4. FLOODS

Description of phenomenon

Floods are natural phenomena in nature. Environmentally, they bring benefits as well as losses. They are an essential part of most river systems, creating and supporting a wide range of habitats. They also maintain the fertility of soils by depositing sediments and flushing salts from the surface layers. But they can also cause severe erosion and completely change a habitat.

Floods are described as hazards, when they threaten human life and property. According to this usage, the physical magnitude is not the crucial factor in making the flood hazardous. It is the presence of human activities in a flood-prone area which implies a hazard. From this viewpoint, most flood hazards could be avoided. However, man often puts himself at risk by developing floodable areas for settlement, agriculture and industry. This tendency of mankind has a long history and now affects 1-2 billion people, particularly in the developing countries.

Physically, flooding can be defined as accumulation of water over areas which are not normally submerged. The rise of a flood is usually fast, while the water level recedes at a slower rate.

There are two main categories of floods — river and coastal. River floods result from a number of causes, which can be divided e.g. as follows:

1. Atmospheric
   - rainfall
   - snowmelt
   - ice jam
2. Technologic
   - dam failures
3. Seismic
   - earthquakes
   - volcanic eruptions

Heavy or prolonged rainfall is the most common cause of river floods particularly in low and middle latitudes. In mountains and high latitudes, substantial flooding may occur during snowmelt period. The most damaging snowmelt floods are in some rivers often accompanied by ice jams, which can cause very rapid rise of water level. Moving ice masses destroy buildings and erode on river banks.

Floods resulting from dam failures are a combination of natural and technological hazard. There are at least 100 000 dams in the world, the failure of which could cause severe damage. Several hundred serious dam breaks have occurred in this century in both industrialized and developing countries.

Volcanic eruptions may cause catastrophic releases of water and rock debris. The release could also occur during the non-eruptive period, without any warning or any possibility to predict the event. An earthquake may induce flooding e.g. by triggering a landslide, which temporarily closes the river channel.

Along low-lying coasts flooding may result from excessively high tides and storm-surges, which are caused by low air pressure and high wind speeds. In Bangladesh 110 million people live on the most vulnerable coastal delta in the world; very high floods may inundate half of the country.

There is a high degree of inter-annual variability in flood damages in all countries. However, some trends can be detected. In developing countries there has been an increasing trend in both human offers and material damage. This can partly be interpreted as physically-driven; the frequency and magnitude of flood events may have an upward trend in some areas. However, land use changes and other human-induced factors play a more important role. Deforestation appears to be a likely cause of higher floods. The destruction of forests is often followed by unsuitable agricultural and grazing practices, which aggravate flooding and erosion particularly in mountainous river basins.

Another important factor in developing countries seems to be the heavy rate of urbanization. New dwellings and shanty towns appear on areas, which have high risk of flood occurrence. The inevitable change of land use due to accompanied urbanization tends to decrease infiltration capacity and vegetation, thus enhancing flood formation.

Hazard prediction

The diversity of river systems causes great variability in the predictability for individual basins. It also depends on the flood type and on the size of the basin.

A rainfall flood in a large river can be modelled to a rather high level of accuracy. The lead time available for forecasting, decision making and control measures is also sufficient in large basins. However, all this requires advanced weather forecasting, hydrological monitoring and telecommunication systems.

In small, rapid-response basins a network of real-time precipitation gauges is needed. This is particularly the case in flash flood areas in semiarid or mountaineous environments. The time of concentration of a flash flood in a small basin is typically only a few hours.

Floods caused by snowmelt are in general the easiest to predict. The rate of snowmelt never reaches that of heavy rain. The case may be entirely different, if snowmelt is accompanied by rain or if ice jams occur. Various river ice phenomena are often the most unpredictable component of flooding in high latitudes.

Best success in the forecasting of coastal floods can be attained with satellites to track storm movements. A special system has been installed in the Pacific area to monitor tsunami waves generated by earthquakes in the sea floor.

Despite of great advances in the ability to forecast floods, the operational forecasting and warning is still ineffective in many countries. It has been estimated that among all the countries in the world with a high risk of major floods, about 15 have no warning system at all and at least a further 40 have inadequate systems (Smith 1992).

Mitigation

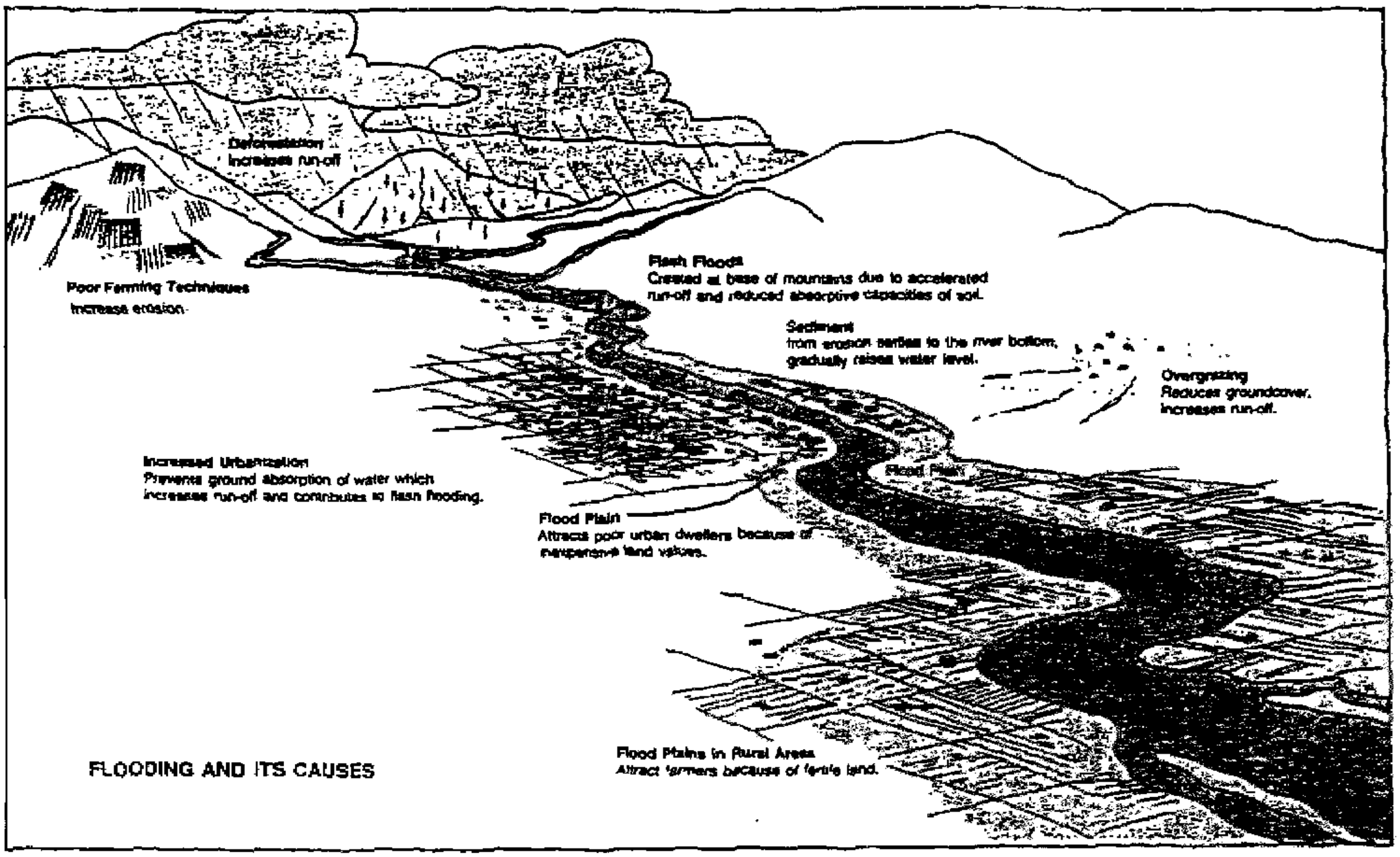
There are several ways of flood adjustment. Their mutual importance varies depending on flood and basin characteristics and on a wide range of man-related factors.

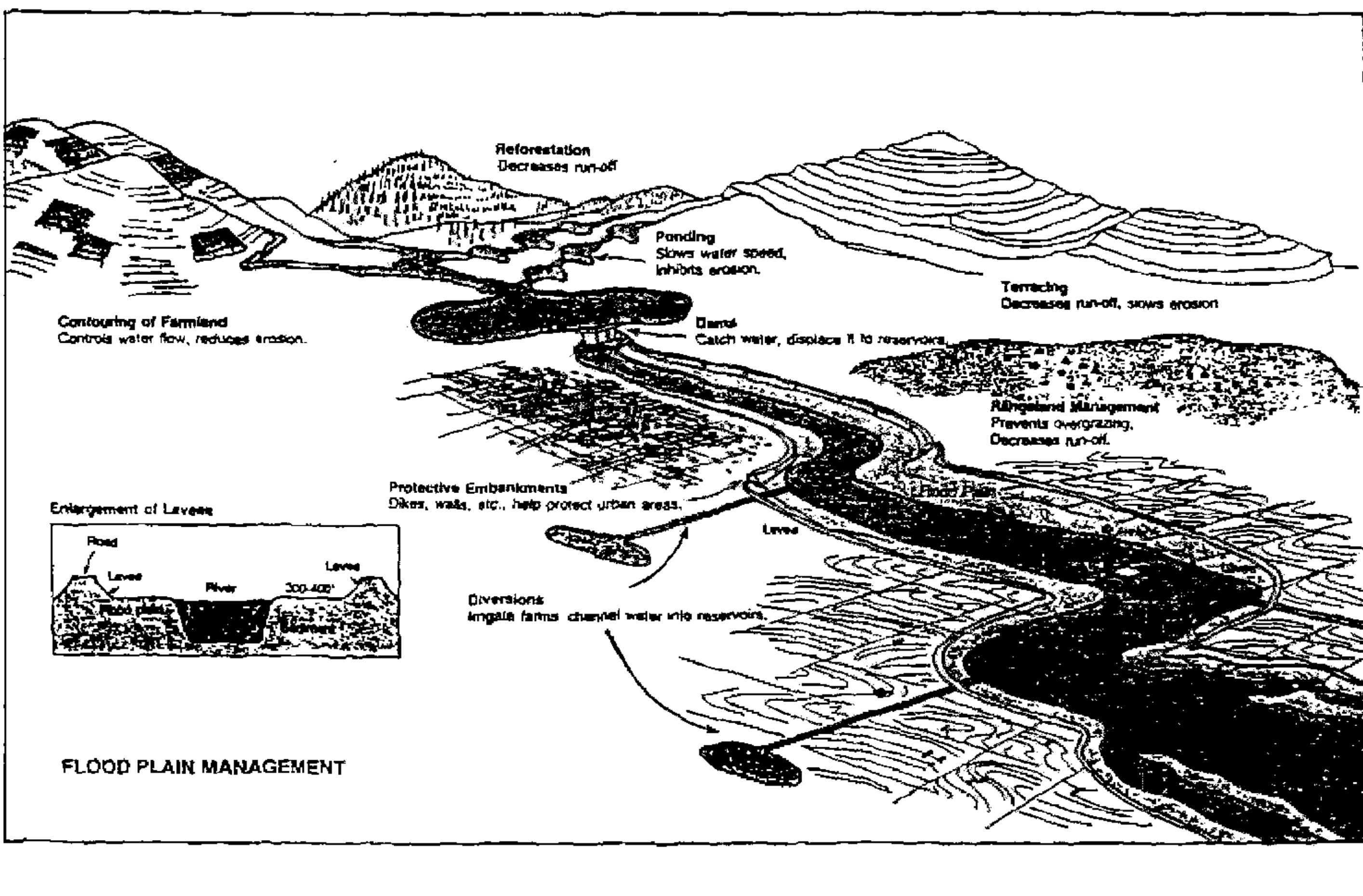
The physical control of floods involves a variety of methods, the traditional ones being the storage and diversion of flood waters and construction of levees. A large number of dams and diversion channels have been built, and the capacity of existing channels improved. Thousands of kilometers of levees, usually simple earth banks, line the channels of many flood-prone rivers all over the world.

Newer attempts include land use planning and various protective measures (e.g. revegetation) on the basin. These are more sustainable than the traditional control works, but the enforcement of e.g. land use regulations may be difficult.

In extreme cases the only means of adjustment may be elevated flood shelters, evacuation and disaster aid. An extensive programme to build hundreds of concrete shelters, each to accommodate 1 000 – 2 000 people, is under way in Bangladesh. The evacuation of people during a major flood in the delta areas of Bangladesh is not possible. Also elsewhere in developing countries a rapid transfer of people out of flood-plain can seldom be a realistic solution.

Flood control may aggravate a catastrophic event. Flood controlling structures increase the risk of loss or damage in downstream communities. Built structures can e.g. increase flood heights and velocities by obstructing the flood flow, reducing floodplain storage capacity, and increasing run-off. Fires, windblows or changes in a river's course, affect flood flows, and e.g. installing storm drainage systems can increase the quality and rate at which rainwaters enter the river system.





Source: Cuny, Frederick; Disasters and Development, 1983

5. GEOLOGIC HAZARDS

The major geologic hazards are earthquakes and volcanoes, together with the secondary hazards of different forms of ground failure or deformation. Landslides are usually considered to be of geologic origin, but their occurrence can be accelerated or aggravated by hydrological factors. They are handled separately in the next chapter (3.6.).

Description of phenomenon

A. Earthquakes and related phenomena

Earthquakes are sudden motions or tremblings of the ground caused by abrupt displacement of rock masses, usually within the upper 15 to 50 km of the Earth's crust. In most cases earthquakes result from the movement of one rock mass over another in response to tectonic forces. Rock is elastic and can accumulate strain where adjacent areas of rock are subjected to forces pushing or pulling them. When the stress exceeds the strength of the rock, the rock breaks along a pre-existing or new fracture called a fault. The rupture extends outward along the fault plane from its point of origin, or focus.

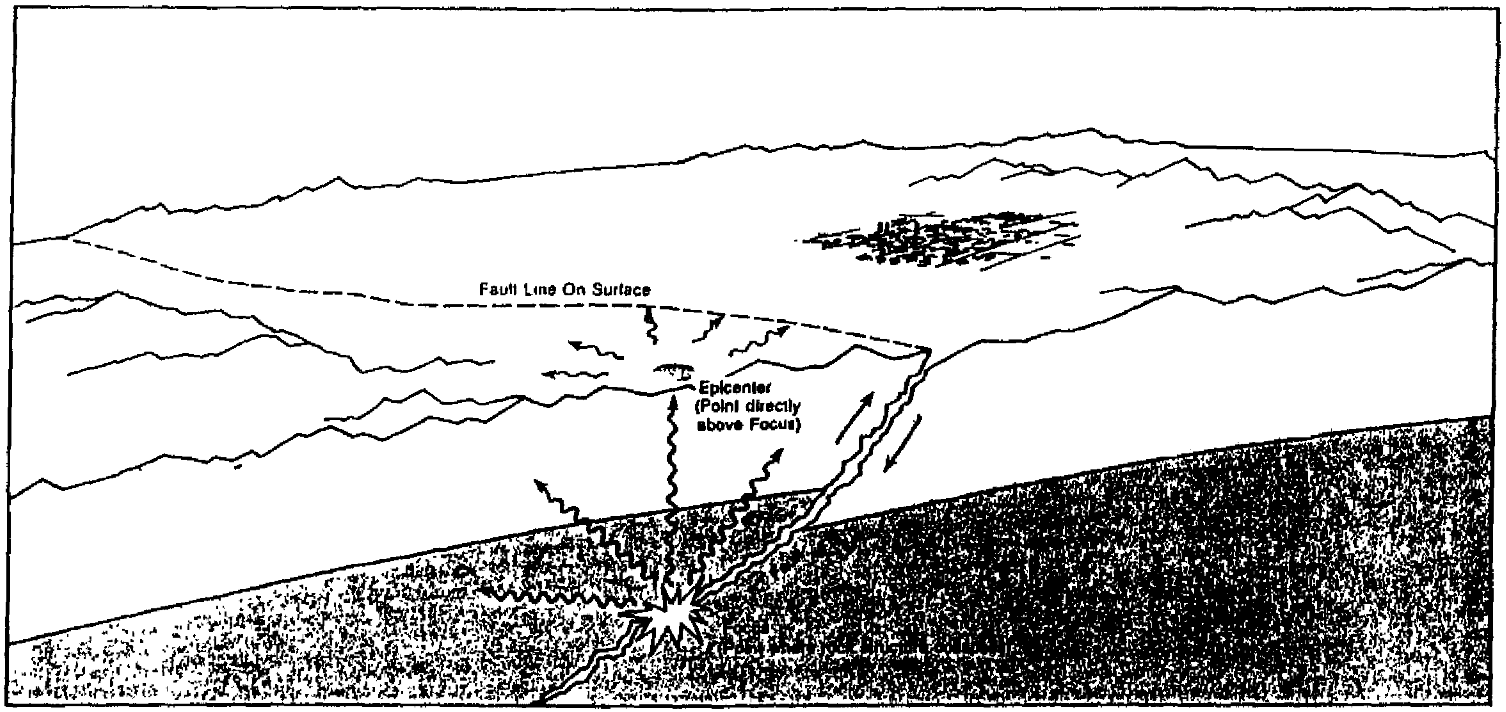
The epicentre of an earthquake is the point on the Earth's surface that is directly above the focus. The rupture usually does not proceed uniformly. For instance, variations in rock properties and overburden pressures can bring the rupture almost to stop and suddenly as a result of the elastic forces it may break free. If the rupture reaches the surface, it makes a visible surface break. Surface can also be heated.

The seismic energy flows from the rupture in a form of seismic waves. The fastest are primary (P) waves or compressional waves (5 km/second), the secondary (S) waves are slower (3 km/second) and the slowest ones are the Rayleigh and Love waves. The body (P & S) and surface (Rayleigh and Love) seismic waves vibrate outward in all directions (0.1 - 30 Hz). In more general terms, the severity of ground shaking increases as magnitude increases and decreases as distance from the epicentre increases.

Built structures vibrate along these waves, and if they cannot withstand these vibrations they are damaged. Most harmful are the S waves that cause a structure to vibrate from side to side. Rayleigh and Love waves are more likely to affect on high buildings and structures. Because amplitudes of low-frequency vibrations decay less rapidly than high-frequency vibrations as distance from the epicentre increases, high buildings located at relatively great distances from a fault are more sensitive to damage, as happened in Mexico City in 1985.

The seismic waves cause the most of all earthquake-induced damage and loss. Shaking affects both directly through the impacts of vibrations on structures and indirectly through secondary effects: landslides, surface faulting, tectonic uplift and subsidence, sensitive clays, liquefaction and tsunamis. Tertiary effects like fire and flooding can be prominent.

The intensity and character of ground shaking depends upon earthquake source parameters: magnitude, driving stress causing the fault to slip, dimensions of the slip surface, distance from the fault. Furthermore, surface geological materials may influence the level and nature of ground motion.



DESCRIPTION OF AN EARTHQUAKE

Motion of the earth's plates causes increased pressure at faults where the plates meet. Eventually the rock structure collapses and movement occurs along the fault. Energy is propagated to the surface above and radiates outward. These waves of motion in the earth's crust shake landforms and buildings, causing damage.

Source: Cuny, Frederick; Disasters and Development, 1983

B. Volcanic eruptions

More than 500 volcanoes have been active in historical times. When magma (a mixture of silicates, containing dissolved gases and sometimes crystallized minerals in suspension) runs towards the surface, the pressure decreases enabling the dissolved gases to bubble and driving magma upwards through a volcanic vent. The magnitude of the eruption is determined mainly by the amount and rate of effervescence of the gases and by the viscosity of the magma. Eruptions vary greatly in magnitude and duration, not only from one volcano to another but even at the same volcano. The frequency of eruptions also varies from volcanoes almost in continuous eruption to those "quiet" ones that erupt with intervals of thousand of years.

Volcanoes of the major rift systems including also the mid-Atlantic and East African rifts or mid-oceanic upwellings produce low viscosity lava. It flows easily and can spread over vast areas in broad sheets or in long and narrow lobes. On a contrary, those volcanoes siting in the great subduction zones around many ocean margins usually produce high viscosity lava. This type of lava usually forms either domes or short and thick flows. High viscosity lava rises the pressure of exploiting gases and as a result gases can carry large amounts of solid (e.g. tephra with rock particles) and molten lava in their suspension.

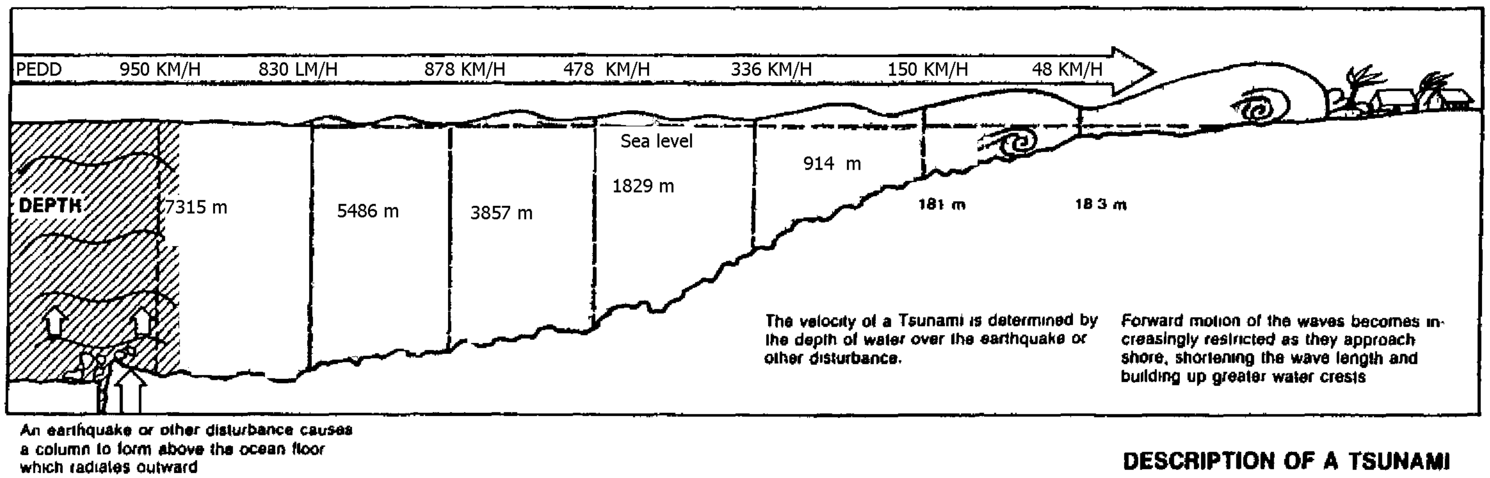
Secondary effects can be prominent: ground failure, ground subsidence, debris avalanches, mudflows, glacier bursts, volcanic earthquakes and tsunamis. Eruptions can end with famine as ash falls can destroy vegetation or toxic gases or acids can kill animals. On the other hand, the decomposition of volcanic materials may result in fertile soils, which can be locally a very important phenomenon in circumstances where normally soils are quite poor in nutrients.

Ash flows pose less risk than other volcanic phenomena: pyrolactic flows, mudflows and lavaflows. Most Volcanic gases are acid and corrosive. Pyrolactic flows are the most lethal, because of intense heat and suspended solid materials. Pyrolastic flows are typical to volcanoes of the circum-Pacific subduction zones and the West Indies. They are less common at volcanoes in the mid-oceanic and continental rift zones, although large prehistoric eruptions of this kind have been identified from e.g. deposits in Ethiopia and in USA (California). Mudflows are most common in regions of high rainfall. The speed of a lavaflow is usually so slow that people and animals are able to escape.

C. Tsunamis

Tsunamis are seismic sea waves induced by large-scale and sudden movement of the sea floor, usually as a result of earthquakes and sometimes as a result of landslides and volcanic eruptions. Tsunamis differ from other earthquake hazards by the large impact area. Once they are born, they run forwards nearly invisible in mid-ocean (with a height of less than one meter) at very high speeds (900 km/hr), and when they reach shallow shore waters, their kinetic energy is being transformed into the height of the wave (25 m). The configuration of the local shoreline and the sea bottom can greatly amplify the effects of tsunamis. Tsunamis are a special threat along the shores of Pacific Ocean.

Seiches are similar kind of phenomena occurring in inland waters, usually in elongated lakes. Waves are lower (less than 3 meters) and oscillatory. Seiches can locally cause flooding and damage in low-lying plains.



DESCRIPTION OF A TSUNAMI

Source: Cuny, Frederick; Disasters and Development, 1983

Hazard prediction

With today's knowledge it is almost impossible to predict accurately **volcanic eruptions**. The periodicity of eruptions is an essential baseline data to be analyzed (e.g. Sourcebook for Volcanic Hazard Zonation/UNESCO).

Earthquake prediction consists of monitoring of the factors of the earth, like changes in water levels, gas emissions (e.g. increased levels of radon gas) and foreshocks. However, it is more than likely that predictions are not accurate. According to recent research major earthquakes do not occur on a same site along faults until sufficient time has gone, and this means usually several decades. In the main seismic zones the "quiet" zones are more at risk. So called seismic gaps along major plate boundaries have been identified. These are areas with known great earthquakes more than 30 years ago. Areas of surface or underground fracturing that can experience earthquakes are known as earthquake fault zones. Recent research shows that the behaviour of some faults appears to be relatively constant and therefore monitoring of these seismic gaps is important part of risk reduction.

About 15 percent of all earthquakes in the world occur in Latin America. Their occurrence concentrates in the area of the Western Cordillera. The Regional Seismologic Centre for South America (Centro Regional de Sismologia para America del Sur; CERESIS) is situated in Lima, Peru and it has gathered data on earthquakes in a map form: "Significant Earthquakes, 1900-1979". The map shows all major earthquakes that have occurred during the period in Latin America.

Basing on the seismic gap theory, the U.S. Geological Survey has prepared maps of the coast of Chile and Peru for USAID. These maps give estimates of earthquake probability and rank earthquake risk for the period 1986 - 2006. USAID is producing similar maps with the same information for the rest part of the Latin American Pacific coast.

In Africa, the Eastern African Rift Zone that runs from Ethiopia southwards to the African Rift through Kenya, Uganda, Rwanda, Burundi, Tanzania, Zambia, Malawi, Mozambique, Zimbabwe and Botswana is a potential source of earthquake activity. Potentially active volcanoes exist in the Eastern African Rift.

The Scientific and Technical Committee (STC) of the UN has endorsed as part of the International Lithosphere Programme a proposal for a Global Seismic Hazard Assessment Programme (GSHAP). The primary goal of the GSHAP is to ensure that national agencies are able to assess seismic hazards in a regionally coordinated fashion and with advanced methods. It will be based on establishment of Regional Centres (in existing geophysical institutions in Mexico City, Rabat, Nairobi, Moscow, Teheran, Beijing, Manila, and one in South America/CERESIS) by the year 1994 to assist national data collection and processing and risk assessments. A final product of these centres will be regional seismic hazard maps that are available at request. The GSHAP programme will cooperate with the already existing monitoring programmes of the International Lithosphere Programme which are: 1) Contemporary Dynamics and Deep Processes - the World Stress Map, 2) the World Map of Active Faults, and 3) Paleoseismicity of the Late Holocene.

At present, there are several information sources that can be used in hazard and risk assessment and planning. Information on earthquakes can be obtained from the following sources: earthquake catalogues (world-wide, regional, national, or more specific areas of occurrence); maps showing damage caused by earthquakes and maps of notable or historic earthquakes (e.g. South and Central America); epicenter maps, data on hypocenters, maps and data on earthquake magnitude and peak horizontal ground acceleration, and earthquake recurrence data (e.g. UNDRO, USAID/OFDA, CERESIS); continental and subregional seismotectonic maps; seismic provinces and source zones (e.g. from Costa Rica, Guatemala, Honduras, Nicaragua, El Salvador 1988/89), macrozonation maps; geologic and geophysical information (national, state, urban municipial governments, universities, private oil/mineral/engineering firms). Information on ground-shaking can be obtained from intensity and magnitude data; seismic attenuation data and site response data (e.g. CERESIS, UNDRO). Earthquake and volcanic data can be used for assessment of future tsunamis. Pacific Tsunami Warning Centre is monitoring the oceans.

Potential severity is usually defined historically. The most severe earthquake ever occurred in the specific site is considered to be the maximum that can occur on a same site again. The severity is defined by either in terms of intensity by the Modified Mercalli Index (MMI) or in terms of magnitude by the Richter Scale (Ms). The likelihood of occurrence is measured as a conditional probability or seismic potential. Conditional probability is an estimate, expressed as a percentage, of how likely such a large or great earthquake will occur within a specific time period.

Mitigation

Earthquakes cannot be prevented. Given the current state of knowledge it is difficult to modify the tectonic processes, but the incorporation of hazard mitigation as earlier as possible into the development planning process can reduce the risk. Structural measures alone seem to be insufficient in risk reduction while earthquake hazards are rapid onsets and while they often have impacts on large areas (e.g. tsunamis). Thus, siting and proper land use offer perhaps more effective means of risk reduction. Special consideration is needed for secondary effects of earthquakes (fire, flooding, power failure etc.). For earthquake induced landslides, the improvement of sites can be economic. Some techniques have been developed to control the amount of energy transferred from ground movement (i.e. seismic waves) to buildings. However, all these techniques are intended only to reduce the vulnerability of structures to ground-shaking.

Land use regulations - site-dependant building regulations or functional regulations - can be of prominent help in keeping the potential damages as small as possible. In an earthquake-prone area there usually already exist information on earlier earthquakes and related seismic hazards. This can be supplemented with geologic and geophysical information and field observations, if needed. Hazard zonation maps should be provided with information of spatial application of special building codes, density of building occupancy and site-specific landslide and flood protection measures. A supplementary map should show relative severity of all seismic hazards (/and stability categories). For instance in areas of high risk of surface faulting all uses except utility or transportation facilities should be prohibited.

Some studies recommend expansion of infrastructural systems in risk reduction of earthquakes and related seismic hazards. The vulnerability of water supply and electricity systems can be reduced by introducing closed loops. This ensures a supply from two ends. Water supply and electrical systems are often small-scaled. The connection of these systems on regional level may reduce risk when there are more sources for water supply.

Volcanoes that can erupt within the next century should be monitored and land use and land management regulations should be effective in areas/sites of high risk. Areas/sites along the volcanoes of long-term frequency (over 100 years) could be less restricted in social development if effective early warning systems exist. Compared with earthquakes volcanic hazards are easier to incorporate into the planning because of the point source and the relatively limited area where active volcanoes exist.

Protection against tsunamis is almost impossible in economic terms, and thus regulations for infrastructural and social development should be used, and effective early warning systems should be created. Land use control and regulations are applicable in areas at risk of seiches to avoid settlements on the borders of large lakes or inundation downstream from large water-retaining structures.

6. LANDSLIDES

Description of phenomenon

Earthquake shaking can dislodge rock and debris on steep slopes, triggering rock falls, avalanches, and slides. Ground-motions can initiate shallow debris slides on steep slopes and, less often, rock slumps and rock slides on moderate to steep slopes. Sometimes shaking can reactivate dormant slumps or block slides. Earthquake shaking can also trigger soil avalanches in weakly-cemented fine-grained materials (e.g. loess) that form steep stable slopes under non-seismic conditions!

Hydrological factors can influence on the process: rising groundwater tables or heavy rainstorm. Certain types of spreads and flows are classified as liquefaction phenomena. Ground-shaking may induce clay-free soil deposits to lose their cohesion strength and behave temporarily like liquids. The occurrence of liquefaction is restricted primarily into areas/sites with relatively young deposits of sands and silts (usually less than 10.000 years old) and with high groundwater tables. It is common in areas with a water table of less than 10 meters in Holocene deltas, river channels, areas of floodplain deposits, eolian parent material, and poorly compacted fills.

Hazard prediction

See previous chapter (5.).

Mitigation

Landslides and other similar hazards such as liquefaction can be prevented by ground stabilization techniques or appropriate engineering design, but both are expensive methods of prevention. Land use regulations are again best available methods of mitigation.

7. PESTS

Description of phenomenon

Locusts and grasshoppers have caused perennial disasters in Africa since centuries. The African continent is at risk to widespread and prolonged locust infestations mainly of the following five species: the desert locust (Schistocerca gregaria, in the Eastern African region), the tropical migratory locust (Locusta migratoria migratorioides, throughout Africa), the red locust (Nomadacris septemfasciata, the brown locust (Locustana pardalina, in Southern Africa), and the Senegalese Grasshopper (Oedaleus senegalensis, in West Africa and the Atlantic Ocean islands). The desert locust is the most widespread, and hence most destructive of these locust species.

During normal years, i.e. the normal drier climatic periods, the locust species are widely spread over a large belt of arid and semi-arid lands as individual grassland herbivores. Major and harmful locust swarms develop as a result of a rapid increase in the locust population. Such rapid increases are caused by heavy and prolonged rains, after a long drought period. These wet periods allow two or three generations of locusts to develop, thus multiplying rapidly. Migratory locust swarms may invade large geographical areas - as has happened - with favourable winds. The behaviour of the different species is not precisely known, and e.g. the International Centre for Insect Physiology and Ecology (ICIPE) in Nairobi is studying physiology and ecology of pests. There is lack of understanding of the locust swarming and migration phenomenon, particularly factors leading to gregarisation and swarming.

The problem of locusts and grasshoppers is being exacerbated with land clearance and land utilization for agricultural purposes. The kind of ecological manipulation favours development and multiplication of various species of grasshoppers.

Hazard prediction

Prediction of locust and grasshopper hazard is closely connected to the effectiveness of existing meteorological early warning systems. As it seems that infestations are in relation to periodic droughts, heavy rainstorms and favourable winds (the ITCZ) this kind of agro-meteorological data is important in prediction of a pest hazard. See chapter 3.3. for prediction (Tropical storms).

Countries especially at risk for pest infestations are Ethiopia, Sudan, Kenya, Libya, India, Pakistan and Morocco.

Mitigation

As the known physiology and ecology of locusts and grasshoppers tends to suggest that certain ecological changes (land clearing and agricultural practices) in the environment favour pest existence it is reasonable to start the mitigation measures with analyzing the available methods of reducing pest existence.Here again, sound land use and land use management are best methods for prevention.

ICIPE is studying indigenous pathogenic organisms that can regulate the density of locust populations. The International Institute of Biological Control in England settled quite recently on a strain of the fungi Metarhizium and related fungus Beauveria that are already well-known in combating the Colorado potato beetle, froghoppers in Brazil and maize stem-borers in China. The fungi is the only disease that can invade the insects through their bodies, it wipes out locusts of all ages, whereas conventional chemicals require different systems to kill the adults and the young hoppers.