LECTURE NOTES
ON
DISASTER MANAGEMENT

Department of Civil Engineering

Government Polytechnic Boudh

Chapter 1
INTRODUCTION TO DISASTER MANAGEMENT

Objectives of the chapter:

The main objective of this chapter is to have a basic understanding of various concepts used in Disaster Management. The concepts explained here are: Disaster, Hazard, Vulnerability, Capacity, Risk and Disaster Management Cycle. Apart from the terminologies, the chapter also tries to explain various types of disasters. In standard VIII, IX and X many of you have already been introduced to some of these concepts. This chapter has been designed to upgrade your knowledge and skill so as to have a better understanding of natural hazards, disasters and their management.

After reading this chapter the students and the teachers will be able to have a basic understanding of the concepts and should be able to differentiate between them with suitable examples.

Background:

The global context:

Disasters are as old as human history but the dramatic increase and the damage caused by them in the recent past have become a cause of national and international concern. Over the past decade, the number of natural and manmade disasters has climbed inexorably. From 1994 to 1998, reported disasters average was 428 per year but from 1999 to 2003, this figure went up to an average of 707 disaster events per year showing an increase of about 60 per cent over the previous years. The biggest rise was in countries of low human development, which suffered an increase of 142 per cent.

The figure 1.1 shows the deadliest disasters of the decade (1992 – 2001). Drought and famine have proved to be the deadliest disasters globally, followed by flood, technological disaster, earthquake, winds-torm, extreme temperature and others. Global economic loss related to disaster events average around US $880 billion per year.

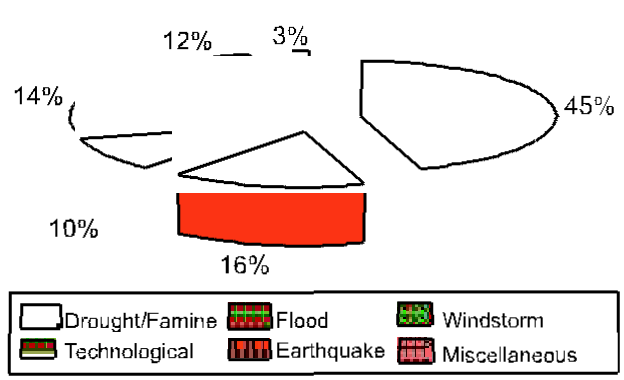


Fig : 1.1 World Scenario: Reported Deaths from all Disasters (1992-2001)

Indian scenario:

The scenario in India is no different from the global context. The super cyclone of Orissa (1999), the Gujarat earthquake (2001) and the recent Tsunami (2004) affected millions across the country leaving behind a trail of heavy loss of life, property and livelihood. Table 1.1 shows a list of some of the major disasters that have caused colossal impact on the community.

Table 1.1 ***Major disasters in India since 1970***

Sl. No	Disaster	Impact
	Cyclone	
1	29th October 1971, Orissa	Cyclone and tidal waves killed 10,000 people
2	19th November, 1977, Andhra Pradesh	Cyclone and tidal waves killed 20,000 people
3	29th and 30th October 1999, Orissa	Cyclone and tidal waves killed 9,000 and 18 million people were affected
	Earthquake	
4	20th October 1991 Uttarkashi	An earthquake of magnitude 6.6 killed 723 people
5	30th September 1993 Latur	Approximately 8000 people died and there was a heavy loss to infrastructure
6	22 May 1997 Jabalpur	39 people dead
7	29th March 1997, Chamoli	100 people dead
8	26th January, 2001, Bhuj, Gujarat	More than 10,000 dead and heavy loss to infrastructure
	Landslide	
9	July 1991, Assam	300 people killed, heavy loss to roads and infrastructure
10	August 1993, Nagaland	500 killed and more than 200 houses destroyed and about 5kms. Road damaged.
11	18th August 1998, Malpa	210 people killed. Villages were washed away
	Flood	
12	1978 Floods in North East India	3,800 people killed and heavy loss to property.
13	1994 Floods in Assam, Arunachal Pradesh, Jammu and Kashmir, Himachal Pradesh, Panjab, Uttar Pradesh, Goa, Kerala and Gujarat	More than 2000 people killed and thousands affected

While studying about the impact we need to be aware of potential hazards, how, when and where they are likely to occur, and the problems which may result of an event. In India, 59 per cent of the land mass is susceptible to seismic hazard; 5 per cent of the total geographical area is prone to floods; 8 per cent of the total landmass is prone to cyclones; 70 per cent of the total cultivable area is vulnerable to drought. Apart from this the hilly regions are vulnerable to avalanches/ landslides/hailstorms/cloudbursts. Apart from the natural hazards, we need to know about the other manmade hazards which are frequent and cause huge damage to life and property. It is therefore important that we are aware of how to cope with their effects.

We have seen the huge loss to life, property and infrastructure a disaster can cause but let us understand what is a disaster, what are the factors that lead to it and its impact.

What is a Disaster ?

Almost everyday, newspapers, radio and television channels carry reports on disaster striking several parts of the world. But what is a disaster? The term disaster owes its origin to the French word "Desastre" which is a combination of two words 'des' meaning bad and 'aster' meaning star. Thus the term refers to 'Bad or Evil star'. A disaster can be defined as *"A serious disruption in the functioning of the community or a society causing wide spread material, economic, social or environmental losses which exceed the ability of the affected society to cope using its own resources"*.

A disaster is a result from the combination of hazard, vulnerability and insufficient capacity or measures to reduce the potential **chances** of risk.

A disaster happens when a hazard impacts on the vulnerable population and causes damage, casualties and disruption. Fig: 1.2 would give a better illustration of what a disaster is. Any hazard – flood, earthquake or cyclone which is a triggering event along with greater vulnerability (inadequate access to resources, sick and old people, lack of awareness etc) would lead to disaster causing greater loss to life and property. For example; an earthquake in an uninhabited desert cannot be considered a disaster, no matter how strong the intensities produced.

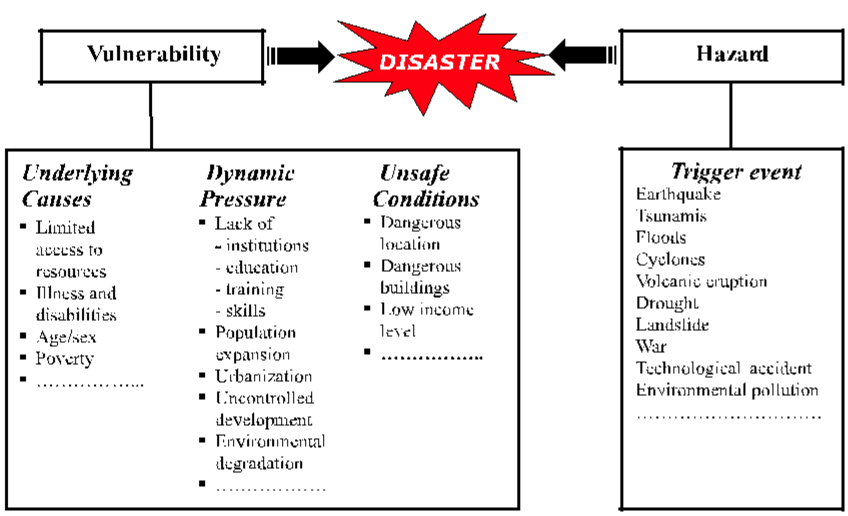


Fig: 1.2

An earthquake is disastrous only when it affects people, their properties and activities. Thus, disaster occurs only when hazards and vulnerability meet. But it is also to be noted that with greater capacity of the individual/community and environment to face these disasters, the impact of a hazard reduces. Therefore, we need to understand the three major components namely **hazard, vulnerability and capacity** with suitable examples to have a basic understanding of disaster management.

What is a Hazard ? How is it classified ?

Hazard may be defined as *"a dangerous condition or event, that threat or have the potential for causing injury to life or damage to property or the environment."* The word 'hazard' owes its origin to the word 'hasard' in old French and 'az-zahr' in Arabic meaning 'chance' or 'luck'. Hazards can be grouped into two broad categories namely natural and manmade.

1. Natural hazards are hazards which are caused because of natural phenomena (hazards with meteorological, geological or even biological origin). Examples of natural hazards are cyclones, tsunamis, earth-quake and volcanic eruption which are exclusively of natural origin. Landslides, floods, drought, fires are socio-natural hazards since their causes are both natural and man made. For example flooding may be caused because of heavy rains, landslide or blocking of drains with human waste.

2. Manmade hazards are hazards which are due to human negligence. Manmade hazards are associated with industries or energy generation facilities and include explosions, leakage of toxic waste, pollution, dam failure, wars or civil strife etc.

The list of hazards is very long. Many occur frequently while others take place occasionally. However, on the basis of their genesis, they can be categorized as follows:

Table 1.2: Various types of hazards

Types	Hazards	
Geological Hazards	1. Earthquake 2. Tsunami 3. Volcanic eruption	4. Landslide 5. Dam burst 6. Mine Fire
Water & Climatic Hazards	1. Tropical Cyclone 2. Tornado and Hurricane 3. Floods 4. Drought 5. Hailstorm	6. Cloudburst 7. Landslide 8. Heat & Cold wave 9. Snow Avalanche 10. Sea erosion
Environmental Hazards	1. Environmental pollutions 2. Deforestation	3. Desertification 4. Pest Infection
Biological	1. Human / Animal Epidemics 2. Pest attacks	3. Food poisoning 4. Weapons of Mass Destruction

Types	Hazards	
Chemical, Industrial and Nuclear Accidents	1. Chemical disasters 2. Industrial disasters	3. Oil spills/Fires 4. Nuclear
Accident related	1. Boat / Road / Train accidents / air crash Rural / Urban fires Bomb /serial bomb blasts 2. Forest fires	3. Building collapse 4. Electric Accidents 5. Festival related disasters 6. Mine flooding

What is vulnerability ?

Vulnerability may be defined as *"The extent to which a community, structure, services or geographic area is likely to be damaged or disrupted by the impact of particular hazard, on account of their nature, construction and proximity to hazardous terrains or a disaster prone area."*

Vulnerabilities can be categorized into physical and socio-economic vulnerability.

Physical Vulnerability: It includes notions of **who** and **what** may be damaged or destroyed by natural hazard such as earth-quakes or floods. It is based on the physical condition of people and elements at risk, such as buildings, infrastructure etc; and their proximity, location and nature of the hazard. It also relates to the technical capability of building and structures to resist the forces acting upon them during a hazard event.

Figure 1.3 shows the settlements which are located in hazardous slopes. Many landslide and flooding disasters are linked to what you see in the figure 1.3. Unchecked growth of settlements in unsafe areas exposes the people to the hazard. In case of an earth-quake or landslide the ground may fail and the houses on the top may topple or slide and affect the settlements at the lower level even if they are designed well for earthquake forces.

Socio-economic Vulnerability: The degree to which a population is affected by a hazard

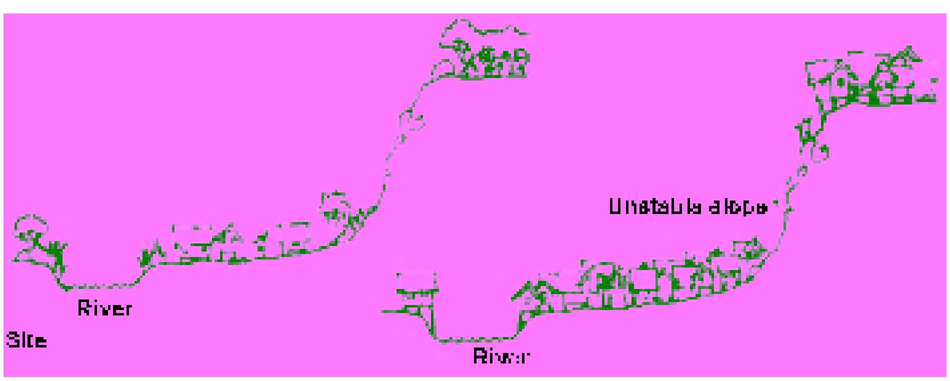


Figure 1.3 : Site after pressures from population growth and urbanization

will not merely lie in the physical components of vulnerability but also on the socio-economic conditions. The socio-economic condition of the people also determines the intensity of the impact. For example, people who are poor and living in the sea coast don't have the money to construct strong concrete houses. They are generally at risk and loose their shelters when ever there is strong wind or cyclone. Because of their poverty they too are not able to rebuild their houses.

What is capacity ?

Capacity can be defined as *"resources, means and strengths which exist in households and communities and which enable them to cope with, withstand, prepare for, prevent, mitigate or quickly recover from a disaster".* People's capacity can also be taken into account. Capacities could be:

Physical Capacity: People whose houses have been destroyed by the cyclone or crops have been destroyed by the flood can salvage things from their homes and from their farms. Some family members have skills, which enable them to find employment if they migrate, either temporarily or permanently.

Socio-economic Capacity: In most of the disasters, people suffer their greatest losses in the physical and material realm. Rich people have the capacity to recover soon because of their wealth. In fact, they are seldom hit by disasters because they live in safe areas and their houses are built with stronger materials. However, even when everything is destroyed they have the capacity to cope up with it.

Hazards are always prevalent, but the hazard becomes a disaster only when there is greater vulnerability and less of capacity to cope with it. In other words the frequency or likelihood of a hazard and the vulnerability of the community increases the risk of being severely affected.

What is risk ?

Risk is a *"measure of the expected losses due to a hazard event occurring in a given area over a specific time period. Risk is a function of the probability of particular hazardous event and the losses each would cause."* The level of risk depends upon:

Nature of the hazard

Vulnerability of the elements which are affected

Economic value of those elements

A community/locality is said to be at 'risk' when it is exposed to hazards and is likely to be adversely affected by its impact. Whenever we discuss 'disaster management' it is basically 'disaster risk management'. Disaster risk management includes all measures which reduce disaster related losses of life, property or assets by either reducing the hazard or vulnerability of the elements at risk.

Disaster Risk Reduction can take place in the following ways:

1. Preparedness

This protective process embraces measures which enable governments, communities and individuals to respond rapidly to disaster situations to cope with them effectively. Preparedness includes the formulation of viable emergency plans, the development of warning systems, the maintenance of inventories and the training of personnel. It may also embrace search and rescue measures as well as evacuation plans for areas that may be at risk from a recurring disaster.

Preparedness therefore encompasses those measures taken before a disaster event which are aimed at minimising loss of life, disruption of critical services, and damage when the disaster occurs.

2. Mitigation

Mitigation embraces measures taken to reduce both the effect of the hazard and the vulnerable conditions to it in order to reduce the scale of a future disaster. Therefore mitigation activities can be focused on the hazard itself or the elements exposed to the threat. Examples of mitigation measures which are hazard specific include water management in drought prone areas, relocating people away from the hazard prone areas and by strengthening structures to reduce damage when a hazard occurs.

In addition to these physical measures, mitigation should also aim at reducing the economic and social vulnerabilities of potential disasters

Disaster Management Cycle

Disaster Risk Management includes sum total of all activities, programmes and measures which can be taken up before, during and after a disaster with the purpose to avoid a disaster, reduce its impact or recover from its losses. The three key stages of activities that are taken up within disaster risk management are:

1. Before a disaster (pre-disaster).

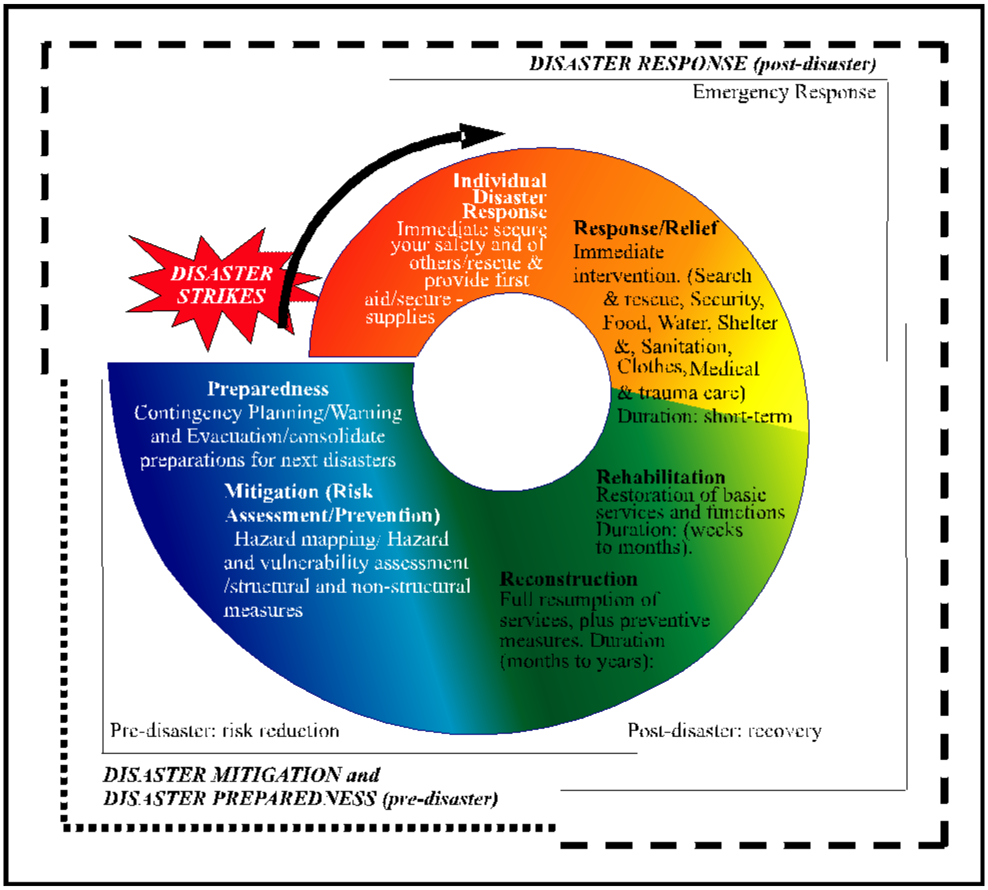
Activities taken to reduce human and property losses caused by a potential hazard. For example carrying out awareness campaigns, strengthening the existing weak structures, preparation of the disaster management plans at household and community level etc. Such risk reduction measures taken under this stage are termed as *mitigation and preparedness activities.*

2. During a disaster (disaster occurrence).

Initiatives taken to ensure that the needs and provisions of victims are met and suffering is minimized. Activities taken under this stage are called *emergency response activities.*

3. After a disaster (post-disaster)

Initiatives taken in response to a disaster with a purpose to achieve early recovery and rehabilitation of affected communities, immediately after a disaster strikes. These are called as *response and recovery activities.*



Reference: Are you prepared? Learning from the Great Hanshin-Awaji Earthquake Disaster - Handbook for Disaster Reduction and Volunteer activities

Figure 1.4 : Disaster Management

In the subsequent chapters we would discuss in detail some of the major hazards prevalent in our country its causes, impact, preparedness and mitigation measures that need to be taken up.

Reference for further reading:

1. Reading materials of 11th Community Based Disaster Risk Management Course, Bangkok, Thailand July 21 – August 1, 2003.

2. Anderson, M. and P. Woodrow. 1989. Rising from the Ashes: Development Strategies in Times of Disaster. UNESCO and West view Press, Inc., Colorado.

3. Anderson M. Vulnerability to Disaster and Sustainable Development: A General Framework for Assessing Vulnerability.

4. UNDP Disaster Management Training Programme.1992. An Overview of Disaster Management.

5. International Federation of Red Crescent Societies World Disaster Report: Focus on Community resilience.

6. http://www.unisdr.org/eng/library/lib-terminology

Exercise

1) Explain with examples the difference between hazard, and vulnerability. How does capacity influence vulnerability?

2) Explain in detail the vulnerability profile of our country.

3) Define risk and suggest two ways of reducing risk with appropriate examples.

4) Briefly discuss the Disaster Management Cycle with suitable examples.

Chapter 2
NATURAL HAZARDS - CAUSES, DISTRIBUTION PATTERN, CONSEQUENCE, AND MITIGATION MEASURES

The discussion on various terminologies has helped us in having a basic understanding of disaster management. However, each hazard has its own characteristics. To understand the significance and implications of various types of hazards we must have a basic understanding about the nature, causes and effects of each hazard type and the mitigation measures that need to be taken up. In this chapter, we would discuss the following hazards namely earthquake, tsunami, landslide, flood, cyclone and drought that we normally face in our country.

2.1 Earthquake

Earthquake is one of the most destructive natural hazard. They may occur at any time of the year, day or night, with sudden impact and little warning. They can destroy buildings and infrastructure in seconds, killing or injuring the inhabitants. Earthquakes not only destroy the entire habitation but may de-stabilize the government, economy and social structure of the country. ***But what is an earthquake?*** It is the sudden shaking of the earth crust. The impact of an earthquake is sudden and there is hardly any warning, making it *impossible* to predict.

Cause of Earthquake :

The earth's crust is a rocky layer of varying thickness ranging from a depth of about 10 kilometers under the sea to 65 kilometers under the continents. The crust is *not* one piece but consists of portions called ***'plates'*** which vary in size from a few hundred to thousands of kilometers (Fig 2.1.1). The '***theory of plate tectonics'*** holds that the plates ride up on the more mobile mantle, and are driven by some yet unconfirmed mechanisms, perhaps thermal convection currents. When these plates contact each other, stress arises in the crust (Fig 2.1.2).

These stresses can be classified according to the type of movement along the plate's boundaries:

a) pulling away from each other,

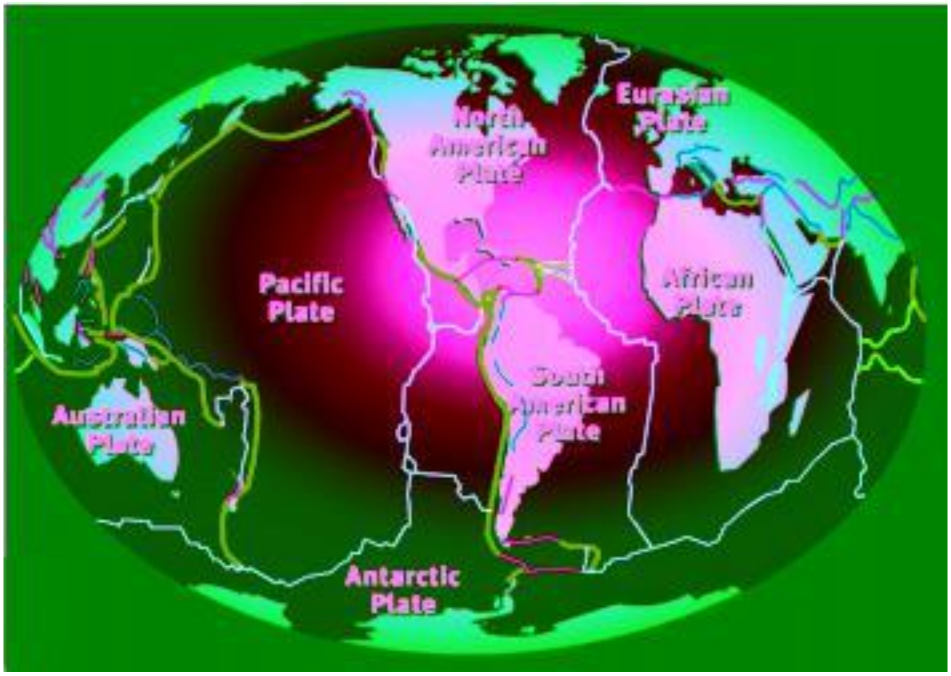
b) pushing against one another and

c) sliding sideways relative to each other.

All these movements are associated with earthquakes.

The areas of stress at plate boundaries which release accumulated energy by slipping or rupturing are known as *'faults'*. The theory of 'elasticity' says that the crust is continuously stressed by the movement of the tectonic plates; it eventually reaches a point of maximum supportable strain. A rupture then occurs along the fault and the rock rebounds under its own elastic stresses until the strain is relieved. The fault rupture generates vibration called seismic (from the Greek 'seismos' meaning shock or

Fig. : 2.1.1 : Tectonic Plates



Seven major plates and several minor ones- They move a few inches a year, riding on semi-molten layers of rock underneath the crust

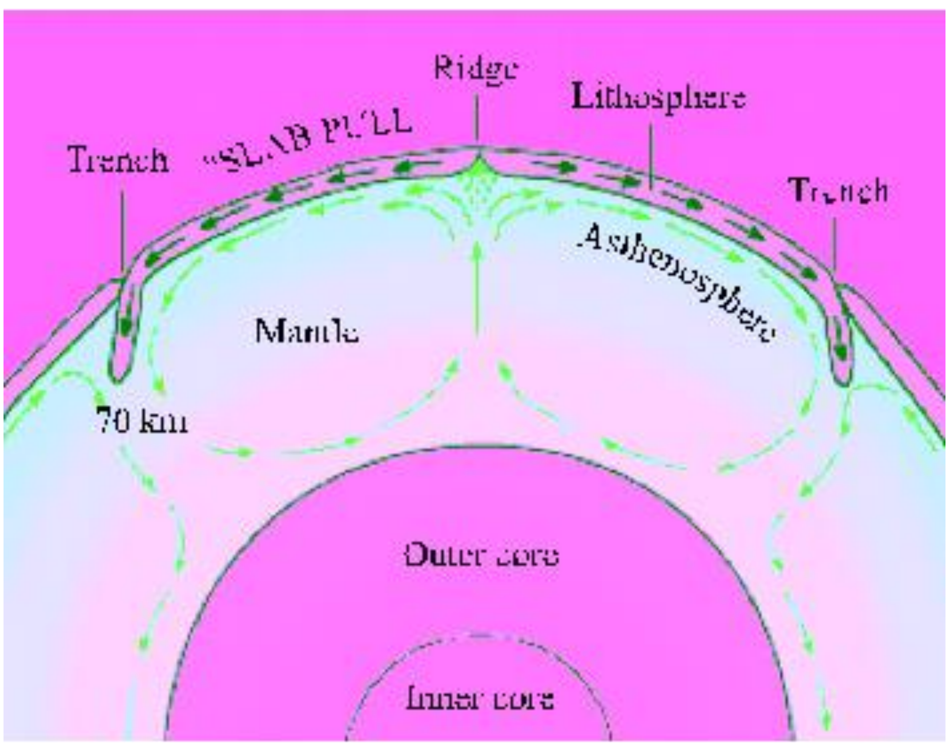
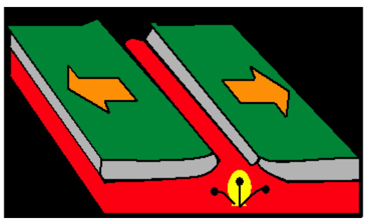
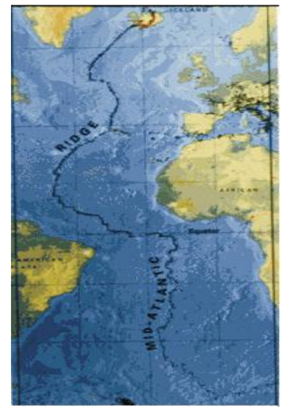
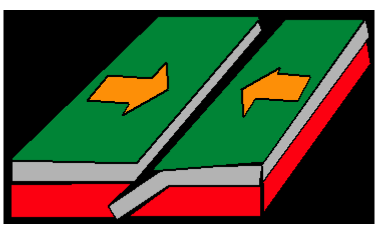
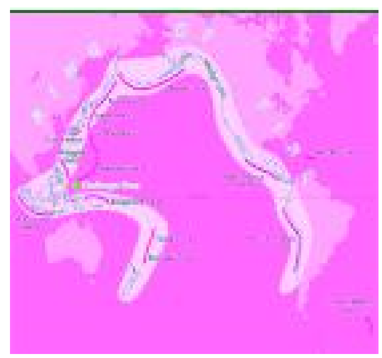
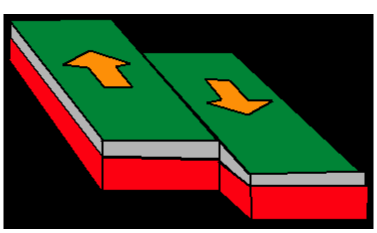


Fig. : 2.1.2 : Tectonic Plates

Table 2.1.1 Different types of plate movement

Plate Motions	**Examples**	**Illustrations**
Divergent - where new crust is generated as the plates pull away from each other. 	The Mid-Atlantic Ridge, which splits nearly the entire Atlantic Ocean north to south, is probably the best-known and most-studied example of a divergent-plate boundary. The rate of spreading along the Mid-Atlantic Ridge averages about 2.5 centimeters per year (cm/yr), or 25 km in a million years.	 Mid Atlantic Ridge
2. Convergent - where crust is destroyed as one plate dives under another. 	Ring of Fire and The Himalayan mountain range dramatically demonstrates one of the most visible and spectacular consequences of plate tectonics.	
3. Transformational - where crust is neither produced nor destroyed as the plates slide horizontally past each other. 	The San Andreas fault slicing through the Carrizo Plain in the Temblor Range east of the city of San Luis Obispo	 San Andreas fault, California, U.S.A

earthquake) waves, which radiates from the focus in all directions.

The point of rupture is called the *'focus'* and may be located near the surface or deep below it. The point on the surface directly above the focus is termed as the *'epicenter'* of the earthquake (see Fig 2.1.3).

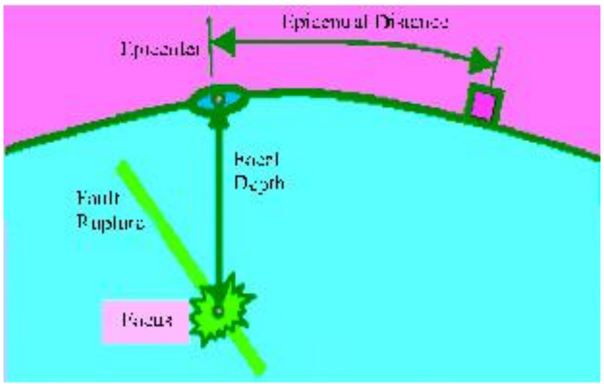


Fig 2.1.3

General characteristics

Earthquake vibrations occur in a variety of frequencies and velocities. The actual rupture process may last for a few seconds to as long as one minute for a major earthquake. The ground shaking is caused by '***body waves' and 'surface wave'.***

Body waves (P and S waves) penetrate the body of the earth, vibrating fast. 'P' waves travel about 6 kilometers per hour and 'S' waves travel with a speed of 4 kilometers per hour.

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

Earthquakes can be of three types based on the focal depth:

- Deep:- 300 to 700 kms from the earth surface
- Medium:- 60 to 300 kms
- Shallow: less than 60 kms

The deep focus earthquakes are rarely destructive because by the time the waves reach the surface the impact reduces. Shallow focus earthquakes are more common and are extremely damaging because of their proximity to the surface.

Measuring Earthquakes

Earthquakes can be described by the use of two distinctively different scales of measurement demonstrating magnitude and intensity. Earthquake **magnitude** or amount of energy released is determined by the use of a ***seismograph'*** which is an instrument that continuously records ground vibration. The scale was developed by a seismologist named *Charles Richter.* An earthquake with a magnitude 7.5 on the Richter scale releases 30 times the energy than one with 6.5 magnitudes. An earthquake of magnitude 3 is the smallest normally felt by humans. The largest earthquake that has been recorded with this system is 9.25 (Alaska, 1969 and Chile, 1960).

The **second type** of scale, the earthquake **intensity** scale measures the effects of an earthquake where it occurs. The most widely used scale of this type was developed in 1902 by *Mercalli* an Italian seismologist. The scale was extended and modified to suit the modern times. It is called the **Modified Mercalli Scale**, which expresses the intensity of earthquake effect on people, structure and the earth's surface in values from I to XII. With an intensity of VI and below most of the people can feel the shake and there are cracks on the walls, but with an intensity of XII there is general panic with buildings collapsing totally and there is a total disruption in normal life.

Predictability: Although some scientists claim ability to predict earthquakes, the methods are controversial. Accurate and exact predictions of such sudden incidents are still not possible.

Typical adverse effects

Physical damage:

Fig 2.1.4 shows the adverse effect s of an earthquake

Damage occurs to human settlement, buildings, structures and infrastructure, especially bridges, elevated roads, railways, water towers, pipelines, electrical generating facilities. Aftershocks of an earthquake can cause much greater damage to already weakened structures.

Secondary effects include fires, dam failure and landslides which may block water ways and also cause flooding. Damage may occur to facilities using or manufacturing dangerous materials resulting in possible chemical spills. There may also be a break down of communication facilities. The effect of an earthquake is diverse. There are large number of casualties because of the poor engineering design of the buildings and close proximity of the people. About 95 per cent of the people who are killed or who are affected by the earthquake is because of the building collapse. There is also a huge loss to the public health system, transport and communication and water supply in the affected areas.

Distribution pattern of Earthquakes in India

India falls quite prominently on the 'Alpine - Himalayan Belt'. This belt is the line along which the Indian plate meets the Eurasian plate. This being a convergent plate, the Indian plate is thrusting underneath the Eurasian plate at a speed of 5 cm per year. The movement gives rise to tremendous stress which keeps accumulating in the rocks and is released from time to time in the form of earthquakes.

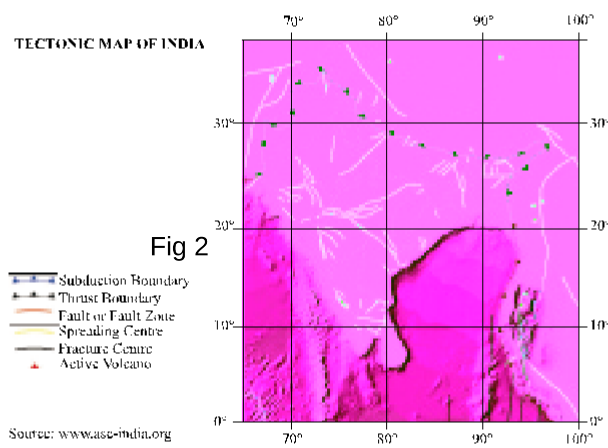


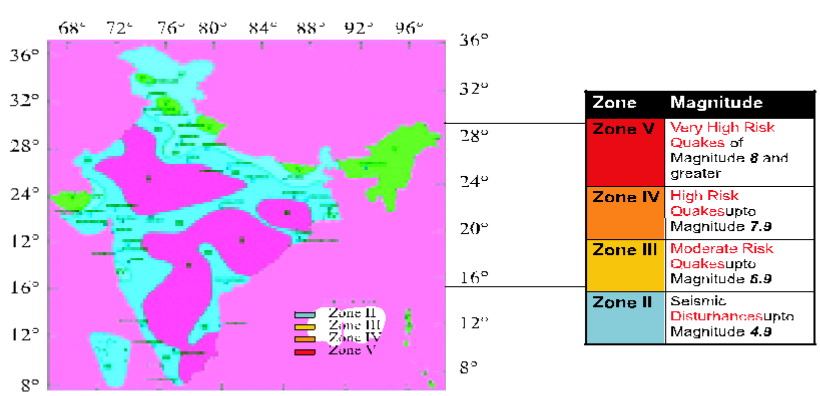
Fig 2.1.5 Fault lines in India

Table 2.1.2: List of significant Earthquakes in India

Year	Location	Magnitude of 6+
1950	Arunachal Pradesh - China Border	8.5
1956	Anjar, Gujarat	7.0
1967	Koyna, Maharashtra	6.5
1975	Kinnaur, Himachal Pradesh	6.2
1988	Manipur - Myanmar Boarder	6.6
1988	Bihar - Nepal Border	6.4
1991	Uttarkashi - Uttar Pradesh Hills	6.0
1993	Latur - Maharashtra	6.3
1997	Jabalpur, Madhya Pradesh	6.0
1999	Chamoli, Uttar Pradesh	6.8
2001	Bhuj, Gujarat	6.9
2005	Muzaffarabad (Pakistan) Impact in Jammu & Kashmir	7.4

The seismic zoning map of India is divided into four zones namely Zone II, III, IV and V, with zone V shown in red colour in figure 2.1.6 being most vulnerable to earthquakes. Much of India lies in zone III. New Delhi the capital city of India lie in zone IV where as big cities like Mumbai and Chennai are in zone III.

Fig: 2.1.6



Source: IS 1893 (Part 1) : 2002 (BIS)

Fig: 2.1.6

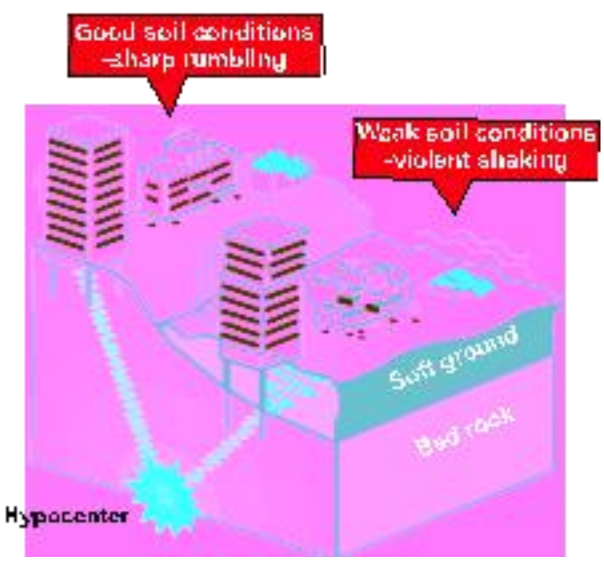
Possible risk reduction measures:

Community preparedness: Community preparedness is vital for mitigating earthquake impact. The most effective way to save you even in a slightest shaking is 'DROP, COVER and HOLD'.

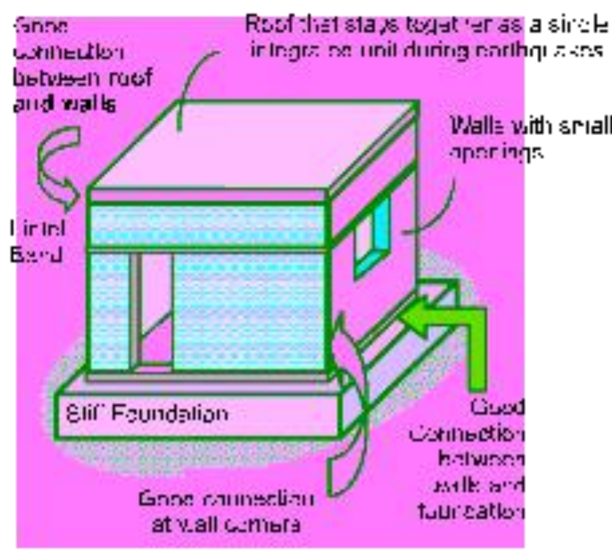
Planning: The Bureau of Indian Standards has published building codes and guidelines for safe construction of buildings against earthquakes. Before the buildings are constructed the building plans have to be checked by the Municipality, according to the laid down **bylaws**. Many existing lifeline buildings such as hospitals, schools and fire stations may not be built with earthquake safety measures. Their earthquake safety needs to be upgraded by retrofitting techniques.

Public education is educating the public on causes and characteristics of an earthquake and preparedness measures. It can be created through sensitization and training programme for community, architects, engineers, builders, masons, teachers, government functionaries teachers and students.

Engineered structures: Buildings need to be designed and constructed as per the building by laws to withstand ground shaking. Architectural and engineering inputs need to be put together to improve building design and construction practices. The soil type needs to be analyzed before construction. Building structures on soft soil should be avoided. Buildings on soft soil are more likely to get damaged even if the magnitude of the earthquake is not strong as shown in Figure 2.1.7. Similar problems persist in the buildings constructed on the river banks which have alluvial soil.



Effect of Soil type on ground shaking



Essential requirements in a Masonry building

Fig: 2.1.7

Web Resources:

- § www.nicee.org: Website of The National Information Center of Earthquake Engineering (NICEE) hosted at Indian Institute of Technology Kanpur (IITK) is intended to collect and maintain information resources on Earthquake Engineer-ing and make these available to the interested professionals, researche-rs, academicians and others with a view to mitigate earthquake disasters in India. The host also gives IITK-BMTPC Earthquake Tips.
- § www.imd.ernet.in/section/seismo/static/welcome.htm Earthquake Information – India Meteorological Department, India. IMD detects and locates earthquakes and evaluates seismicity in different parts of the country.
- § www.bmtpc.org In order to bridge the gap between research and development and large scale application of new building material technologies, the erstwhile Ministry of Urban Development, Government of India, had established the Building Materials And Technology Promotion Council in July 1990.
- § www.earthquake.usgs.gov Source for science about the Earth, its natural and living resources, natural hazards, and the environment.

Exercise:

1. What are earthquakes ? List out the causes of an earthquake.
2. Differentiate between magnitude and intensity of an earthquake. How are they measured ?
3. Identify three major mitigation measures to reduce earthquake risk.

2.2 Tsunami

The term Tsunami has been derived from a Japanese term Tsu meaning 'harbor' and nami meaning 'waves'. Tsunamis are popularly called tidal waves but they actually have nothing to do with the tides. These waves which often affect distant shores, originate by rapid displacement of water from the lake or the sea either by seismic activity, landslides, volcanic eruptions or large meteoroid impacts. What ever the cause may be sea water is displaced with a violent motion and swells up, ultimately surging over land with great destructive power. The effects of a tsunami can be unnoticeable or even destructive.

Causes of a Tsunami

The geological movements that cause tsunamis are produced in three major ways. The most common of these are *fault movements on the sea floor*, accom-panied by an earth-quake. They release huge amount of energy and have the capacity to cross oceans. The degree of movement depends on how fast the earthquake occurs and how much water is displaced. Fig 3.1 shows how an earthquake causes tsunami.

The second most common cause of the tsunami is a *landslide* either occurring under water or originating above the sea and then plunging into the water. The largest tsunami ever produced by a landslide was in Lituya

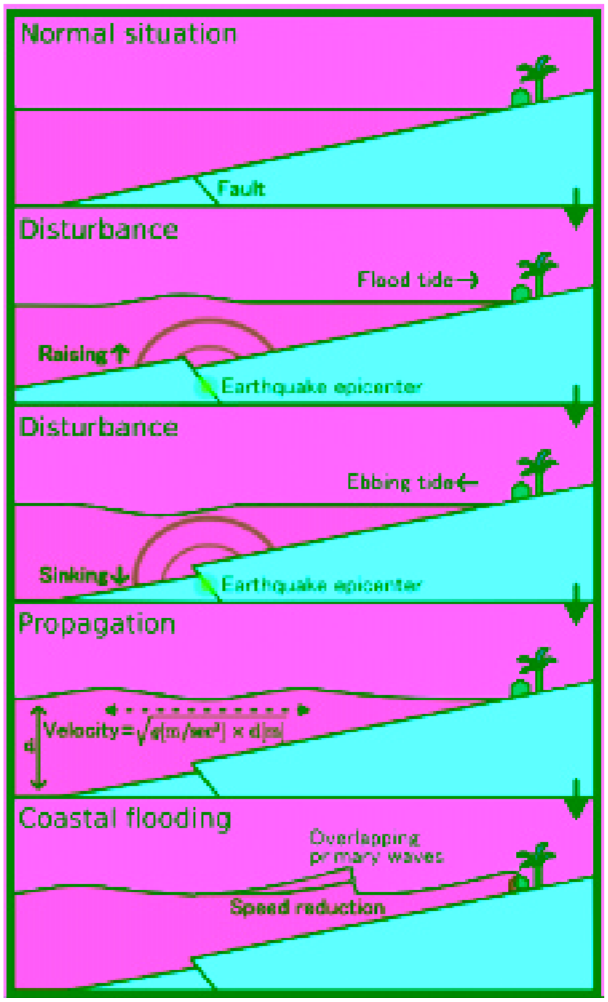


Fig 3.1 An Earthquake causing Tsunami

Bay, Alaska 1958. The massive rock slide produced a wave that reached a high water mark of 50 - 150 meters above the shoreline.

The third major cause of tsunami is *volcanic activity*. The flank of a volcano located near the shore or under water may be uplifted or depressed similar to the action of a fault, or, the volcano may actually explode. In 1883, the violent explosion of the famous volcano, Krakotoa in Indonesia, produced tsunami measuring 40 meters which crushed upon Java and Sumatra. Over 36,000 people lost their lives in this tyrant waves.

Fig 2.2.2 Picture of a Tsunami

General Characteristics:

Tsunami differs from ordinary ocean waves, which are produced by wind blowing over water. The tsunamis travel much faster than ordinary waves. Compared to normal wave speed of 100 kilometers per hour, tsunami in the deep water of the ocean may travel the speed of a jet airplane - 800 kilometers per hour! And yet, in spite of their speed, tsunami increases the water height only 30-45cm and often passes unnoticed by ships at sea.

Contrary to the popular belief, the tsunami is not a single giant wave. It is possible for a tsunami to consist of ten or more waves which is then termed as 'tsunami wave train'. The waves follow each other 5 to 90 minutes apart. Tsunami normally causes flooding as a huge wall of water enters the main land.

Predictability:

There are two distinct types of tsunami warning:

a) International tsunami warning systems and

b) Regional warning systems.

Fig 2.2.3 Flooding caused by the 2004 Tsunami in Tamil Nadu

Tsunamis have occurred in all the oceans and in the Mediterranean Sea, but the great majority of them have occurred in the Pacific Ocean. Since scientists cannot exactly predict earthquakes, they also cannot exactly predict when a tsunami will be generated.

a) *International Tsunami Warning Systems:* Shortly after the Hilo Tsunami (1946), the Pacific Tsunami Warning System (PTWS) was developed with its operational center at the Pacific Tsunami Warning Center (PTWC) near Honolulu, Hawaii. The PTWC is able to alert countries several hours before the tsunami strikes. The warning includes predicted arrival time at selected coastal communities where the tsunami could travel in few hours. A tsunami watch is issued with subsequent arrival time to other geographic areas.

b) *Regional Warning Systems* usually use seismic data about nearby earthquakes to determine if there is a possible local threat of a tsunami. Such systems are capable enough to provide warnings to the general public in less than 15 minutes.

In 1995 the US National Oceanic and Atmospheric Administration (NOAA) began developing the Deep Ocean Assessment and Reporting of Tsunami (DART) system. By 2001 six stations had been deployed in the Pacific Ocean. Each station consists of a sea bed bottom pressure recorder (at a depth of about 6000 m) which detects the passage of a tsunami and transmits the data to a surface buoy. The surface buoy then radios the information to the PTWC.

In India, the ***Survey of India*** maintains a tide gauge network along the coast of India. The gauges are located in major ports as shown in the figure 2.2.4. The day-to-day maintenance of the gauge is carried with the assistance from authorities of the ports.

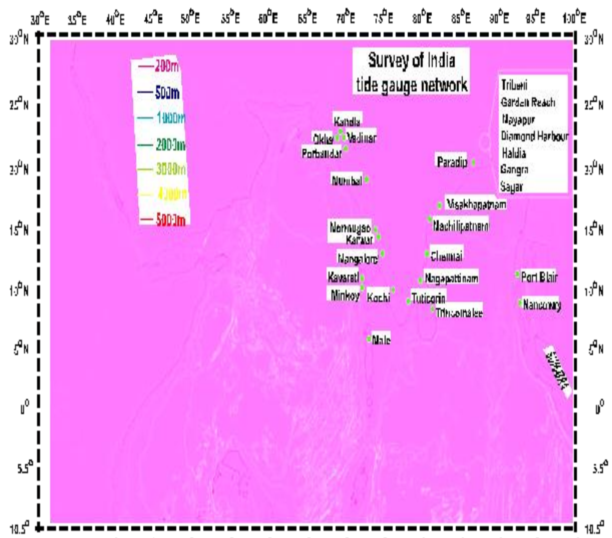


Fig. 2.2.4 : Tide gauge network in India

Apart from the tide gauge, tsunami can be detected with the help of radars. The 2004 Indian Ocean tsunami, recorded data from four radars and recorded the height of tsunami waves two hours after the earthquake. It should be noted that the satellites observations of the Indian Ocean tsunami would not have been of any use in delivering warnings, as the data took five hours to process and it was pure chance that the satellites were overhead at that time. However, in future it is possible that the space-based observation might play a direct role in tsunami warning.

Typical adverse effects:

Local tsunami events or those less than 30 minutes from the source cause the majority of damage. The force of the water can raze everything in its path. It is normally the flooding affect of the tsunami that causes major destruction to the human settlements, roads and infrastructure thereby disrupting the normal functioning of the society.

Withdrawal of the tsunami causes major damage. As the waves withdraw towards the ocean they sweep out the foundations of the buildings, the beaches get destroyed and the houses carried out to sea. Damage to ports and airports may prevent importation of needed food and medical supplies. Apart from the physical damage, there is a huge impact on the public health system. Deaths mainly occur because of drowning as water inundates homes. Many people get washed away or crushed by the giant waves and some are crushed by the debris, causes.

There are very few evidences which show that tsunami flooding has caused large scale health problem.

Availability of drinking water has always been a major problem in areas affected by a disaster. Sewage pipes may be damaged causing major sewage disposal problems. Open wells and other ground water may be contaminated by salt water and debris and sewage. Flooding in the locality may lead to crop loss, loss of livelihood like boats and nets, environmental degradation etc.

Tsunami - A Terror

The year 2004 has come to an end.
A memorable year it has been. Ups
and downs and highs and lows in
the past year we have seen. The
year went by smoothly but came to
a crashing end.
Nature's fury shattered the life of so many
Broken pieces we are still to mend.
Tsunami - a huge tidal wave swept
over the life of all. Nature's wrath
spared none Mankind suffered a
great fall. Thousands of homes were
destroyed Thousands of lives were
taken.
We have taken nature for granted and
a heavy price we have forsaken.

The aftershocks of the
disaster We are still enduring.
The ones alive are being given
help Their pains we are curing.
In the history of mankind
This blemish will remain forever.
When reminded of this grave calamity
The world will always shiver.
The wounds will take time to heal
This disaster will always remain in our
mind.
But we will stand up with a smile
And walk ahead leaving this terror
behind.

Ashwathi Thampi
J.K. Singhania School
(Standard VIII), Thane

Distribution pattern of Tsunami in India:

Even though India has not faced frequent Tsunamis but there is a need to identify the areas that are generally affected by Tsunamis. The whole of the Indian coastal belt is prone to Tsunami. Table 2.2.1 shows incidents of tsunamis that have affected our country.

Table 2.2.1: History of tsunami's in India

Date	Location	Impact
1524	Near Dabhol, Maharashtra	Sufficient data not available
02 April 1762	Arakan Coast, Myanmar	Sufficient data not available
16 June 1819	Rann of Kachchh, Gujarat	Sufficient data not available
31 October 1847	Great Nicobar Island	Sufficient data not available
31 December 1881	An earthquake of 7.9 in the Richter scale in Car Nicobar Island	Entire east coast of India and Andaman & Nicobar Islands; 1m tsunamis were recorded at Chennai.
26 August 1883	Explosion of the Krakatoa volcano in Indonesian.	East coast of India was affected; 2m tsunamis were recorded at Chennai.
26 June 1941	An 8.1 Richter scale earthquake in the Andaman archipelago.	East coast of India was affected but no estimates of height of the tsunami is available
27 November 1945	An 8.5 Richter scale earthquake at a distance of about 100km south of Karachi	West coast of India from north to Karwar was affected; 12m tsunami was felt at Kandla.
26 December 2004	Banda Aceh, Indonesia; Tamil Nadu, Kerala, Andhra Pradesh, Andaman and Nicobar Islands, India; Sri Lanka; Thailand; Malaysia; Kenya; Tanzania	The East cost of India was affected. The waves measured around 10 m high killing more than 10,000 precious lives.

Possible risk reduction measures:

While it is of course not possible to prevent a tsunami, in certain tsunami prone countries some measures have been taken to reduce the damage caused on shore. *Japan* has implemented an extensive programme of building *tsunami walls* of up to 4.5m (13.5 ft) high in front of populated coastal areas. Other localities have built *flood gates* and channels to redirect the water from incoming tsunamis. However, their effectiveness has been questioned, as tsunamis are often higher than the barriers. For instance, the tsunami which hit the island of Hokkaido on July 12, 1993 created waves as much as 30m (100 ft) tall - as high as a 10-story building. The port town of Aonae on Hokkaido was completely surrounded by a tsunami wall, but the waves washed right over the wall and destroyed all the wood-

Fig 2.2.5 Tsunami walls in populated coastal areas of Japan

framed structures in the area. The wall may have succeeded in slowing down and moderating the height of the tsunami but it did not prevent major destruction and loss of life.

Some other systematic measures to protect coastlines against tsunamis include:

Site Planning and Land Management- Within the broader framework of a comprehensive plan, site planning determines the location, configuration, and density of development on particular sites and is, therefore, an important tool in reducing tsunami risk.

Fig 2.2.6 Damaged houses constructed on the sea coast in Chennai

- The designation and zoning of tsunami hazard areas for such open-space uses as agriculture, parks and recreation, or natural hazard areas is recommended as the first land use planning strategy. This strategy is designed to keep development at a minimum in hazard areas.

- In areas where it is not feasible to restrict land to open-space uses, other land use planning measures can be used. These include strategically controlling the type of development and uses allowed in hazard areas, and avoiding high-value and high-occupancy uses to the greatest degree possible.

Engineering structures – Most of the habitation of the fishing community is seen in the coastal areas. The houses constructed by them are mainly of light weight materials without any engineering inputs. Therefore there is an urgent need to educate the community about the good construction practices that they should adopt such as:

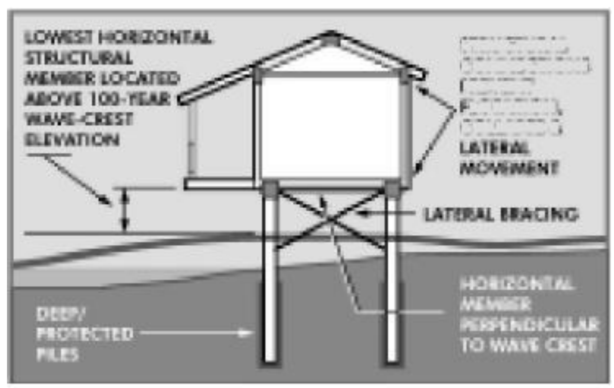


Fig 2.2.7 Design solution to tsunami effect

- Site selection – Avoid building or living in buildings within several hundred feet of the coastline as these areas are more likely to experience damage from tsunamis.
- Construct the structure on a higher ground level with respect to mean sea level.

- Elevate coastal homes: Most tsunami waves are less than 3 meters in height. Elevating house will help reduce damage to property from most tsunamis.
- Construction of water breakers to reduce the velocity of waves.
- Use of water and corrosion resistant materials for construction.
- Construction of community halls at higher locations, which can act as shelters at the time of a disaster.

Flood management - Flooding will result from a tsunami. Tsunami waves will flood the coastal areas. Flood mitigation measures could be incorporated.

Web Resources:

§ http://ioc.unesco.org/itsu/ IOC/UNESCO International Coordination group for the Tsunami Warning System in the Pacific (ICG/ ITSU), Paris, France

§ http://quake.usgs.gov/tsunami/ Tsunamis and Earthquakes, USGS, USA

§ www.asc-india.org Amateur Seismic Centre is a comprehensive website carrying details of state wise seismicity for the country. This also has extensive reports on various past Earthquakes/Tsunamis.

§ http://www.prh.noaa.gov/pr/itic/ International Tsunami Information Center, Honolulu, Hawaii

§ http://www.tsunami.org/ Pacific Tsunami Museum site. Includes answers to frequently asked questions, links, and information related to Pacific Ocean tsunamis.

Exercise:

1. What is Tsunami? Identify three causes, consequences and impact of tsunami waves.
2. How can we predict Tsunami?
3. Suggest five risk reduction measures that can be taken up to prevent severe damage.

2.3 CYCLONE

What is a Cyclone?

Cyclone is a region of low atmospheric pressure surrounded by high atmospheric pressure resulting in swirling atmospheric disturbance accompanied by powerful winds blowing in anticlockwise direction in the Northern Hemisphere and in the clockwise direction in the Southern Hemisphere. They occur mainly in the tropical and temperate regions of the world. Cyclones are called by various names in different parts of the world as mentioned in box on the next page.

General Characteristics:

Cyclones in India are moderate in nature. Some of the general characteristics of a cyclone are:

1. Strong winds
2. Exceptional rain
3. Storm surge

Cyclones are generally accompanied by

Cyclones are known by different names in different parts of the world:

- *Typhoons in the Northwest Pacific Ocean west of the dateline*
- *Hurricanes in the North Atlantic Ocean, the Northeast Pacific Ocean east of the dateline, or the South Pacific Ocean.*
- *Tropical cyclones - the Southwest Pacific Ocean and Southeast Indian Ocean.*
- *Severe cyclonic storm" (the North Indian Ocean)*
- *Tropical cyclone (the Southwest Indian Ocean)*
- *Willie-Willie in Australia*
- Tornado in South America

strong winds which cause a lot of destruction. In some cases it is accompanied by heavy downpour and also the rise in the sea which intrudes inland there by causing floods.

Fig 2.3.1 Orissa Super Cyclone

29th October 1999, Super-cyclone with wind speed of 260-300 km/hour hit the 140 kilometer coast of Orissa with a storm surge created in the Bay-of-Bengal with water level 9 metres higher than normal. The super

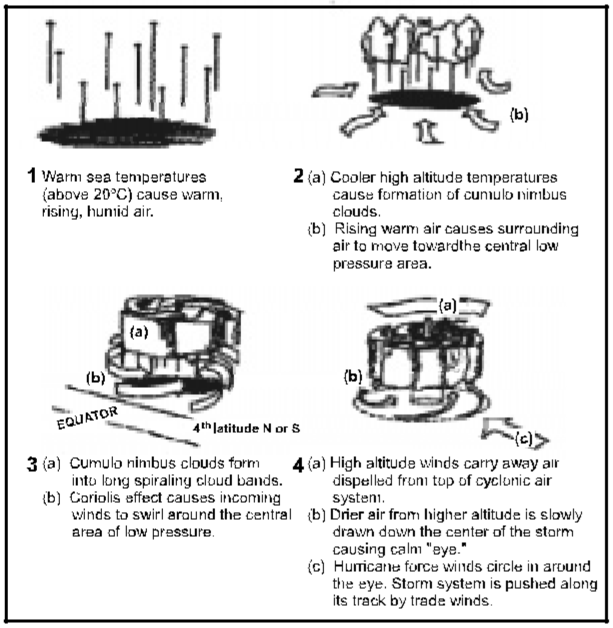


Fig 2.3.2 Stages of cyclone formation

storm travelled more than 250 km inland and within a period of 36 hrs ravaged more than 200 lakh hectares of land, devouring trees and vegetation, leaving behind a huge trail of destruction. The violent cyclone was merciless and broke the backbone of Orissa's economy and killed thousands and devastated millions.

The development of a cyclone covers ***three*** stages namely

a) **Formation and initial development state:** Four atmospheric/ oceanic conditions are necessary for the formation of a cyclone namely:

- A warm sea temperature in excess of 26 degree centigrade, to a depth of 60 meters, which provides abundant water vapour in the air by evaporation.
- High relative humidity (degree to which the air is saturated by

water vapor) of the atmosphere to a height of about 7000 meters, facilitates condensation of water vapor into droplets and clouds, releases heat energy and induces drop in pressure.

- Atmospheric instability (an above average decrease of temperature with altitude) encourages considerable vertical cumulus cloud convection when condensation of rising air occurs.

- A location of at least 4-5 latitude degrees from the Equator allow the influence of the force due to the earth's rotation (Coriolis force) to take effect in inducing cyclonic wind circulation around low pressure centers.

Fig 2.3.3 Cyclone formation

b) **Fully matured:** The main feature of a fully mature tropical cyclone is a spiral pattern of highly turbulent giant cumulus thundercloud bands. These bands spiral inwards and form a dense highly active central cloud core which raps around a relatively calm zone. This is called the **"eye"** of a cyclone. The eye looks like a black hole or a dot surrounded by thick clouds. The outer circumference of the thick cloud is called the **'eye wall'.**

c) **Weakening or decay:** A tropical cyclone begins to weaken as soon as its source of warm moist air is abruptly cut off. This is possible when the cyclone hits the land, on the cyclone moves to a higher altitude or when there is the interference of another low pressure.

Depending on their track on the warm tropical sea and proximity to land a cyclone may last for less than 24 hours to more than 3 weeks. On an average the life cycle of a cyclone (a cyclone to complete these three stages mentioned above) takes six days. The longest cyclone is typhoon John which lasted for 31 days (August to September, 1994 in the north east and north west pacific basins).

Indian Cyclones

Cyclones vary in frequency in various parts of the world. The 7516.6 kilometers long Indian coastline is the earth's most cyclone battered stretch of the world. Around 8 per cent of the total land area in India is prone to cyclones. About two-third of the cyclones that occur in the Indian coastline occur in the Bay of Bengal. The states which are generally affected in the east coast are West-Bengal, Orissa, Andhra Pradesh; Tamil Nadu and on the west coast Gujarat, Maharashtra, Goa, Karnataka and Kerala.

Distributional Pattern:

The map of India (Fig 2.3.4) shows the areas that are generally affected by strong winds/ cyclones. Some of the major cyclones that have affected the country in the past are as mentioned in table 2.3.1

Fig 2.3.4 Wind and Cyclone map of India

damage. The satellites track the movement of these cyclones based on which the people are evacuated from areas lively to be affected. It is difficult to predict the accuracy. Accurate landfall predictions can give only a few hours' notice to threatened population.

India has one of the best cyclone warning systems in the world. The India Meteorological Department (IMD) is the nodal department for wind detection, tracking and forecasting cyclones. Cyclone tracking is done through INSAT satellite. Cyclone warning is disseminated by several means such as satellite based disaster warning systems, radio, television, telephone, fax, high priority telegram, public announcements and bulletins in press. These warnings are disseminated to the general public, the fishing community

Table 2.3.1: Death associate with noteworthy Tropical Cyclones (1970 – 2005)

Sl No	Year	Area	Death toll
1	1971	Eastern Coast	9658
2	1972	Andhra Pradesh and Orissa	100
3	1977	Chennai, kerala & Andhra Pradesh	14,204
4	1979	Andhra Pradesh	594
5	1981	Gujarat	470
6	1982	Gujarat & Maharashtra	500
7	1984	Tamil Nadu & Andhra Pradesh	512
8	1985	Andhra Pradesh	5000
9	1990	Andhra Pradesh	957
10	1990	Orissa	250
11	1999	Orissa	8913

(Source: Office of the US Foreign Disaster Assistance)

Warning:

Low pressure and the development can be detected hours or days before it causes especially those in the sea, port authorities, commercial aviation and the government machinery.

Elements at Risk: Strong winds, torrential rains and flooding cause a huge loss to life and property. The 1999 Super Cyclone of Orissa killed more than 10,000 precious lives with women and children greatly affected. Apart from loss to life there is a huge loss to infrastructures like houses built of mud, older buildings with weak walls, bridges, settlements in low lying areas.

Typical Adverse effect:

First, in a sudden, brief onslaught, high winds cause major damage to infrastructure and housing, in particular fragile constructions. They are generally followed by heavy rains and floods and, in flat coastal areas by storm surge riding on tidal waves and inundating the land over long distances of even upto 15 kilometer inland.

2.3.5 Mangrove plantation on the coastal belt

Physical damage – structures will be damaged or destroyed by the wind force, flooding and storm surge. Light pitched roofs of most structures especially the ones fitted on to industrial buildings will suffer severe damage.

Casualties and public heath – caused by flooding and flying elements, contamination of water supplies may lead to viral outbreaks, diarrhea, and malaria.

Water supplies – Ground and pipe water supply may get contaminated by flood waters.

Crops and food supplies – high winds and rains ruin the standing crop and food stock lying in low lying areas. Plantation type crops such as banana and coconut are extremely vulnerable. Salt from the sea water may get deposited on the agricultural land and increase the salinity. The loss of the crop may lead to acute food shortage.

Communication – severe disruption in the communication links as the wind may bring down the electricity and communication towers, telephone poles, telephone lines, antennas and satellite disk and broadcasting services. Transport lines (road and rail) may be curtailed, Lack of proper communication affects effective distribution of relief materials.

Possible Risk Reduction Meas-ures:

Coastal belt plantation - green belt plantation along the coastal line in a scientific interweaving pattern can reduce the effect of the hazard. Providing a cover through green belt sustains less damage. Forests act as a wide buffer zone against strong winds and flash floods. Without the forest the cyclone travel freely inland. The lack of protective forest cover allows water to inundate large areas and cause destruction. With the loss of the forest cover each consecutive cyclone can penetrate further inland.

Hazard mapping – Meteorological records of the wind speed and the directions give the probability of the winds in the region. Cyclones can be predicted several days in advance. The onset is extensive and often very destructive. Past records and paths can give the pattern of occurrence for particular wind speeds. A hazard map will illustrate the areas vulnerable to cyclone in any given year. It will be useful to estimate the severity of the cyclone and various damage intensities in the region. The map is prepared with data inputs of past climatological records, history of wind speed, frequency of flooding etc. Fig.2.3.6 shows the wind and cyclone zone map of Andhra Pradesh.

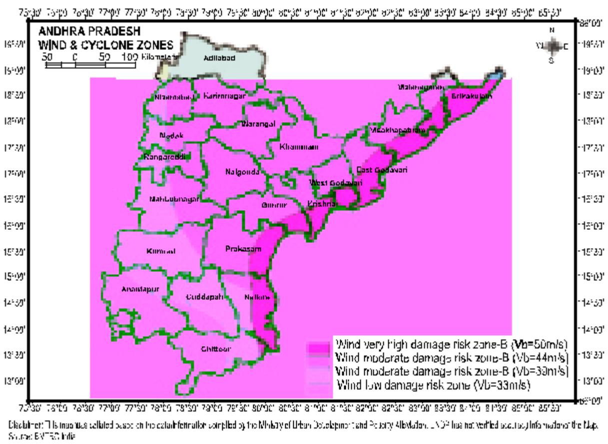


Fig. 2.3.6 Andhra Pradesh state wind and cyclone zone map

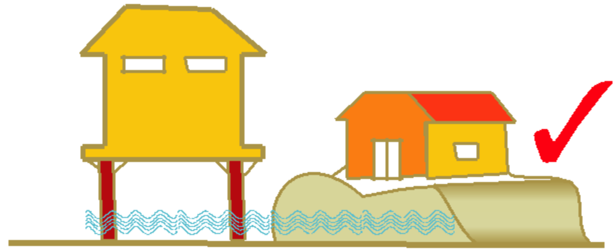
Land use control designed so that least critical activities are placed in vulnerable areas. Location of settlements in the flood plains is at utmost risk. Siting of key facilities must be marked in the land use. Policies should be in place to regulate land use and building codes should be enforced.

Fig 2.3.7 A shelter with special feature to withstand cyclones and floods. Traditional homes can be improved by building in disaster resistant features. Such homes could withstand cyclones with moderate speeds.

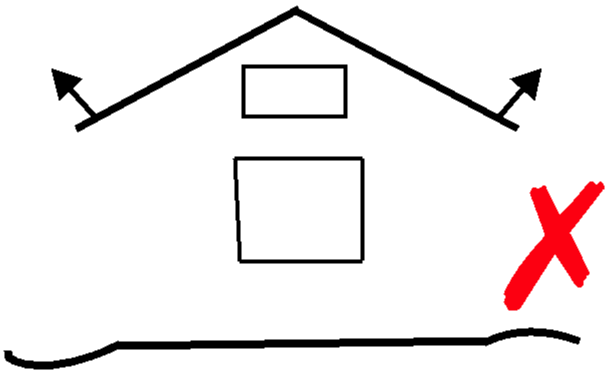
Engineered structures – structures need to be built to withstand wind forces. Good site selection is also important. Majority of the buildings in coastal areas are built with locally available materials and have no engineering inputs. Good construction practice should be adopted such as:

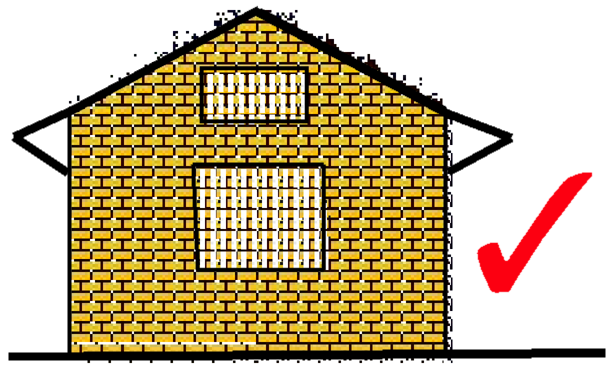
- Cyclonic wind storms inundate the coastal areas. It is advised to construct on stilts or on earth mound.
- Houses can be strengthened to resist wind and flood damage. All elements holding the structures need to be properly anchored to resist the uplift or flying off of the objects. For example, avoid large overhangs of roofs, and the projections should be tied down.
- A row of planted trees will act as a shield. It reduces the energy.
- Buildings should be wind and water resistant.
- Buildings storing food supplies must be protected against the winds and water.
- Protect river embankments. Communication lines should be installed underground.
- Provide strong halls for community shelter in vulnerable locations.

Construction at ground level –risk of inundation



If natural elevation is not available construction on stilts or on artificially raised earth mounds





Large overhangs get lifted and broken. For large overhangs, use ties. Fig. 2.3.8 Safe Construction Practices

Flood management – Torrential rains, strong wind and storm range leads to flooding in the cyclone affected areas. There are possibilities of landslides too. Flood mitigation measures could be incorporated (see section on floods for additional information).

Improving vegetation cover – The roots of the plants and trees keep the soil intact and prevent erosion and slow runoff to prevent or lessen flooding. The use of tree planted in rows will act as a windbreak. *Coastal shelterbelt plantations* can be developed to break severe wind speeds. It minimizes devastating effects. The Orissa calamity has also highlighted the need for urgent measures like shelterbelt plantation along cyclone-prone coastal areas. Species chosen for this purpose should not only be able to withstand the impact of strong cyclonic winds, but also check soil erosion.

Fig 2.3.9 Coastal belt plantation

Web Resources:

§ www.imd.ernet.in Indian Meteorologi-cal Department (IMD) provides all India weather report, end of monsoon season report, weather charts, satellite images, rainfall maps, earthquake reports and severe weather warnings. IMD provides cyclone warnings from the Area Cyclone Warning Centres (ACWCs) It has developed the necessary infrastructure to originate and disseminate the cyclone warnings at appropriate levels. It has made operational a satellite based communication system called Cyclone Warning Dissemination System for direct dissemination of cyclone warnings to the cyclone prone coastal areas.

§ www.ndmindia.nic.in Natural Disaster Management India. Provides current news on Flood, Drought and Cyclones, Weather Links from NIC and weather conditions/ temperatures on Indian Ocean (www.weather.nic.in).

§ www.bmtpc.org/disaster.htm In order to bridge the gap between research and development and large scale application of new building material technologies, the erstwhile Ministry of Urban Development, Government of India, had established the Building Materials And Technology Promotion Council in July 1990.

§ www.gsdma.org/cycpre.htm Link to Cyclone preparedness on the Gujarat State Disaster Management Authority website. The Government of Gujarat (GOG) established the Gujarat State Disaster Management Authority to co-ordinate the comprehensive earthquake recovery program.

§ www.osdma.org website of Orissa State Disaster Mitigation Authority. The Government of Orissa established the Orissa State Disaster Management Authority to co-ordinate the comprehensive Orissa Super Cyclone recovery program. Visit the section 'Safety Tips' for cyclones and other hazards.

§ www.tropmet.res.in The IITM functions as a national centre for basic and applied research in monsoon meteorology of the tropics in general with special reference to monsoon meteorology of India and neighborhood. Its primary functions are to promote, guide and conduct research in the field of meteorology in all its aspects.

§ www.colorado.edu/hazards is an excellent site having a comprehensive coverage of disaster-related information organized in an easy to read way.

Exercise

1. Explain the characteristics of a cyclone.
2. Explain in detail the conditions necessary for the development of a cyclone.
3. Identify risk reduction measures for cyclones.

2.4 FLOOD

Flood is a state of high water level along a river channel or on the coast that leads to inundation of land, which is not usually submerged. Floods may happen gradually and also may take hours or even happen suddenly without any warning due to breach in the embankment, spill over, heavy rains etc.

There are different types of floods namely: flash flood, riverine flood, urban flood, etc. **Flash floods** can be defined as floods which occur within six hours of the beginning of heavy rainfall, and are usually associated with cloud bursts, storms and cyclones requiring rapid localized warnings and immediate response to reduce damage. Wireless network and telephone connections are used to monitor flood conditions. In case of flash floods, warnings for timely evacuation may not always be possible.

Causes:

There are several causes of floods and differ from region to region. The causes may vary from a rural area to an urban area. Some of the major causes are:

a. Heavy rainfall

b. Heavy siltation of the river bed reduces the water carrying capacity of the rivers/stream.

c. Blockage in the drains lead to flooding of the area.

d. Landslides blocking the flow of the stream.

e. Construction of dams and reservoirs

f. In areas prone to cyclone, strong winds accompanied by heavy down pour along with storm surge leads to flooding.

Typical Adverse Effects:

The most important consequence of floods is the loss of life and property. Structures like houses, bridges; roads etc. get damaged by the gushing water, landslides triggered on account of water getting saturated, boats and fishing nets get damaged. There is huge loss to life and livestock caused by drowning. Lack of proper drinking water facilities, contamination of water (well, ground water, piped water supply) leads to outbreak of epidemics, diarrhoea, viral infection, malaria and many other infectious diseases.

Flooding also leads to a large area of agricultural land getting inundated as a result there is a huge crop loss. This results in shortage of food, and animal fodder. Floods may also affect the soil characteristics. The land may be rendered infertile due to erosion of top layer or may turn saline if sea water floods the area.

Distributional Pattern of floods in India

Floods occur in almost all the river basins of the country. The Vulnerability Atlas of India shows pictorially the areas liable to floods. Around 12 per cent (40 million hectare) of land in India is prone to floods.

Fig 2.4.1 Map showing Flood Zones in India

Most of the flood affected areas lie in the Ganga basin, Brahmaputra basin (comprising of Barak, Tista, Torsa, Subansiri, Sankosh, Dihang and Luhit), the northwestern river basin (comprising Jhelum, Chenab, Ravi, Sutlej, Beas and the Ghagra), peninsular river basin (Tapti, Narmada, Mahanadi, Baitarani, Godavari, krishna, Pennar and the Kaveri) and the coastal regions of Andhra Pradesh, Tamilnadu, orissa and Kerela. Assam, Uttar Pradesh, Bihar and Orissa are some of the states who have been severely prone to floods. Our country receives an annual rainfall of 1200 mm, 85% of which is concentrated in 3-4 months i.e June to September. Due to the intense and periodic rain, most of the rivers of the country are fed with huge quantity of water, much beyond their carrying capacity.

Table 2.4.1 below shows some of the major floods that have affected the country.

level rises. Except for flash floods there is usually a reasonable warning period. Heavy precipitation will give sufficient warning of the coming river flood. High tides with high winds may indicate flooding in the coastal areas. Evacuation is possible with suitable monitoring and warning. Warning is issued by the Central Water Commission (CWC), Irrigation & Flood Control Department,

Table 2.4.1 Death Toll in major floods of India

Year	Number of people killed	Location
1961	2,000	North
1968	4,892	(1) Rajasthan, Gujarat - (2) North-East, West Bengal, Assam
1971	1,023	North India
1978	3,800	North, Northeast
1980	1,600	Uttar Pradesh, Bihar, Gujarat, Kerala, Haryana
1989	1,591	Maharashtra, Andhra Pradesh, Gujarat
1994	2,001	Assam, Arunachal Pradesh, Jammu and Kashmir, Himachal, Punjab, Uttar Pradesh, Goa, Kerala, Gujarat states
1995	1,479	Bihar, Haryana, Jammu & Kashmir, Punjab, Uttar Pradesh, West Bengal, Maharashtra
1997	1,442	Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Gujarat, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Maharashtra, Madhya Pradesh, Orissa, Punjab, Rajasthan, Sikkim, Uttar Pradesh, West Bengal states
1998	1,811	Assam, Arunachal, Bihar, Kerala, Meghalaya, Punjab, Sikkim, Uttar Pradesh, West Bengal states
2000	1,290	Gujarat, Andhra Pradesh, Assam, Arunachal Pradesh, Bihar, Himachal Pradesh, Kerala, Madhya Pradesh, Punjab, Uttar Pradesh, West Bengal

Warning:

Flood forecasting and warning has been highly developed in the past two decades. With the advancement of technology such as satellite and remote-sensing equipments flood waves can be tracked as the water and Water Resources Department. CWC maintains close liaison with the administrative and state engineering agencies, local civil authorities to communicate advance warning for appropriate mitigation and preparedness measures.

Possible Risk Reduction Measures:

Mapping of the flood prone areas is a primary step involved in reducing the risk of the region. Historical records give the indication of the flood inundation areas and the period of occurrence and the extent of the coverage. Warning can be issued looking into the earlier marked heights of the water levels in case of potential threat. In the coastal areas the tide levels and the land characteristics will determine the submergence areas. Flood hazard mapping will give the proper indication of water flow during floods.

Land use control will reduce danger of life and property when waters inundate the floodplains and the coastal areas. The number of casualties is related to the population in the area at risk. In areas where people already have built their settlements, measures should be taken to relocate to better sites so as to reduce vulnerability. No major development should be permitted in the areas which are subjected to high flooding. Important facilities like hospitals, schools should be built in safe areas. In urban areas, water holding areas can be created like ponds, lakes or low-lying areas.

Fig 2.4.2 Houses constructed on stilts in slum areas

Fig 2.4.3 Khash Dhalai Flood Shelter.
Flood shelters like this are just one example of how communities can protect themselves from the worst of the floods. Banks of earth are raised by up to 5 metres and cover an area of several kilometres. The people dig a huge pond in the middle and use this earth to raise the ground. Whenever the floods come, people can bring their livestock, possessions – even their homes – to safety. The pond in the middle becomes an important source of food, as it is used to farm fish.

Construction of engineered structures in the flood plains and strengthening of structures to withstand flood forces and seepage. The buildings should be constructed on an elevated area. If necessary build on stilts or platform.

Flood Control aims to reduce flood damage. This can be done by decreasing the amount of runoff with the help of reforestation (to increase absorption could be a mitigation strategy in certain areas), protection of vegetation, clearing of debris from streams and other water holding areas, conservation of ponds and lakes etc. *Flood Diversion* include levees, embankments, dams and channel improvement. Dams can store water and can release water at a manageable rate. But failure of dams in earthquakes and operation of releasing the water can cause floods in the lower areas. *Flood Proofing* reduces the risk of damage. Measures include use of sand bags to keep flood water away, blocking or sealing of doors and windows of houses etc. Houses may be elevated by building on raised land. Buildings should be constructed away from water bodies.

Flood Management In India, systematic planning for flood management commenced with the Five Year Plans, particularly with the launching of National Programme of Flood Management in 1954. During the last 48 years, different methods of flood protection structural as well as non-structural have been adopted in different states depending upon the nature of the problem and local conditions. Structural measures include storage reservoirs, flood embankments, drainage channels, anti-erosion works, channel improvement works, detention basins etc. and non-structural measures include flood forecasting, flood plain zoning, flood proofing, disaster preparedness etc. The flood management measures undertaken so far have provided reasonable degree of protection to an area of 15.81 million hectares through out the country.

Web Resources:

- www.cwc.nic.in website of the Central Water Commission of India, (CWC) of India.
- http://wrmin.nic.in website of the Ministry of Water Resources, GoI.
- www.imd.ernet.in Indian Meteorological Department (IMD) provides all India weather report, end of monsoon season report, weather charts, satellite images, rainfall maps, earthquake reports and severe weather warnings.
- www.ndmindia.nic.in Natural Disaster Management India. Provides current news on Flood, Drought and Cyclones, Weather Links from NIC and weather conditions temperatures on Indian Ocean (www.weather.nic.in).
- www.nih.ernet.in India National Institute of Hydrology perform tasks such as Ground water zone mapping, Flood plain mapping, land use, salinity, sedimentation, Soil erosion, water-logging etc.

Exercise

1. Define Flood. List out some of the causes and adverse effects of floods.
2. Name two basins in India that are frequently affected by flood and explain the warning dissemination system of India in the flood affected areas.
3. Explain in detail atleast five possible risk reduction measures for floods.

2.5 DROUGHT

What is Drought?

Drought is either absence or deficiency of rainfall from its normal pattern in a region for an extended period of time leading to general suffering in the society. It is interplay between demand that people place on natural supply of water and natural event that provides the water in a given geographical region. ***The state of Kerala which receives more than 3000 mm of rainfall every year is declared drought affected as it is insufficient to have two good crops.*** The more the imbalance in supply the higher is the drought. The following will help explaining this general definition of the drought further.

- It is a slow on-set disaster and it is difficult to demarcate the time of its onset and the end.
- Any unusual dry period which results in a shortage of useful water.

- Drought is a normal, recurrent feature of climate. Climate is expected to show some aberrations and drought is just a part of it.
- Drought can occur by improper distribution of rain in time and space, and not just by its amount.
- Drought is negative balance between precipitation and water use (through evaporation, transpiration by plants, domestic and industrial uses etc) in a geographical region.

The effects of drought accumulate slowly over a considerable period of time.

Causes of Drought

Can you think of what causes drought?

Though drought is basically caused by deficit rainfall, which is a meteorological phenomenon, it manifests into different spheres because of various vulnerability factors associated with them (see the box). Some of these factors are human induced. Though drought is a natural disaster, its effects are made worst in developing countries by over population, over grazing, deforestation, soil erosion, excessive use of ground and surface water for growing crops, loss of biodiversity.

General Characteristics:

–Types of droughts

Drought proceeds in sequential manner. Its impacts are spread across different domains as listed below.

What on earth do you know about water?

- **Approximately 80 per cent of earth's surface is covered with water but only 1% of it is fresh water that we can use.**
- **About 2.7 per cent of the total water available on the earth is fresh water of which about 75.2 per cent lies frozen in Polar Regions and another 22.6 per cent is present as ground water. The rest is available in lakes, rivers, atmosphere, moisture, soil and vegetation. This 1% of water is now threatened by pollution!**
- **Today, we have approximately the same amount of water as when the Earth was formed. Earth will not get/generate any more water!**
- **We are using up the fresh water faster than we are recharging our groundwater**

–Meteorological drought

Meteorological drought is simple absence/deficit of rainfall from the normal. It is the least severe form of drought and is often identified by sunny days and hot weather.

–Hydrological drought

Hydrological drought often leads to reduction of natural stream flows or ground water levels, plus stored water supplies. The main impact is on water resource systems.

–Agricultural drought

This form of drought occurs when moisture level in soil is insufficient to maintain average crop yields. Initial consequences are in the reduced seasonal output of crops and other related production. An extreme agricultural drought can lead to a famine, which is a prolonged shortage of food in a restricted region causing widespread disease and death from starvation.

Socio-economic drought

Socio-economic drought correlates the supply and demand of goods and services with the three above-mentioned types of drought. When the supply of some goods or services such as water and electricity are weather dependant then drought may cause shortages in supply of these economic goods.

Measuring Drought :

Elements at Risk

In general, all those elements that are primarily dependent on water are most affected. It affects the rainfed crops and then slowly creeps into the irrigated crops. People who are dependent on agriculture and areas where the other livelihood opportunities are least developed are greatly affected. The herdsman, landless labourer, subsistence farmers, women, children and farm animals are the most vulnerable groups.

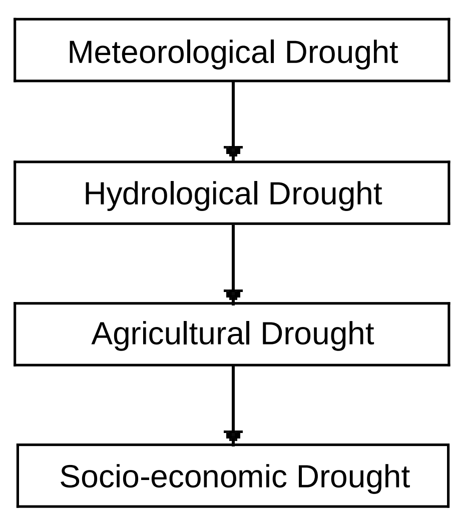
Can you think of some more vulnerability factors to drought?

- Low soil moisture holding capacity
- Absence of irrigation facilities
- Livestock without adequate fodder storage facilities
- Poor water management
- Deforestation
- Over grazing
- Water consuming cropping patterns
- Excessive ground water draft
- Soil erosion
- Population growth and urbanization
- Industrialization
- Global warming

Can you believe it!!!

Cherapunji in Meghalaya, which was said to receive highest rainfall in the world, is now reeling under acute drinking water problem. This is because of water runoff, denudation and no storage facilities.

Fig 2.5.1



Drought Mathematics

The following criteria have been set by the Indian Meteorological Division (IMD) for identifying the drought.

- *Onset of drought:* Deficiency of a particular year's rainfall exceeding 25 per cent of normal.
- *Moderate drought:* Deficit of rainfall between 26-50 per cent of normal.
- *Severe drought:* Deficit of rainfall more than 50 per cent of normal.

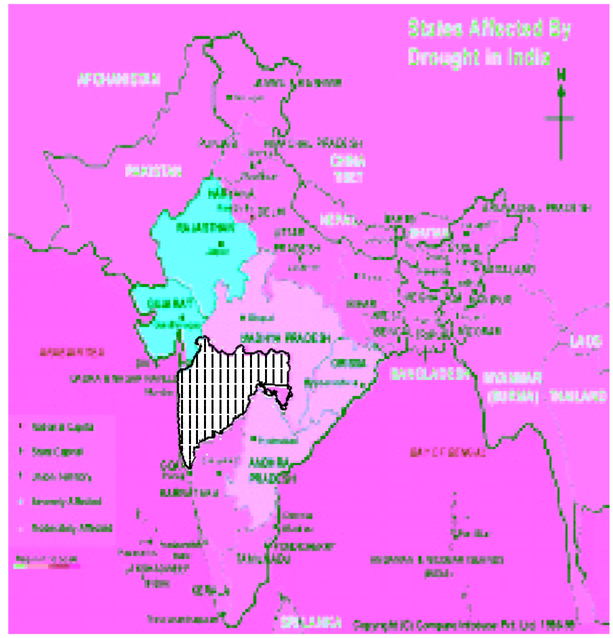


Fig 2.5.2 Map showing drought prone states in India.

Typical adverse effects

Drought, different from any other natural disaster, does not cause any structural damages. As the meteorological drought turns into hydrological drought, the impacts start appearing first in agriculture which is most dependant on the soil moisture. Irrigated areas are affected much later than the rainfed areas. However, regions surrounding perennial rivers tend to continue normal life even when drought conditions are prevailing around. The impacts slowly spread into social fabric as the availability of drinking water diminishes, reduction in energy production, ground water depletion, food shortage, health reduction and loss of life, increased poverty, reduced quality of life and social unrest leading to migration.

Distribution Pattern

Ø Around 68 per cent of India's total area is drought prone to drought.

Ø 315 out of a total of 725 Talukas in 99 districts are drought prone.

Ø 50 million people are annually affected by drought.

Ø In 2001 more than eight states suffered the impact of severe drought.

Ø In 2003 most parts of Rajasthan experienced the fourth consecutive year of drought.

Possible Risk Reduction Measures:

There are various mitigation strategies to cope up with drought.

1. ***Public Awareness and education:*** If the community is aware of the do's and don'ts, then half of the problem is solved. This includes awareness on

the availability of safe drinking water, water conservation techniques, agricultural drought management strategies like crop contingency plans, construction of rain water harvesting structure. Awareness can be generated by the print, electronic and folk media.

2. ***Drought Monitoring:*** It is continuous observation of the rainfall situation, availability of water in the reservoirs, lakes, rivers etc and comparing with the existing water needs in various sectors of the society.

3. ***Water supply augmentation and conservation*** through rainwater harvesting in houses and farmers' fields increases the content of water available. *Water harvesting* by either allowing the runoff water from all the fields to a common point (e.g. Farm ponds, see the picture) or allowing it to infiltrate into the soil where it has fallen (*in situ*) (e.g. contour bunds, contour cultivation, raised bed planting etc) helps increase water availability for sustained agricultural production.

4. ***Expansion of irrigation*** facilities reduces the drought vulnerability. **Land use** based on its capability helps in optimum use of land and water and can avoid the undue demand created due to their misuse.

5. ***Livelihood planning*** identifies those livelihoods which are least affected by the drought. Some of such livelihoods include increased off-farm employment opportunities, collection of non-timber forest produce from the community forests, raising goats, carpentry etc.

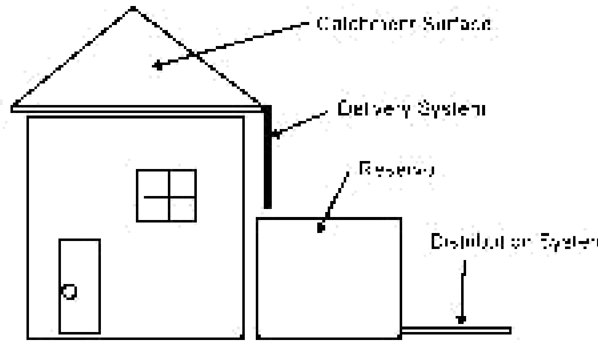


Fig. 2.5.3 Rain Water harvesting

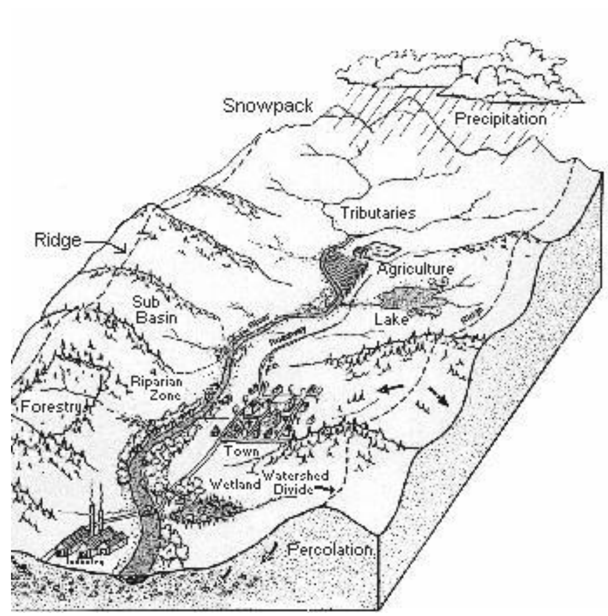


Fig 2.5.4 A watershed showing collection of water to common point.

6. ***Drought planning:*** the basic goal of drought planning is to improve the effectiveness of preparedness and response efforts by enhancing monitoring, mitigation and response measures.

7. Planning would help in effective coordination among state and national agencies in dealing with the drought. Components of drought plan include establishing drought taskforce which is a team of specialists who can advise

the government in taking decision to deal with drought situation, establishing coordination mechanism among various agencies which deal with the droughts, providing crop insurance schemes to the farmers to cope with the drought related crop losses, and public awareness generation.

Ralegan, before drought mitigation efforts

Ralegan, after drought mitigation efforts

Fig 2.5.5

What a mitigation approach can do? A success story

The people of Ralegan Siddhi in Maharashtra transformed the dire straits to prosperity. Twenty years ago the village showed all traits of abject poverty. It practically had no trees, the topsoil had blown off, there was no agriculture and people were jobless. Anna Hazare, one of the India's most noted social activists, started his movement concentrating on trapping every drop of rain, which is basically a *drought mitigation* practice.

So the villagers built check dams and tanks. To conserve soil they planted trees. The result: from 80 acres of irrigated area two decades ago, Ralegan Siddhi has a massive area of 1300 acres under irrigation. The migration for jobs has stopped and the per capita income has increased ten times from Rs.225 to 2250 in this span of time.

The entire effort was only people's enterprise and involved no funds or support from the Government.

Web Resources:

http://dmc.kar.nic.in/default.htm
www. watershedindia.net
www.rainwaterharvesting.org
www.drought.unl. edu

Exercise

1. Why is drought a slow onset disaster? Identify five factors that cause drought.
2. Explain the four different types of drought
3. Identify the elements that are at risk in areas that are prone to drought and identify five risk reduction measures to combat drought.

2.6 LANDSLIDE

What is a landslide?

The term' landslide' includes all varieties of mass movements of hill slopes and can be defined as the downward and outward movement of slope forming materials composed of rocks, soils, artificial fills or combination of all these materials along surfaces of separation by falling, sliding and flowing, either slowly or quickly from one place to another. Although the landslides are primarily associated with mountainous terrains, these can also occur in areas where an activity such as surface excavations for highways, buildings and open pit mines takes place. They often take place in conjunction with earthquakes, floods and volcanoes. At times, prolonged rainfall causing landslide may block the flow of river for quite some time. The formation of river blocks can cause havoc to the settlements downstream on its bursting. Some of the common definitions are below in table 1.

Fig 2.6.1 Landslide in hilly terrain of India

Causes of Landslide

There are several causes of landslide. Some of the major causes are as follows:

1. *Geological Weak material:* Weakness in the composition and structure of rock or soil may also cause landslides.
2. *Erosion:* Erosion of slope toe due to cutting down of vegetation, construction of roads might increase the vulnerability of the terrain to slide down.
3. *Intense rainfall:* Storms that produce intense rainfall for periods as short as several hours or have a more moderate intensity lasting several days have triggered abundant landslides. Heavy melting of snow in the hilly terrains also results in landslide.
4. *Human Excavation of slope* and its toe, loading of slope/toe, draw down in reservoir, mining, deforestation, irrigation, vibration/blast, Water leakage from services.

Table 1 : Definitions

Landslide Hazard refers to the potential of occurrence of a damaging landslide within a given area; such damage could include loss of life or injury, property damage, social and economic disruption, or environmental degradation.

Landslide Vulnerability reflects the extent of potential loss to given elements (or set of elements) within the area affected by the hazard, expressed on a scale of 0 (no loss) to 1 (total loss); vulnerability is shaped by physical, social, economic and environmental conditions.

Landslide Risk refers to the probability of harmful consequences-the expected number of lives lost, persons injured, extent of damage to property or ecological systems, or disruption of economic activity –within a landslide prone area. The risk may be individual or societal in scope, resulting from an interaction between the hazard and individual or societal vulnerability.

Landslide Risk Evaluation is the application of analyses and judgments (encompassing physical, social, and economic dimensions of landslide vulnerability) to determine risk management alternatives, which may include determination that the landslide risk is acceptable or tolerable.

Fig 2.6.2 Bhachau Landslide - The land slipped during the 26th January 2001 earthquake event in Bhachau. Note that people are still camped beneath. Monsoon rains could possibly wash the soil down slope.

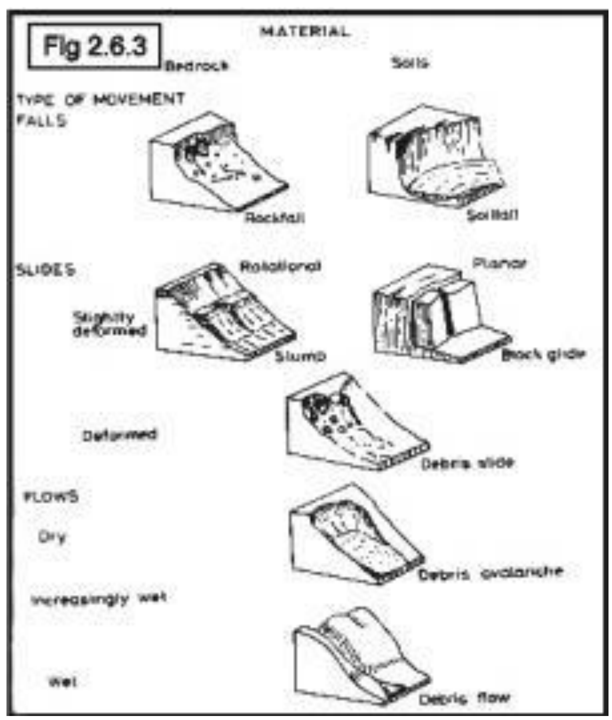
5. *Earthquake shaking* has triggered landslides in many different topographic and geologic settings. Rock falls, soil slides and rockslides from steep slopes involving relatively thin or shallow dis-aggregated soils or rock, or both have been the most abundant types of landslides triggered by historical earthquakes.

6. *Volcanic eruption* Deposition of loose volcanic ash on hillsides commonly is followed by accelerated erosion and frequent mud or debris flows triggered by intense rainfall.

Type of Landslides:

The common types of landslides are described below. These definitions are based mainly on the work of Varnes (Varnes, D.J., 1978).

- **Falls:** Abrupt movements of materials that become detached from steep slopes or cliffs, moving by free-fall, bouncing, and rolling.
- **Flows:** General term including many types of mass movement, such as debris flow, debris avalanche, lahar, and mudflow.
- **Creep:** Slow, steady downslope movement of soil or rock, often indicated by curved tree trunks, bent fences or retaining walls, tilted poles or fences.
- **Debris flow** Rapid mass movement in which loose soils, rocks, and organic matter combine with entrained air and water to form slurry that then flows down slope, usually associated with steep gullies.
- **Debris avalanche** A variety of very rapid to extremely rapid debris flow.



- **Lahar** Mudflow or debris flow that originates on the slope of a volcano, usually triggered by heavy rainfall eroding volcanic deposits, sudden melting of snow and ice due to heat from volcanic vents, or the breakout of water from glaciers, crater lakes or lakes dammed by volcanic eruptions

- **Mudflow** Rapidly flowing mass of wet material that contains at least 50 per cent sand, silt, and clay-sized particles.

- **Lateral spreads** Often occur on very gentle slopes and result in nearly horizontal movement of earth materials. Lateral spreads usually are caused by liquefaction, where saturated sediments (usually sands and silts) are transformed from a solid into a liquefied state, usually triggered by an earthquake.

- **Slides** Many types of mass movement are included in the general term "landslide." The two major types of landslides are rotational slides and translational landslides.

- **Topple** A block of rock that tilts or rotates forward and falls, bounces, or rolls down the slope.

Adverse Effects:

The most common elements at risk are the settlements built on the steep slopes, built at the toe and those built at the mouth of the streams emerging from the mountain valley. All those buildings constructed without appropriate foundation for a given soil and in sloppy areas are also at risk. Roads, communication lines are vulnerable.

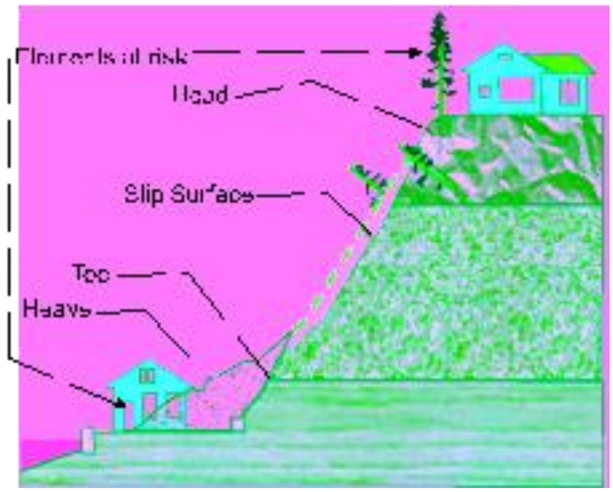


Fig 2.6.4 adverse effects of landslide

Distributional Pattern:

Landslides constitute a major natural hazard in our country, which accounts for considerable loss of life and damage to communication routes, human settlements, agricultural fields and forest lands. The Indian subcontinent, with diverse physiographic, seismic, tectonic and climatological conditions is subjected to varying degree of landslide hazards; the Himalayas including Northeastern mountains ranges being the worst affected, followed by a section of Western Ghats and the Vindhyas. Removal of vegetation and toe erosion have also triggered slides. Torrential rainfall on the deforested slopes is the main factor in the Peninsular India namely in Western Ghat and Nilgiris. Human intervention by way of slope modification has added to this effect.

Fig 2.6.5 Spots showing major landslides in India

One of the worst tragedies took place at Malpa Uttarkhand (UP) on 11th and 17th August 1998 when nearly 380 people were killed when massive landslides washed away the entire village. This included 60 pilgrims going to Lake Mansarovar in Tibet. Consequently various land management measures have been initiated as mitigation measures. Fig. 2.6.6 shows landslide hazard zonation map of India with red being areas more susceptible to landslides than areas depicted in light yellow.

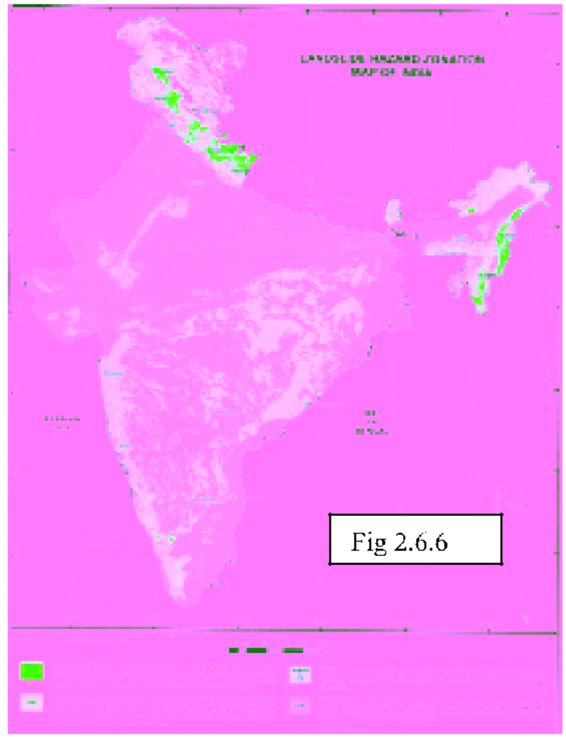


Fig 2.6.6

Table 2.6.2 : Some of the major Landslides in the last one decade

October 1990	Nilgris	36 people killed and several injured. Several buildings and communication network damaged
July 1991	Assam	300 people killed, road and buildings damaged
November 1992	Nilgiris	Road network and buildings damaged, Rs.5 million damage estimate
July 1993	Itanagar	25 people buried alive 2 km road damaged
August 1993	Kalimpong, West Bengal	40 people killed, heavy loss of property
August 1993	Kohima, Nagaland	200 houses destroyed, 500 people died, about 5 km road stretch was damaged
November 1993	Nilgris	40 people killed, property worth several lakhs damaged

January 1994	Kashmir	National Highway 1A severely damaged
June 1994	Varundh ghat, Konkan Coast	20 people killed, breaching of ghat road damaged to the extent of 1km at several places
May 1995	Aizwal Mizoram	25 people killed. Road severely damaged
September 1995	Kullu, HP	22 persons killed and several injured. About 1 km road destroyed
14,August 1998	Okhimath	69 people killed
18,August 1998	Malpa, Kali river	205 people killed. Road network to Mansarovar disrupted
August 2003	Uttarkashi	Heavy loss of infrastructure

Possible risk reduction measures:

Hazard mapping locates areas prone to slope failures. This will help to avoid building settlements in such areas. These maps will also serve as a tool for mitigation planning.

Land use *practices such as:*

- Areas covered by degraded natural vegetation in upper slopes are to be afforested with suitable species. Existing patches of natural vegetation (forest and natural grass land) in good condition, should be preserved
- Any developmental activity initiated in the area should be taken up only after a detailed study of the region has been carried out.
- In construction of roads, irrigation canals etc. proper care is to be taken to avoid blockage of natural drainage
- Total avoidance of settlement in the risk zone should be made mandatory.
- Relocate settlements and infrastructure that fall in the possible path of the landslide
- No construction of buildings in areas beyond a certain degree of slope

Retaining Walls can be built to stop land from slipping (these walls are commonly seen along roads in hill stations). These are constructed to prevent smaller sized and secondary landslides that often occur along the toe portion of the larger landslides.

Fig. 2.6.7 Retaining wall - Reinforced wall constructed as a mitigation measure.

Surface Drainage Control Works The surface drainage control works are implemented to control the movement of landslides accompanied by infiltration of rain water and spring flows.

Engineered structures with strong foundations can withstand or take the ground movement forces. Underground installations (pipes, cables, etc.) should be made flexible to move in order to withstand forces caused by the landslide

Increasing vegetation cover is the cheapest and most effective way of arresting landslides. This helps to bind the top layer of the soil with layers below, while preventing excessive run-off and soil erosion.

Insurance will assist individuals whose homes are likely to be damaged by landslides or by any other natural hazards.

References for further reading:

§ http://www.csre.iitb.ac.in/rn/resume/landslide/lsl.htm Landslide Information System - Center of Studies in Resource Engineering IIT Mumbai.

§ http://landslides.usgs.gov USGS National Landslide Hazards Program (NLHP)

§ http://www.fema.gov/hazards/landslides/landslif.shtm Federal Emergency Management Agency FEMA, USA is tasked with responding to, planning for, recovering from and mitigating against disasters.

§ http://ilrg.gndci.pg.cnr.it/ The International Landslide Research Group (ILRG) is an informal group of individuals concerned about mass earth movement and interested in sharing information on landslide research.

Exercise

1. What are landslides ? List out five major causes of landslides in India.
2. Identify major type of landslides.
3. Suggest risk reduction measures for landslide mitigation.