastern Pacific; “typhoon” in Western Pacific.

Cyclone panel — an element within the typhoon committee with principal interest in the Bay of Bengal/Indian Ocean.

— D —

Damage classification — evaluation and recording of damages to structures, facilities, or objects according to three categories: 1) “severe damage,” which precludes further use of the structure, facility, or object for its intended purpose. 2) “moderate damage,” or the degree of damage to principal members, which precludes effective use of the structure, facility, or object
for its intended purpose, unless major repairs are made short of complete reconstruction. 3) “light damage,” such as broken windows, slight damage to roofing and siding, interior partitions blown down, and cracked walls. The damage is not severe enough to preclude use of the installation for the purpose for which it was intended.

*Damage forecasting* — studies of the probable effects of a given disaster upon a particular population or community, based on an assumed magnitude of hazard and an estimated vulnerability of potential victims and property.

*Debris flow* — a mass movement involving a rapid flow of debris from various kinds of earth material in various conditions. Specifically, a high-density mud flow with abundant coarse-grained materials and resulting invariably from an unusually heavy rainfall.

*Declaration of disaster* — issuance of a state of emergency by designated authorities in the wake of a large-scale calamity, in order to activate those measures contained in the national disaster plans, preparedness plans, and emergency operations manuals. Such declarations are in effect for a limited time.

*Deforestation* — the clearing of a previously forested area. Though humans are the primary deforesters, natural agents, such as volcanic eruptions, erosion, and landslides may also contribute. Clear cutting, if followed by reforestation, is not an act of deforestation.

*Desertification* — the process by which an already arid area becomes even more barren, because of prolonged drought, sand drift, or human-made degradation of the environment.

*Disaster* — occurrence of widespread severe damage, injury, or loss of life or property, with which a community cannot cope and during which the affected society undergoes severe disruption. Disasters may be human-made or have natural causes and may include earthquakes, floods, fires, hurricanes, cyclones, major storms, volcanic eruptions, spills, air crashes, and creeping disasters such as droughts, epidemics or serious food shortages, as well as disasters of civil strife in which many victims may be left homeless as much property is seriously damaged or destroyed.

*Disaster act* — law(s) of a nation or its provinces that provides the government with the powers to employ the designated resources at national, state, or local levels to meet emergency demands and to administer disaster plans.

*Disaster area survey team (DAST)* — a group that is deployed in an area after a disaster to ascertain the extent of damage to population and property and to recommend appropriate responses.

*Disaster assistance* — provision of measures to prevent, reduce the impact of, and reverse the effects of disasters; phases include relief, rehabilitation, reconstruction and preparedness, and prevention and mitigation.

*Disaster plan* — the basic principles, policies, responsibilities, preparations, and responses developed to enable a society to meet any kind of emergency or disaster.

*Disaster planning strategy* — the national strategy of a country for achieving civil and state defense emergency preparedness, which defines the overall purposes, systems, methods and
organizations (public and private), and the ways and means of achieving coordination and prompt response to needs as they arise.

*Displaced person* — one who flees or is separated from his/her community, as a result of political conflicts, civil strife, or natural disasters, but still remains within his/her own national boundaries.

*DKM scale* — the Dalton King magnitude scale, developed at OFDA, which provides a magnitude of disaster damage relative to all other disasters on the basis of the number of victims, deaths, and dollar damages ascribed to a given disaster. *Dollar damage* — the extent or physical damage in terms of cost of destroyed or damaged public and private assets in U.S. dollars.

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*Earth flow* — a mass movement of land characterized by downslope translation of soil and weathered rock over a discrete sheer surface (landslide) within well-defined lateral boundaries.

*Earthquake* — a sudden break in the rock of the earth’s crust below or at the surface, which results in the vibration of the ground, and the potential collapse of buildings and possible destruction of life and property if the quake is of sufficient magnitude.

*Earthquake forecasting* — estimating the probability of the occurrence of an earthquake in relative time, place, and magnitude.

*Earthquake swarm* — a series of minor earth tremors (none of which may be identified as the main shock) that occurs within a limited area and time.

*Ecosystem* — any group of living organisms; animals, plants, and bacteria, and their interrelated physical and chemical environment.

*Elastic wave* — a wave that is propagated by some kind of elastic deformation, i.e., a deformation that disappears when the forces are removed. A seismic wave is a type of elastic wave.

*Emergency broadcasting system* — radio and television broadcast stations that have been authorized by the government to disseminate information during a state of disaster or other national emergency.

*Emergency operations center (EOC)* — protected site from which government and nongovernment officials coordinate emergency relief responses.

*Emergency operations plan* — a description of emergency actions and instructions concerned with the threat and/or impact of a disaster. It is usually issued by the civil defense agency and includes the Red Cross, other voluntary agencies, industry, and individuals. The plan states the method for taking coordinated action to meet the needs of the situation, and assigns tasks and priorities for completing these actions based upon predetermined assumptions, objectives, capabilities, and the requirements of each disaster type.
Emergency welfare — public and private assistance programs to locate and reunite family members during an emergency and provide essential welfare services, such as shelter, food, and medical attention.

Environmental degradation — variously applied to the effects of erosion, reduced water absorption and nutrient loss, e.g., after fire, overgrazing, or poor cultivation practices. Long-term changes are implied.

Epicenter — that point on the earth’s surface directly above the place of origin, focus, or hypocenter of an earthquake.

Epidemic — a rapid and widespread outbreak of disease.

Epidemiology — the study of healthy and diseased populations, and the environmental interrelationships affecting these states; also the surveillance of and techniques for discovery of sources, causes and control of epidemics.

Erosion — depletion or loss of soil as a result of moving surface water or wind. Erosion can seriously affect the crop production capacity of the remaining soil.

Establishment forestry — the process of developing a forest crop to a stage at which the young trees may be considered established, i.e., safe from normal adverse influences, such as frost or browsing, and no longer in need of special protection or tending.

Evacuation plan — procedure whereby persons can be removed from a threatened or impacted area.

Evapotranspiration — the combined loss of water from a given area, during a specific period of time, by evaporation from the soil and by transpiration from plants.

Executive order (EO) — an order with the force of law issued by the chief executive of a country. In time of disaster, an executive order may be issued to ensure that emergency services will be forthcoming to the population in need.

Exploitation cutting — the removal of trees for immediate marketing with little or no regard for environmental needs.

Eye (of the storm) — the calm center of a tropical cyclone.

— F —

Fall — a type of landslide, characterized by a very rapid downward movement of rock mass or earth.

Fallout — the descent to earth of radioactive particles from the atmosphere; this may arise from 1) natural causes, 2) atomic bomb or thermonuclear bomb explosion and 3) induced radioactivities and fission products from atomic reactor operations.
Fault — a planar or gently curved fracture in the earth’s crust across which relative displacement has occurred.

First aid — the immediate but temporary care given to the victims of an accident or sudden illness in order to avert complications, lessen suffering, and sustain life until the services of a physician can be obtained.

First arrival — in seismology, the first recorded signal attributed to a seismic wave traveling from a known source.

Flash flood — a sudden and extreme volume of water that flows rapidly and causes inundation of land areas. It can result in heavy loss of life and destruction of property.

Flood control — the management of water resources through construction of dams, reservoirs, embankments, etc. to avoid floods.

Floodplain — an area adjacent to a river, formed by the repeated overflow of the natural channel bed.

Floodplain zoning — a plan that defines the main zones of a potential flood area, usually accompanied by housing restrictions or other recommendations.

Flow — a mass movement of unconsolidated material that exhibits a continuity of motion and plastic or semifluid behavior, resembling that of a viscous fluid. It may be termed a creep, an earthflow, a mudflow, or a debris avalanche. Water is usually required for most types of flow movements.

Focal depth — distance from the earth’s surface at which a seismic wave first originates, i.e., at the hypocenter of an earthquake.

Focal zone — the rupture zone of an earthquake. In the case of a great earthquake, the focal zone may be several hundred kilometers in length.

Focus — a point beneath the earth’s surface where the first motion of an earthquake and its elastic waves originate.

Food shortage — a scarcity of food, in a given area, which has not yet reached famine proportions. Food shortages usually require some external food assistance but usually do not result in loss of life (see famine).

Foreshock — precursory seismicity that commonly precedes a main shock (earthquake) by anywhere from seconds to weeks and usually originates at or near the focal zone of the main earthquake.

Forest cover — organic debris or humus on the surface of the forest soil.

Forest/grassland fire — fires in forest or brush grasslands that cover extensive areas and usually do extensive damage. They may start by natural causes such as volcanic eruptions or lighting, or they may be caused by arsonists or careless smokers, by those burning wood, or by clearing a forest area.
Forestation — the establishment of a forest, either natural or human-made, on an area that previously have had none.

Frequency — the repetition of various forms of waves, expressed in cycles per second.

— G —

Geomorphology — a science that deals with the form and surface configuration of the solid earth. It attempts to reveal the interrelationships between the origin of surface features and the causes of their alteration.

Geophysics — the science that deals with physical occurrences at and below the surface of the earth, including geology, oceanography, geodesy, seismology, hydrology, etc.

G.M.T. — Greenwich Mean Time, or Zulu time or Z. time, or Zero Meridian. A standard reference time used throughout the world, based on the time at the Royal Observatory. In Greenwich time, subtract five hours for Eastern Standard Time (EST), six hours for Central Standard Time (CST), seven hours for Mountain Standard Time (MST), eight hours for Pacific Standard Time (PST). Add one hour to the above time zones for “daylight-saving time,” which is in effect during the summer months in the United States and some other countries.

Global/plate tectonics — the concept that the earth’s surface is made up of several large plates or crustal slabs that move and are continually altering the crust of the earth.

Greenbelt — an area of trees and other natural vegetation, or an area of general conservation works, including tree plantings.

Groundwater level — the level at which soil and porous rock is saturated with water. This may vary from area to area, being surface level or higher in marshy areas, and substantially subsurface in desert regions.

— H —

Ham radio — the international amateur radio network, sometimes the only surviving communication system after a disaster occurs. Ham radio operators often play an invaluable role in transmitting disaster assessment and needs information between victims and disaster relief specialists.

Hazard — physical forces (hurricane, flood, volcano, etc.) that, when in proximity to populations, may cause disasters.

Health resources — public and private hospitals and clinics, medical personnel, medical and drug supplies, and pharmaceutical distributors.

History of disasters — a data file, prepared by the Office of U.S. Foreign Disaster Assistance, that records notable disasters of the 20th century, arranged by disaster number, disaster type, number killed, number of victims, number homeless, and dollar damage.
Hurricane — in the Western Hemisphere, a major storm with a wind velocity of 75 miles per hour (120 kilometers per hour) or more. Also called typhoons in the Pacific Ocean, and cyclones in the Indian Ocean and South Pacific. See Beaufort scale.

Hydrology — the science that studies the land-trapped waters of the earth, their occurrence, circulation, and distribution; their chemical and physical properties; and their interaction with the environment, including the relationship to living things.

Hydrometeorology — the study of the occurrence, movement, and changes in the state of water in the atmosphere. The term is also used in a more restricted sense to mean the study of the exchange of water between the atmosphere and continental surfaces.

Hypocenter — the location of the focus of an earthquake, calculated by the geographic coordinates and depth from the surface.

--- I ---

ICRC — International Committee of the Red Cross

Induced seismicity — earthquake activity resulting from human-made causes such as liquid intrusion and construction of reservoirs.

In kind — commodity donations given at the time of a disaster; these may consist of food, blankets, medicines, tents, etc.

Insect infestation — 1) the contamination of harvested or stored stocks by insects, usually remedied by the use of appropriate insecticides and fumigants; 2) the contamination of a crop area by insects, which requires the application of insecticides in order to protect crops from destruction.

Intensity — a subjective measurement of the force of an earthquake at a particular place as determined by its effects on persons, structures, and earth materials. Intensity is a measure of effects, while magnitude is a measure of energy. The modified Mercalli scale is the principal intensity scale used in the United States.

Isobar — a line represented on a map or chart, connecting points on the earth’s surface that have equal barometric pressure over a given time or period.

Isohyet — a line drawn through geographic points recording equal amounts of precipitation for a specified period or for a particular storm.

Isoseismal line — a line connecting points on the earth’s surface at which earthquake intensity is or is expected to be the same.

--- K ---

Kanamori scale (MW) — a magnitude scale used to measure the seismic energy of great earthquakes, i.e., earthquakes with rupture lengths greater than 100 kilometers.
Land degradation — refers generally to erosion and other damages to land, especially caused by land misuse.

Landsat — orbiting, earth resource sensing satellite used for mapping, environmental change detection, and disaster damage assessment.

Landslide — a rapid or marginally rapid downhill movement of soil and rock.

Lava flow — the residue of an eruption from a volcano, usually consisting of molten magma and ash, and usually moving at a moderate pace (in comparison to an ash flow) down a mountain side, often threatening life and property below.

Life support — food, water, sanitation, shelter, and medical aid during the 60 to 90 days following a disaster.

Local conditions — usually refers to weather conditions, significant to the disaster business in time of storms. When local conditions warrant, low-lying coastal areas must be evacuated and other appropriate storm precautions must be taken to mitigate loss of life and property. Also refers to soil conditions.

LORCS — League of Red Cross Societies (also known by cable address. LICROSS).

Low-velocity zone — any layer of the earth in which seismic velocities are lower than in the layers above and below it.

Magma — the molten matter under the earth’s crust from which igneous rock is formed.

Magnitude — a measurement of the strength of an earthquake, using a scale graduated by the logarithm of the maximum seismic wave amplitude, as recorded on a seismograph at a specified distance from the earthquake’s epicenter. Each magnitude step on the Richter scale represents an increase of 10 times the measured wave amplitude of the earthquake.

Major accident — refers to occurrences of catastrophic proportion. These may be separate or cumulative accidents on land, sea, or air; serious crashes of ships, trains, or airplanes; multiple auto accidents; destructive accidents in chemical, petrol, or nuclear power plants or at sewage and disposal plants; widespread electrical failures; and collapse of major structures. They may require emergency response or create a public demand for such a response either by government or by various voluntary or private agencies.

Major disaster — flood, hurricane, earthquake, drought, volcanic eruption, epidemic, fire, or other catastrophe of a severity that causes serious disruption to societal, economic and infrastructure elements. In general, a disaster rating 10 or above on DKM scale.

Major earthquake — an earthquake having a magnitude of seven or greater on the Richter scale.
**Malnutrition** — the condition of severe shortage of protein and calorie intake to such a degree that wasting and shrinking of muscles occurs and performance of daily tasks is drastically inhibited. Malnutrition is measured by several indicators, including upper arm circumference, weight/height, weight/age ratios. These measurements are compared to a standard for a well-nourished individual of the same age.

**Mass care** — provision of help, usually through public feeding centers where portions of a disaster-stricken population are provided with at least one balanced meal per day. Mass care involves the orderly feeding to families of a predetermined quantity and type of food matched, as closely as possible, to the particular preferences of the region or country in question.

**Mass wasting** — a general term for the dislodging and downslope transport of soil and rock material under the direct application of gravitational body stresses.

**Medical self-help** — training programs to help people prepare for survival in time of disaster when conventionally trained medical help is not available or accessible.

**Mercalli scale** — a scale for rating earthquake intensity as humanly perceived, rated numerically from "I — Not felt except by a very few," to "XII — Damage total." Also is called a modified Mercalli scale or MM scale when used in North America.

**Meteorology** — the science concerned with the atmosphere and related phenomena. Meteorologists observe the atmosphere, temperature, winds, density, clouds, and precipitation, and analyze its observed structure and evolution in terms of the laws of physics.

**Microclimate** — the fine climate structure of the air space that extends from the surface of the earth to a height at which the effects of the immediate characteristics of the underlying surface can no longer be distinguished from the general local climate (mesoclimate or macroclimate).

**Microearthquake** — an earthquake having a magnitude of 2 or less on the Richter scale (see Richter scale).

**Microseismicity** — small earthquake activity.

**Microzonation** — subdivision of a region into zones that have exposure to similar earthquake-related effects.

**Mitigation** — long-term measures taken to reduce the effects of disaster through alteration of the physical environment, such as floodplain zoning and control, afforestation, land terracing, torrent control, sand dune stabilization, and planting of shelterbelts or windbreaks.

**MM scale** — see Mercalli scale.

**Monsoon** — seasonally heavy rains and wind, particularly in the Indian Ocean and South Asian areas. It can contain winds that change direction with the season, may cause severe damage, and could require emergency response and disaster relief.
Needs assessment — the estimate of what assistance is needed by a region or country following a disaster.

NGO — nongovernmental organization.

NOAA — National Oceanic and Atmospheric Administration of the U.S. Department of Commerce.

Oceanography — the exploration and scientific study of the ocean and its phenomena.

Office of U.S. Foreign Disaster Assistance (OFDA) — the office that has been established by the United States government to respond to the needs of victims outside the United States who have either been threatened by a disaster or are already disaster victims.

Oil spill — the contamination of a water or shore area by oil from a damaged ship or storage facilities. Oil spills usually require at least minimal emergency response and, if serious enough, may require emergency evacuation of an area.

Operations control — that which is exercised by the emergency operations center in time of disaster to coordinate all activities relative to emergency relief.

Palmer index — a mathematical representation of “meteorological drought” for evaluating the scope, frequency, and severity of prolonged periods of abnormal weather. Its terms include: available water capacity of the soil, evapotranspiration, moisture loss from surface of underlying soil layers, normal precipitation, temperature and runoff.

Potential evapotranspiration (PET) — the amount of moisture that would be removed from a given land area by evapotranspiration.

Phase — the onset of a displacement or oscillation on a seismogram, indicating the arrival of a different type of seismic wave.

Plantation — an artificial forest stand. A human-made forest raised by the sowing of seed or by planting.

Pollution — contamination of the environment by industrial, chemical, or natural waste products, and from debris flow or other human-made causes such as oil or other chemical spill.

Population at risk — a given population whose lives, property, and livelihoods are threatened by natural hazards.

Potable — fit to drink.
Precipitation — in meteorology, water droplets or ice particles condensed from atmospheric water vapor and sufficiently massive to fall to the earth’s surface, i.e., rain, snow, sleet, hail.

Preparedness — may be described as action designed to minimize loss of life and damage, and to organize and facilitate timely and effective rescue, relief and rehabilitation in cases of disaster. Preparedness is concerned with understanding the threat, forecasting and warning; educating and training officials and the population; establishing organization for and management of disaster situations, including preparation of operational plans, training relief groups, stockpiling supplies, and earmarking necessary funds.

Prevention — measures designed to preclude natural phenomena from causing or resulting in disaster or other emergency situations. Prevention concerns the formulation and implementation of long-range policies and programs to eliminate the occurrence of disasters. Prevention includes legislation and regulatory measures, principally in the fields of physical and urban planning, public works, and building. It also encompasses the manifestation of such plans.

Protection forest — an area wholly or partly covered with woody growth, managed primarily to regulate stream growth, maintain water quality, minimize erosion, stabilize drifting sand, or exert any other beneficial influences.

Public awareness — the state of being informed about the actions needed to save lives and property in the event of a disaster. Public awareness may involve public or adult education, radio or television broadcasts, the establishment of emergency centers in convenient locations, and the use of the print media.

Private voluntary organization (PVO) — a group that aids needy people around the world on a regular basis as well as in times of disaster.

— R —

Radio Amateur Civil Emergency Service (RACES) — skilled amateur radio operators worldwide who communicate emergency messages in accordance with approved civil defense communication plans.

Radar — instrument used for detection and ranging of objects. Doppler weather radar determines velocity of a storm by measuring the frequency change in a transmitted pulse caused by the target’s motion. Airborn radar is used in photo reconnaissance for mapping or assessment purposes.

Radial fissure — a term used in connection with earthquakes or volcanic eruptions, meaning a narrow opening or crack moving from the center outward or from the circumference inward along a radius.

Range management — the planning and directing of land use. Range management secures and sustains maximum production of livestock, milk and/or cut forage compatible with other uses such as the conservation of natural resources.
Reconstruction — as used by OFDA, actions taken to reestablish a community after a period of rehabilitation subsequent to a disaster. Actions would include construction of permanent housing, full restoration of all services, and complete resumption of the pre-disaster state.

Reforestation — the establishment of a tree crop on forest land following deforestation.

Rehabilitation — as used by OFDA, actions taken in the weeks or months immediately following a disaster to restore basic services, construct temporary housing, and allow a population to function at near pre-disaster level.

Relief — the meeting of immediate needs for food, clothing, shelter and medical care for disaster victims. As used by the OFDA, the assistance given to save lives and alleviate suffering in the days and weeks following a disaster. For creeping disasters the relief period may be months or even years.

Remote sensing satellite — an orbiting spacecraft carrying a variety of instruments for measuring visible and invisible electromagnetic radiation.

Rescue — see search and rescue.

Resource inventory — a listing of the personnel and material available to disaster managers in time of emergency.

Richter scale — a scale, not limited at the top or the bottom, that measures the magnitude of an earthquake from 1 (least) to 10 (greatest), with each magnitude step on the scale representing an increase of 10 times in measured wave amplitude of the earthquake. An increase of one magnitude step has been found to correspond to an increase of 30 times the amount of energy released as seismic waves.

Risk mapping — maps that identify types and degrees of hazards, and natural phenomena of areas that may be affected by disasters.

Rockfall — free-falling or precipitous movement of a newly detached segment of bedrock of any size from a cliff or other very steep slope. A rockfall is the fastest moving landslide and is most frequent in mountain areas during spring and fall when there is repeated freezing and thawing.

Rockslide — a landslide involving a downward, usually sudden and rapid movement of newly detached segments of bedrock over an inclined surface or over pre-existing features. The moving mass is greatly deformed and usually breaks up into many smaller slides. Rockslides frequently occur in the high mountain ranges.

Rossi-Forel scale — the first scale used to measure earthquake intensity. It is commonly indicated by the abbreviation R.F. followed by the Roman numeral of the scale degree.

Runoff — the rainwater not absorbed by the ground that runs over the land surface during or following a storm.

Rupture zone — area of deformation (collapse) delineated by location of earthquake aftershocks.
Sand dune stabilization — the obstruction of moving dunes by the use of mechanical or vegetative means including afforestation.

Search and rescue — the process of locating and assisting disaster victims, sometimes through the use of specialized teams, dogs, and/or equipment.

Sea surge — a rise in sea level that results in the inundation of areas along coastlines. These phenomena are caused by the movement of ocean and sea currents, winds and major storms.

Secondary hazards — those hazards that occur as a result of another hazard or disaster, i.e., fires or landslides following earthquakes, epidemics following famines, food shortages following drought or floods.

Sedimentation — the filling of reservoirs and other areas with silt, caused by runoff, flooding, and/or soil erosion.

Seiche — a free or standing wave oscillation of the surface of water in an enclosed basin that is initiated by local atmospheric changes, tidal currents or earthquakes.

Seismic belt — an elongated earthquake zone; usually concentrated along the margins of tectonic plates, i.e. Chile, Peru, the eastern Caribbean, Central America, southern Mexico, California, southern Alaska, the Aleutians, the Kuriles, Japan, Taiwan, the Philippines, Indonesia, New Zealand, and the Alpine-Caucasian-Himalayan belt.

Seismograph — an instrument for recording vibratory movements of the ground.

Seismography — the study of earthquake measurement and analysis.

SFB — Soy-fortified bulgur

SFCM — Soy-fortified cornmeal

Shelter — housing to meet basic needs of disaster victims. Immediate post-disaster needs are met by the use of tents. Alternatives may include polypropylene houses, plastic sheeting, geodesic domes, and other similar types of temporary housing.

Shelterbelt — a strip of trees along a farm, used to protect fields or crops against wind. Also called a field windbreak.

Shock series — the foreshocks(s), the main shock, the aftershock(s), associated with earthquakes.

Siltation — see sedimentation.

Slide — see landslide.

SMS/GOES (synchronous meteorological satellites/global-observing environmental satellites) — satellites orbiting over the equator at the same rate as earth’s rotation and providing images of
visible and infrared portions of the spectrum for the same area every 30 minutes. The satellites can collect and distribute environmental data from remote unattended data collection platforms on land, in water, or in the atmosphere and quickly transmit these data to ground receiving stations.

Snow melt — liquification of snow masses, which can produce a flood as the water travels down mountain slopes and streams.

Soil conditions — the conditions of earth (moisture content, disaggregation, density, etc.) that may mitigate or intensify disaster agents, such as drought, flooding, or seismic movement.

Soil creep — the gradual and steady movement of soil and loose rock material down a slope that may be gentle but is usually steep; it is also called surficial creep.

Soil map — a map showing the distribution of soil types in relation to the various physical features of the earth.

Soil moisture — moisture within the zone of aeration of the soil, including water vapor (also part of the soil air) present in the soil pores. In some cases refers strictly to moisture within the root zone of plants.

Solfatera — a volcanic vent that emits only gases.

Staple food — a food that is regularly consumed in a country or community and from which a substantial proportion of the total calorie supply is obtained, especially by the poor population and in times of food shortage.

State of disaster — a situation of emergency.

Storm surge — a sudden rise of sea as a result of high winds and low atmospheric pressure; sometimes called a storm tide, storm wave, or tidal wave. Generally affects only coastal areas but may intrude several miles inland.

Submarine eruption — a volcanic eruption below the surface of the ocean.

Support EOCs — a system of facilities with the necessary staffing and communications to provide direction and control for one or more emergency functions of a community; e.g., police, fire, public works engineering, or backup to the main disaster operations center. Some emergency plans call for support EOCs to direct or control one or more types of emergency operations in specific geographic areas in their jurisdiction, in support of and reporting to the main EOC (see emergency operations center).

Technology transfer — information and equipment provided by one country or area to another, along with the responsibility of training individuals in the use of that information, technology and/or equipment.
Telemetry — the use of communications devices for the purpose of monitoring, measuring, and transmitting data on the physical conditions of an area, such as temperature, radiation, etc., to a receiving station. Used especially in flood monitoring, earthquake analysis, tsunami and crop forecasting.

Terracing — horizontal cuts, benches or embankments made along hillsides to reduce erosion, improve cropping, hold back runoff, improve infiltration of rain, or carry out some other function of conservation.

Tidal bore — an abrupt rise of tidal water (caused by atmospheric activities) moving rapidly inland from the mouth of an estuary.

Tornado — localized, violently destructive windstorm occurring over land. Characterized by a long funnel-shaped cloud composed of condensation and debris extending to the ground and marking the path of greatest destruction (see cyclone).

Torrent control — structures (rock or other materials) constructed to halt the erosion of stream channels.

Traction — a general term for a mode of transporting debris by running water, in which the particles are swept along close to the bed of the stream.

Trauma — injury or shock that can result when individuals are suddenly and violently thrust into a disaster situation; may be physical or mental.

Tremor — quick vibrating or shaking movement of the ground associated with an earthquake.

Tropical cyclone — a storm originating over tropical seas with winds of up to 200 miles per hour rotating around a low pressure area. Most commonly observed in the Northern Hemisphere from May to November and in the Southern Hemisphere from December to June. In the Northern Hemisphere, winds spin counterclockwise around a warm center core. In the Southern Hemisphere, the rotation is clockwise.

Tropical depression — a definite closed circulation (in the sense of a closed isobar) with a maximum sustained wind speed of below 34 knots.

Tropical disturbance — the formative weather pattern from which a cyclone may develop. It forms only in low latitudes over oceans with a warm surface temperature and is characterized by a slow fall in barometric pressure. Its strongest winds arise to the north and east of the developing center or vortex in the Northern Hemisphere, and to the south and east of the developing center or vortex in the Southern Hemisphere. Surface pressure drops to about 1010 to 1000 millibars (29.82-29.53 inches).

Tropical storm — see tropical cyclone, hurricane, typhoon.

Tsunami — the preferred Japanese term meaning sea waves generated by submarine disturbances (see seismic sea wave).

Typhoon — in the Western Pacific, a violent wind and rain storm that results from the existence of certain conditions (see cyclone, hurricane).
**Typhoon committee** — in 1968, the Economic and Social Commission for Asia and the Pacific (ESCAP) and the World Meteorological Organization jointly sponsored the establishment of an intergovernmental typhoon committee responsible for coordinating the planning and implementation of measures to minimize typhoon damage in the ESCAP region. The committee's program includes meteorological and hydrological activities, disaster prevention and preparedness, training and research.

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**U**

**Undernutrition** — the state of calorie/protein intake that is less than recommended minimum requirements and may be the result of poor eating habits, inadequate knowledge of nutritional requirements, or limited availability of necessary nutrients. Undernutrition can be a constant and undetected condition for several years before becoming debilitating.

**UNDP** — United Nations Development Program. Basic development tool of the U.N. system, with headquarters in New York and resident coordinators in each developing member country. The resident coordinator serves as UNDRO representative for disaster relief and preparedness matters in lieu of UNDRO presence.

**UNDRO** — Office of the United Nations Disaster Relief Coordinator: Geneva based organization with responsibility for coordinating disaster prevention, preparedness and relief operations within the U.N. system and among member countries.

**UNEP** — United Nations Environmental Program.

**UNESCO** — United Nations Educational, Scientific, and Cultural Organization.

**UNICEF** — United Nations Children's Fund.

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**V**

**Volag** — voluntary agency/private voluntary agency.

**Volcanic eruption** — the sudden discharge of heated matter, i.e., lava, cinders, ashes, gases, and dust, from a volcanic vent.

**Volcanic seismicity** — the shaking of the ground near a volcano, which may precede an eruption. Generally microseismic, yet increasing in magnitude within hours of potential eruption.

**Volcano** — a vent in the earth’s crust through which molten lava, gases, etc., are discharged; the mountain formed by such discharges.

**Voluntary agencies (or volags)** — nongovernmental agencies or organizations that exist in many countries throughout the world. Some possess personnel trained to assist when disaster strikes. Some volags have capabilities that extend from the local to national and international levels.

**Vortex** — the eye or center of a cyclone, hurricane, or typhoon.
**Vulnerability** — the extent to which a country, area, community or structure risks being damaged by a disaster.

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**W**

*Warning system* — communications capability designed to disseminate information on conditions that are likely to result in drought, flood, earthquake, or other similar disasters.

*Watershed* — all land and water within the confines of a drainage divide. This is also called a “catch basin,” or “drainage basin,” i.e., an area of land where runoff flows into the same stream.

*Weathering* — a process that breaks up weaker or softer rocks by atmospheric activities and gravity.

*Weather modification* — the change of natural weather phenomena by humans to effect fog dispersal, cloud modification, rainmaking, hail and lightning suppression. The modification of severe storms, however, is still in its infancy.

*Weather facsimile communications system (WEFAX)* — used to protect houses, crops, or animals against wind damages.

*Windbreak* — a barrier, such as a strip of trees, used to protect houses, crops, or animals against wind damages.

*World Meteorological Organization (WMO)* — headquartered in Geneva, Switzerland. A specialized agency of the United Nations, which promotes international cooperation in the establishment of meteorological networks, provides uniform standards in information dissemination, and encourages training and research in meteorology and hydrology.

*World Food Program (WFP)* — an agency of the United Nations Food and Agriculture Organization, located in Rome, which provides food assistance using contributions from the international community. The food assistance may be used in development activities or for emergencies.

*WSB* — Wheat-soya blend, precooked blend of whole wheat flour, defatted soy flour, vitamins, sugar, and chemicals, sometimes distributed in supplementary feeding during a disaster.

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**Z**

*Zonation* — the arrangement of an area, country, or region into zones according to its disaster incidence rate; particularly significant with regard to earthquakes (see microzonation).

*Zulu time* — see Greenwich Mean Time.
Appendix II
Organizational Resources and Sources of Information

AIA Research Corporation
Director, Earthquake and Flood Research Program
1735 New York Avenue, N.W.
Washington, D.C. 20006
U.S.A.

Building Research Establishment
Overseas Division
Building Research Station
Garston, Watford, Herts
United Kingdom

Caulfield Institute of Technology
Centre for Information and Research on Disasters and Natural Hazards (CIRDNH)
P.O. Box 197
Caulfield, East
Melbourne, Victoria 3145
Australia

Centre de Recherche sur l’Epidemiologie des Desastres
Ecole de Sante Publique
Unite d’Epidemiologie
Universite Catholique de Louvain
Clos Chapelle-aux-Champs, 30
B-1200 Bruxelles
Belgium

Disaster Management Center
University of Wisconsin–Madison
432 North Lake Street
Madison, WI  53706
U.S.A.

Earthquake Engineering Research Institute (EERI)
2620 Telegraph Avenue
Berkeley, California
U.S.A.

International Council of Building Research Studies and Documentation
704 Weena
P.O. Box 20704
Rotterdam 3
Netherlands

85 Marylebone High Street
London W1M 3DE
United Kingdom

International Institute of Seismology and Earthquake Engineering
Building Research Institute
Ministry of Construction
3-28-8 Hyakunin-cho
Shinjuku-ku, Tokyo
Japan
International Society on Disaster Medicine
10-12 Chemin de Surville
1213 Petit-Lancy
Geneva
Switzerland

International Tsunami Information Center (ITIC)
P.O. Box 50027
Honolulu, Hawaii 96850
U.S.A.

INTERTECT
P.O. Box 10502
Dallas, Texas 75207
U.S.A.

James Cook University of North Queensland
Center for Disaster Studies
P.O. James Cook University
Queensland 4811
Australia

League of Red Cross Societies
17 Chemin des Crets, Petit-Saconnex
1211 Geneva 19
Switzerland

James Lewis
101 High Street
Marshfield, Avon
Nr. Chippenham SN14 8LT
United Kingdom

Middle East Technical University
Earthquake Engineering Research Institute
Ankara
Turkey

Munchener Ruckversicherungs-Gesellschaft
Koniginstrasse 107
D-8000 Munchen 40
Federal Republic of Germany

National Building Research Station
Director, Small Buildings Under Earthquake Stress Program
Rorkee
North India

National Climatic Center
NOAA Tropical Cyclone File
Federal Building
Asheville, North Carolina 28801
U.S.A.
National Geophysical and Solar-Terrestrial Data Center
NOAA Earthquake Data File
Environmental Data and Information Service
Boulder, Colorado 80303
U.S.A.

National Information Service for Earthquake Engineering
EERC, 415 RFS
47th Street and Hoffman Boulevard
Richmond, California 94804
U.S.A.

National Science Foundation
Earthquake Hazard Mitigation
1800 G Street, N.W.
Washington, D.C. 20550
U.S.A.

Oxford Polytechnic
Ian Davis
Disaster and Human Settlements Group
Headington, Oxford OX3 OBP
United Kingdom

PADCO, Inc.
1834 Jefferson Place, N.W.
Washington, D.C. 20036
U.S.A.

Pan American Health Organization
Dr. Claude de Ville de Goyet
Emergency Preparedness and Disaster Relief Coordination
525 Twenty-Third Street, N.W.
Washington, D.C. 20037
U.S.A.

United Nations Development Programme
One U.N. Plaza
New York, New York 10017
U.S.A.

United Nations Disaster Relief Office (UNDRO)
Palais des Nations
Ch — 1211 Geneva 10
Switzerland

United Nations High Commissioner for Refugees
Palais des Nations
Ch — 1211 Geneva 10
Switzerland

United Nations Regional Housing Center
Nirman Bhawan, Maulana Azad Road
New Delhi 110011
India
University of Colorado
Natural Hazard Research Program
Institute of Behavioral Science No. 6
Boulder, Colorado 80309
U.S.A.

University of Michigan
Professor Glen V. Berg
Earthquake Codes Program
Department of Civil Engineering
Ann Arbor, Michigan
U.S.A.

University of Minnesota
Underground Space Center
11 Mines and Metallurgy Building
221 Church Street, S.E.
Minneapolis, Minnesota 55455
U.S.A.

Universidad Nacional de San Juan
Instituto de Investigaciones Antisismicas
San Juan
Argentina

University of Toronto
Natural Hazard Research Program
Department of Geography 45 Toronto, Ontario
Canada

U.S. Department of Housing and Urban Development
Office of International Affairs
Washington, D.C. 20410
U.S.A.

U.S. Department of State
Agency for International Development
Office of Foreign Disaster Assistance
Washington, D.C. 20523
U.S.A.

Volunteers in Technical Assistance, Inc. (VITA)
3706 Rhode Island Avenue
Mt. Rainier, Maryland 20822
U.S.A.
Natural Hazards: Causes and Effects

Course Evaluation

This information will be used to improve the course for other students. Thank you for taking a moment to complete this form and return to: UW-DMC, 432 North Lake St., Madison, Wisconsin, 53706, U.S.A.

Date you finished the course: __________________________________________

What is your present position? _______________________________________

How many years have you spent in disaster-related work? ________________

How many years of formal education do you have?

☐ 0 to 6 years   ☐ 7 to 12 years   ☐ 12 to 16 years   ☐ more than 16 years

How was the content level of this course?

☐ too difficult    ☐ about right    ☐ too easy

Was the course material relevant to your work?

☐ yes   ☐ no

How useful were the self-assessment tests to you?

☐ very useful    ☐ OK    ☐ not useful

How valuable was the total course?

☐ very valuable    ☐ of some value    ☐ not valuable

Additional comments: _____________________________________________________

_______________________________________________________________________

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_______________________________________________________________________

Please copy and return this form by mail or fax, or send the information via e-mail to:
University of Wisconsin–Disaster Management Center
432 Lake Street
Madison, Wisconsin 53706, USA
Fax: 1-608-263-3160 E-mail: dmc@engr.wisc.edu
Examination Request Form

This exam must be proctored (supervised) just as it would be for a course taken on campus. Generally, proctors do not charge for this service. In all cases the academic department offering the course must approve the choice of proctor. Qualified proctors include university or college registrars, deans or counselors or professors; high school principals or counselors; directors of educational services at universities, other educational organizations, correctional institutions or the armed services; certified librarians in a supervisory position; or the delegated officials at university testing centers. Students residing outside of the United States may also request, as their proctor, a local director of educational services or an officer of the United States embassy or consulate. Please copy this form as needed.

Date Submitted

Course Title

Student Information:

Name
Mailing Address

Proctor Information:

Name
Title
Organization

Complete Mailing Address (Please provide street address, in case courier service is used.)

Phone Number OR Email Address

Please return this form by mail or fax, or send the information via e-mail to:
University of Wisconsin–Disaster Management Center
432 Lake Street
Madison, Wisconsin 53706, USA
Fax: 1-608-263-3160 E-mail: dmc@engr.wisc.edu