GEOLOGIC HAZARDS

As an engineer, you should be aware of the existence of geologic hazards and their potential impact on engineering projects. Geologic hazards are geologic phenomena that present common risks to life or property. Geologic hazards are usually identified during site exploration and investigation. The purpose of the lectures on natural hazards is to familiarize you with both the causes and effects of such occurrences and alert you to proper scientific solutions and land-use management practices that can alleviate or eliminate disastrous consequences.

Natural geologic hazards can be divided into two groups. First, those associated with particular earth materials. Examples include swelling soils and rocks, toxic minerals (asbestos, acid drainage) and toxic gases (radon gas). The second group includes hazards associated with earth processes (earthquakes, volcanoes, landslides, avalanches, rock slides and rock falls, soil creep, subsidence, floods, frost heave, coastal hazards).

Natural hazards are complemented with man-made hazards such as water pollution, mine subsidence, rock bursts, pumping, waste disposal, carbon emission, global warming, and ozone depletion. Understanding these hazards requires a multidisciplinary approach. These issues are interdisciplinary with biology, engineering, chemistry, and environmental sciences.

Geologic hazards are not predictable and often result in loss of life, property losses and indirect losses (e.g. business disruption). Geologic hazards are not trivial or forgiving; in terms of loss of life, geologic hazards compare with the most severe catastrophes of this century (see Tables 1 and 2). Precise figures are difficult to compute, but the monetary and human loss due to such hazards is staggering. Natural disasters annually wrench more than $40 billion from the global economy and take an average of 200,000 human lives. The Federal Emergency Management agency (FEMA) estimates the nation’s annual earthquake property damage losses at about $4.4 billion. This compares to annual flood losses of $5.2 billion between 1989 and 1998 according to National Weather Service data. The National Climatic Data Center estimates $5.4 billion in annual hurricane losses for that period. The United States has been losing of the order of $1 billion per week to natural disasters in recent years. Since 1989, the United States has suffered more than $90 billion in insured losses from natural disasters.

With growing urbanization and more extensive land use, the threat of loss of life and property from geologic occurrences has increased. For example, the 1906 San Francisco earthquake, with a magnitude of 8.3 on the Richter scale, caused an estimated $350 million to $1 billion in damage and took about 500 lives. According to the U.S.’s Insurance Information Institute, if an earthquake with an 8.3 magnitude were to hit San Francisco, as it did in 1906, losses could reach $225 billion.

In response to the rapid escalating toll of human and economic losses from natural disasters, the United Nations (UN) General Assembly proclaimed the decade of 1990 – 2000, in its resolution 44/236 of 1989, as the International Decade for Natural Disaster Reduction (IDNDR). The resolution made clear a statement of its objectives:

SOURCES of CASUALTIES	NUMBERS of CASUALTIES
Wars versus Earthquakes	
U.S. Battle Deaths in World War II	292,131
Atomic Bomb, Hiroshima, Japan 1945	80,000 to 200,000
EARTHQUAKE, Tangshan, China, 1976	242,000
U.S. Murders versus Single Volcanic Eruption	
Total murders U. S. , 1990	20,045
VOLCANIC ERUPTION, Colombia, 1985	22,000
AIDS Deaths in United States versus Single Landslide Event	
Total AIDS deaths U. S., through April, 1992	141,200
LANDSLIDES, Kansu, China, 1920	200,000
Greatest Atrocity versus Greatest Flood Events	
The Holocaust, Europe, 1939-1945	6,000,000
FLOOD Yellow River, China, 1887	900,000 to 6,000,000
FLOOD Yangtze River, China, 1931	3,700,000

(data on familiar societal catastrophes from *The World Almanac*, 1993, New York, Pharos Books; and *The Universal Almanac*, 1993, Kansas City, Andrews and McMeel; geological catastrophes compiled from Tufty, 1969, and Office of Foreign Disaster Assistance, 1992, *Disaster History*.)

Table 1. Casualties from specific geologic hazards compared with familiar societal catastrophes (from *The Citizen's Guide to Geologic Hazards*, 1993.)

"The objective of the Decade is to reduce through concerted international action, especially in the developing countries, the loss of life, property damage, and social and economic disruption caused by natural disasters, such as earthquakes, wind storms, tsunamis, floods, landslides, volcanic eruptions, wildfires, grasshopper and locust infestations, drought and desertification and other calamities of natural origin."

The targets set by the UN General Assembly for the decade were that, by the year 2000, all countries, as part of their plan to achieve sustainable development, should have the following in place: (1) comprehensive national assessments of risk of natural hazards, with these assessments taken into account in development plans, (2) mitigation plans at the national level and or local levels involving long-term prevention awareness, and (3) ready access to global, regional, national, and local warning systems and broad dissemination of warnings.

Ironically, losses due natural hazards have not declined between 1990 and 2000; they have risen dramatically. Hurricane Andrew ($27 billion), the Midwest floods of 1993 ($21 billion), and the Northridge earthquake of 1994 ($45 billion) each inflicted losses of tens of billions of dollars.

How can we cope with geologic hazards? There are four options:

(1) Avoid the areas where known hazards exist. Such areas can be converted into parks, for instance.

GEOLOGIC HAZARD	COST in 1990 Dollars*	SOURCE(S)
	HAZARDS from MATERIALS	
Swelling Soils	$6 to 11 billion annually	Jones and Holtz, 1973, Civil Engrg. v. 43, n. 8, pp. 49-51; Krohn and Slosson, 1980, ASCE Proc. 4th Intnl. Conf. Swelling Soils pp. 596-608.
Reactive Aggregates 1	No estimate	———
Acid Drainage	$365 million annually to control; $13 to 54 billion cumulative to repair	USBM, 1985, IC 9027; Senate Report, 1977, 95-128
Asbestos	$12 to 75 billion cumulative for remediation of rental & commercial buildings; total well above $100 billion including litigation and enforcement	Croke and others, 1989, The Environmental Professional, v. 11, pp. 256-263. Malcolm Ross, USGS, 1993, personal communication. Costs depend on extent and kind of remediation done; removal is most expensive option.
Radon	$100 billion ultimately to bring levels to EPA recommended levels of 4 PCi/L	Estimate based on remediating about 1/3 of American homes at $2500 each plus costs for energy and public buildings.
	HAZARDS from PROCESSES	
Earthquakes	$230 million annually decade prior to 1989; over $6 billion in 1989	USGS, 1978, Prof. Paper 950; Ward and Page, 1990, USGS Pamphlet, "The Loma Prieta Earthquake of October 17, 1989"
Volcanoes	$4 billion in 1980; Several million annually in aircraft damage	USGS Circular 1065, 1991, and Circular 1073, 1992
Landslides/Avalanches	$2 billion /$0.5 million annually	Schuster & Fleming, 1986, Bull. Assoc. Engrg. Geols., v. 23, pp. 11-28/ Armstrong & Williams, 1986, *The Avalanche Book*
Subsidence 2 and Permafrost 3	At least $125 million annually for human-caused subsidence; $5 million annually from natural karst subsidence	Holzer, 1984, GSA Reviews in Engrg. Geology VI; FEMA, 1980, Subsidence Task Force Report
Floods	$ 3 to 4 billion annually	USGS Prof. Paper 950
Storm Surge 4 and Coastal Hazards	$700 million annually in coastal erosion; over $40 billion in hurricanes & storm surge 1989 - early 1993	Sorensen and Mitchell, 1975 Univ. CO Institute of Behavioral Sci., NSF-RA-E-75-014; Inst. of Behavioral Sci., personal comm.

*Costs from dates reported in "SOURCE(S)" column have been reported in terms of 1990 dollars. This neglects changes in population and land use practice since the original study was done but gives a reasonable comparative approximation between hazards. [1]**Aggregates** are substances such as sand, gravel or crushed stone that are commonly mixed with cement to make concrete. [2]**Subsidence** is local downward settling of land due to insufficient support in the subsurface. [3]**Permafrost** consists of normally frozen ground in polar or alpine regions that may thaw briefly due to warm seasons or human activities and flow . [4]**Storm surge** occurs when meteorological conditions cause a sudden local rise in sea level that results in water piling up along a coast, particularly when strong shoreward winds coincide with periods of high tide. Extensive flooding then occurs over low-lying riverine flood plains and coastal plains.

Table 2. Economic costs of geologic hazards in the U.S. (from *The Citizen's Guide to Geologic Hazards*, 1993.)

(2) Evaluate the potential risk of a hazard, if activated.
(3) Minimize the effect of the hazards by engineering design and appropriate zoning.
(4) Develop a network of insurance and contingency plans to cover potential loss or damage from hazards.

References

Geology and the Conduct of Local Government: An Urban Geologist's Viewpoint (1978), J. A. Pendleton, Ph.D. dissertation, University of Colorado, Department of Geological Sciences, Boulder.

Geology of Boulder, Colorado (1987), Bilodeau et al., published by the Assoc. of Eng. Geol., Vol.

24, No.3, pp. 289-332.

Home Buyer's Guide to Geologic Hazards (1996), published by the American Institute of Professional Geologists (AIPG).

The Citizen's Guide to Geologic Hazards (1993), E. Nuhfer et al, published by the American Institute of Professional Geologists (AIPG).

Homework Assignment # 7 (Due Wednesday February 18, 2009)

1) Find an estimate of the losses associated with recent geo-hazards between 2000 and now.

2) Visit the Colorado Geological Survey web: http://geosurvey.state.co.us/Default.aspx?tabid=35. Browse through the list of documents addressing geologic hazards in the State of Colorado. Counties and municipalities in Colorado primarily regulate geologic hazards in four different ways. What are they?

3) Go to the following web sites:
   - Colorado Geological Survey: http://geosurvey.state.co.us
   - Boulder County Comprehensive Plan: www.co.boulder.co.us/lu/bccp
   - Geology of the Boulder area: http://bcn.boulder.co.us/basin/watershed/geology
   - Geologic History of Boulder area: http://bcn.boulder.co.us/basin/natural/geology/historic.html
   - Map of Geologic Hazards for Boulder County: www.co.boulder.co.us/lu/bccp/images/ghca.jpg
   - Read the article "Geology of Boulder, USA" by S. Bilodeau et al. (1987). Two copies of the article have been placed outside ECOT 546 with a sign-up sheet.

   Answer the following questions:

   - What is the difference between a geologic hazard and a geologic constraint?
   - What are the major geologic hazards and constraints in Boulder City and Boulder County?
   - Where should one go to get more information about the extent and importance of those hazards and constraints (city offices, county offices, etc.)?

   This is a group project.