# LECTURE NOTES: EMGT 234

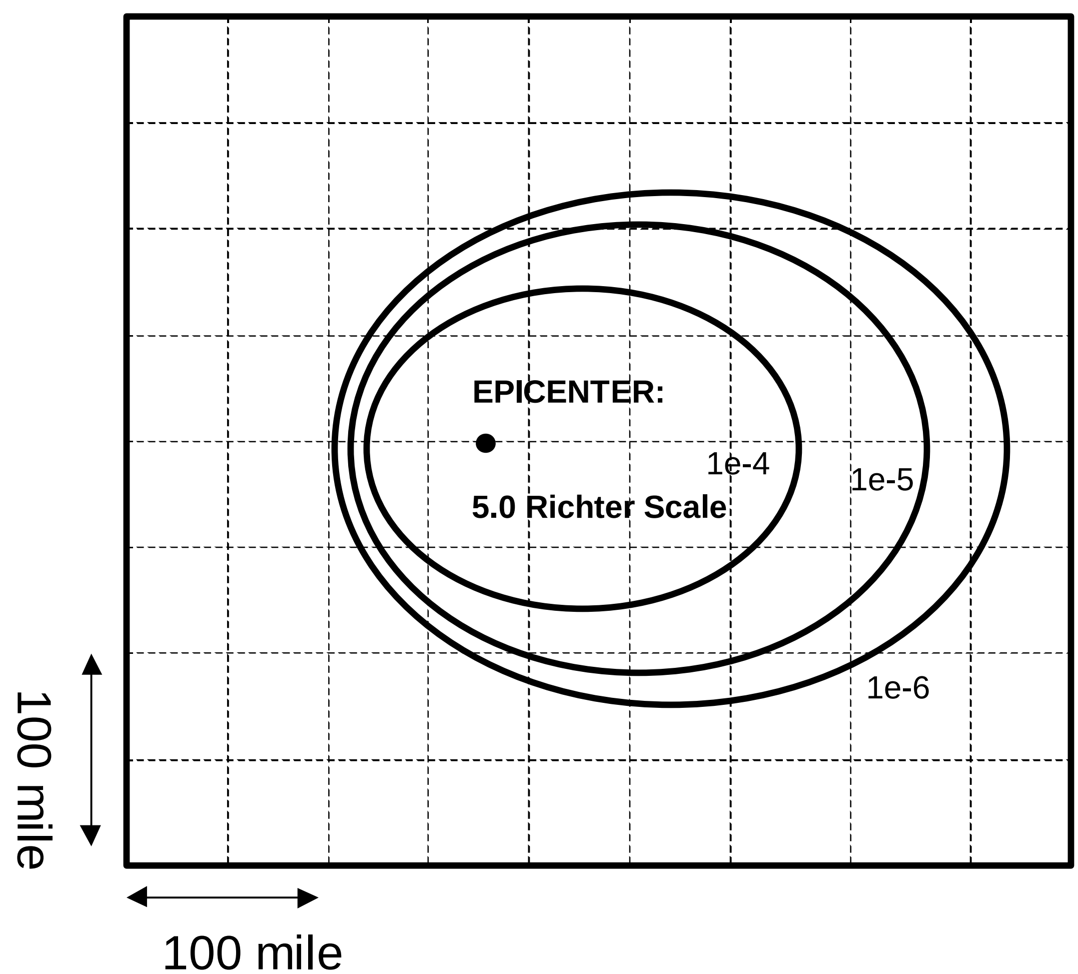
## INTRODUCTION TO NATURAL HAZARDS

SOURCE:

**Level 1 Individual Risk:**
Annual Probability of death for individual attributable to a Natural Hazard.

**Assumption:**
Person is on a fixed location outside any buildings. Person is present at this location for 24 hours and does not move.

**Risk Contours are used to present Individual Risk**



**Level 1 Societal Risk:**
Concentrates on consequence in terms of number of fatalities per year attributed to Natural Hazard.

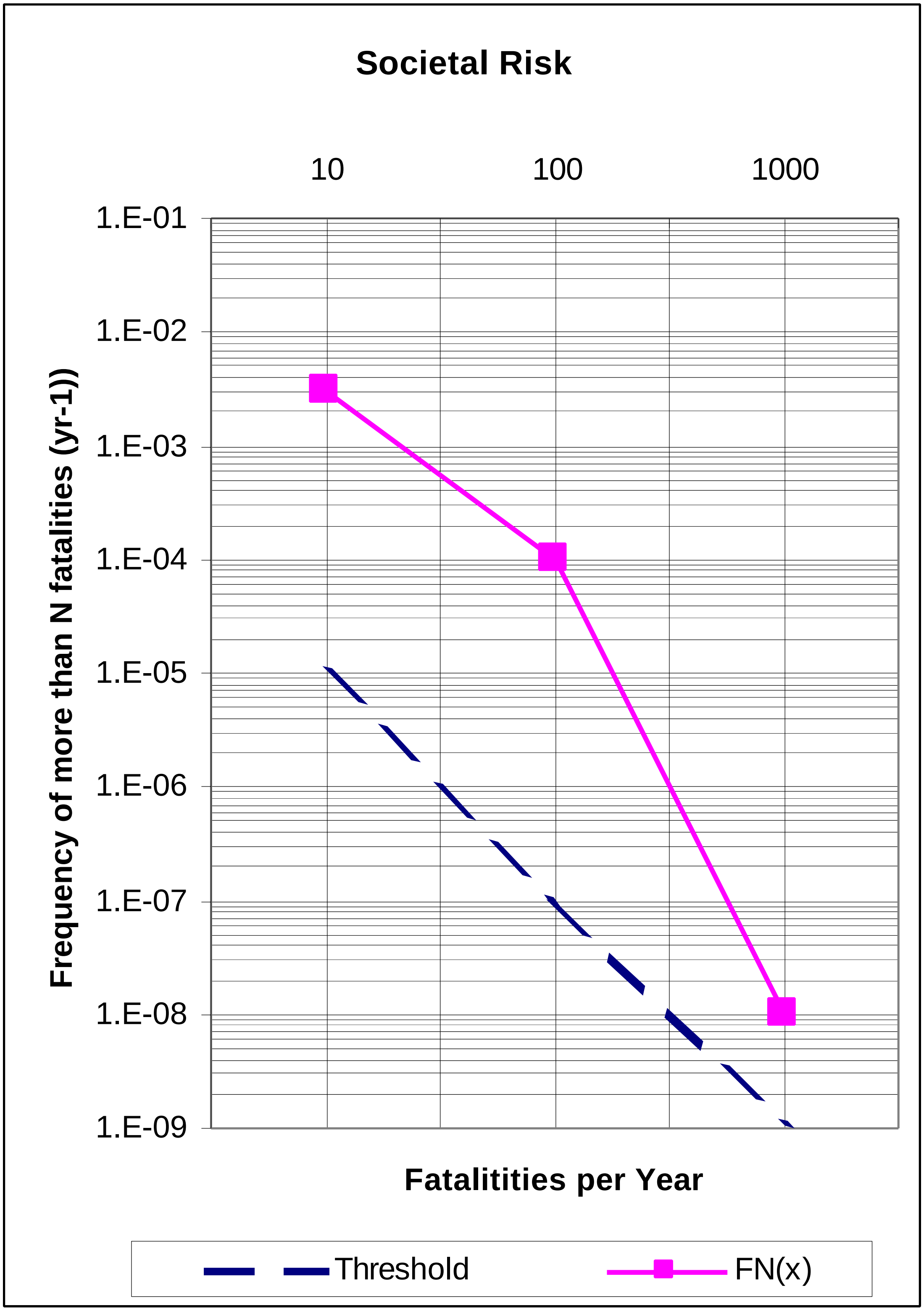
FN-Curve: The exceedance probability of number of deaths

D = Number of Deaths per year attributable to activity

F(x) : CDF of attributable to hazardous activity - $Pr(D \leq x)$

$$\text{FN-Curve: } FN(x) = 1 - F(x)$$

**Assumption:**
Population is distributed according to population statistics and is assumed to remain on a fixed location and outside any buildings. Population remain at this location for 24 hours and does not move.


Societal Risk
10
100
1000
1.E-01
1.E-02
1.E-03
1.E-04
1.E-05
1.E-06
1.E-07
1.E-08
1.E-09
Frequency of more than N fatalities (yr-1))
Fatalitities per Year
Threshold
FN(x)

**Level 2 Individual Risk:**
Annual Probability of death for individual attributable to a Natural Hazard.

**Assumption:**
Person is on a fixed location inside building on that location, if there is one. Person is present at this location for 24 hours and does not move.

**Level 2 Societal Risk:**
Concentrates on consequence in terms of number of fatalities per year attributed to Natural Hazard.

FN-Curve: The exceedance probability of number of deaths

$$D = \text{Number of Deaths per year attributable to activity}$$

$$F(x) : \text{CDF of attributable to hazardous activity - } Pr(D \le x)$$

$$\text{FN-Curve: } FN(x) = 1 - F(x)$$

**Assumption:**
Population is distributed according to population statistics and is assumed to remain on a fixed location and inside buildings on that location. Population remain at this location for 24 hours and does not move.

# POTENTIAL STUDY APPROACH

## Apply Decomposition Principle

**Assumption:**
A Natural Hazard has a particular area of initial impact (e.g. epicenter for earth quakes, location land fall for hurricanes, length shore line for tsunami's etc.) and intensity level (e.g. Richter scale for earth quakes, category for hurricanes, wave height for tsunami's etc).

**Question 1:**
Determine the annual frequency of occurrence the natural hazard particular to a geographical region/country.

**Question 2:**
Given the occurrence of a natural hazard what is the likelihood distribution over the different intensity levels.

**Question 3:**
Given the occurrence of the natural hazard determine the probability or it occurring at a particular location within this region/country.

If necessary, answer question 3 for all the different intensity levels of the natural hazard.

**Possible Simplifying assumption**:
Likelihood of geographical location of impact and likelihood of intensity level are independent uncertain events given the occurrence of the natural hazard.

**Question 4:**

Given a natural hazard occurring impacting at location X with Intensity Level Y, what is the size of Consequence area Z.

**Question 5:**

Given a natural hazard occurring impacting at location X with Intensity Level Y, and consequence area of size Z, does intensity level Y apply to the entire consequence Area or does the intensity level decrease with an increase in distance from the initial point of impact.

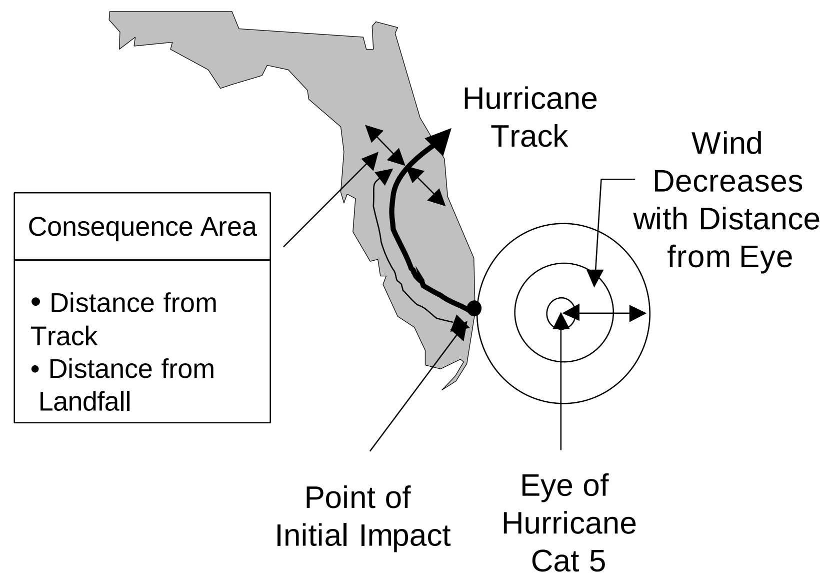
**OBSERVATION:**

1. Answers to Question 1 to 5 establish the uncertainty characteristics of the Natural Hazard. They describe:
   - the uncertainty in annual occurrence,
   - the uncertainty in intensity level given occurrence
   - the uncertainty in location given occurrence,
   - the uncertainty of intensity propagation in the consequence area given the occurrence at a particular location.

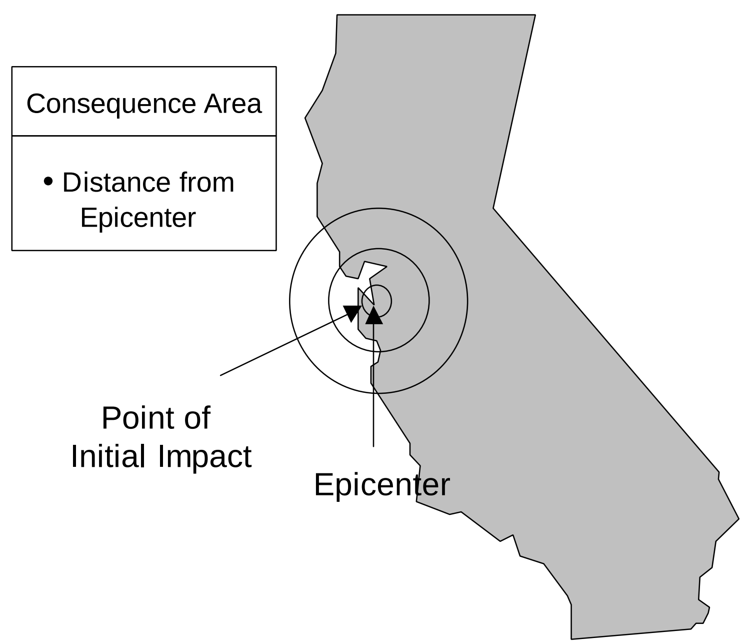
2. Answers to Question 1 to 5 are necessary input to a natural hazard risk assessment regardless whether our definition of risks focuses on

- Fatalities
- Building Losses
- Long Term Economic Losses
- Etc.

# HURRICANE EXAMPLE



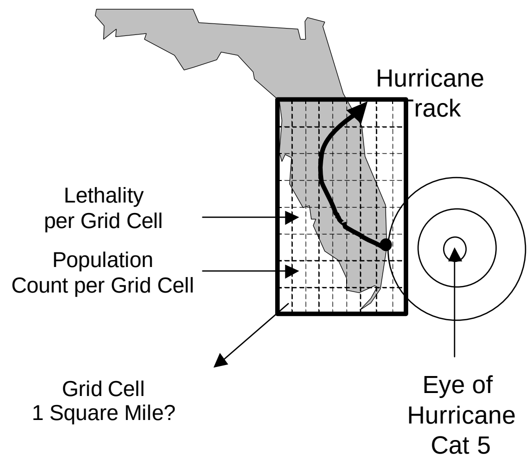

# Earth Quake Example



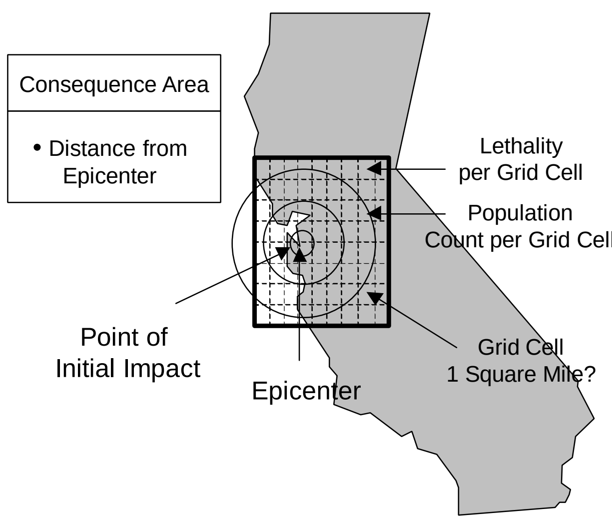
# Question 6A: Level 1 Individual Risk and Societal Risk

Given a natural hazard occurring impacting at location X with Intensity Level Y and Consequence Area of Size Z, what is the probability of lethality over the consequence Area.

## HURRICANE EXAMPLE

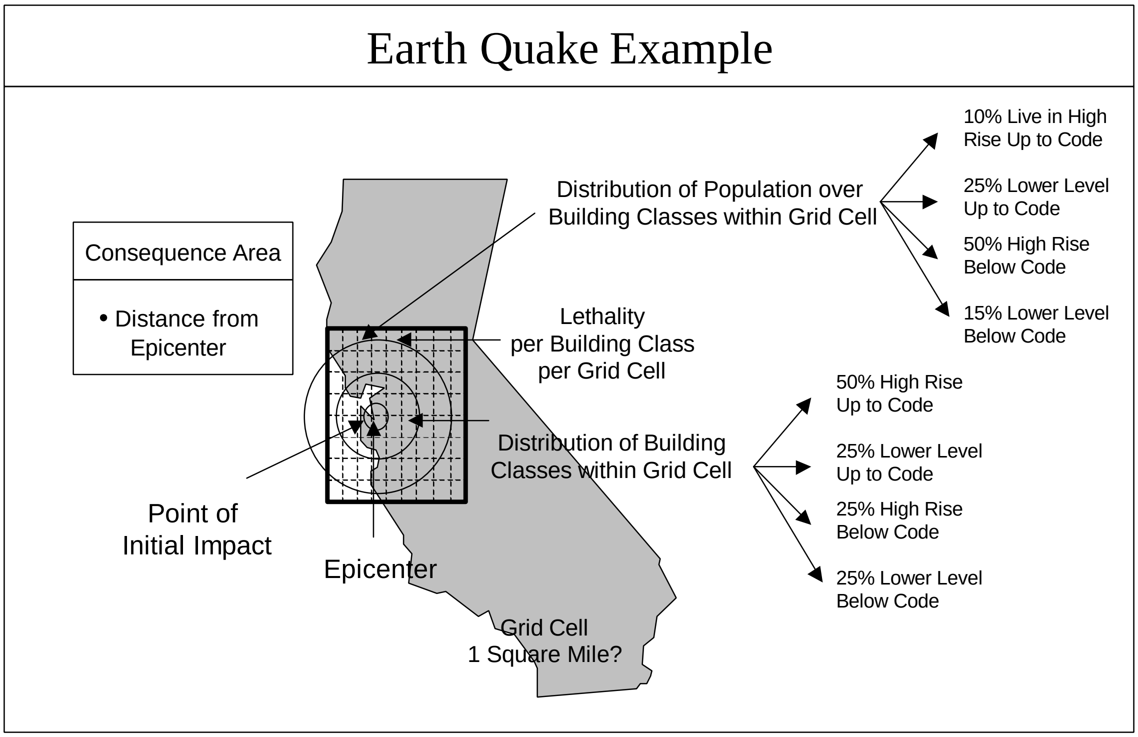



## Earth Quake Example



## Question 6B: Level 2 Individual Risk and Societal Risk

Given a natural hazard occurring impacting at location X with Intensity Level Y and Consequence Area of Size Z, what is the probability of various levels of destruction of particular building classes.



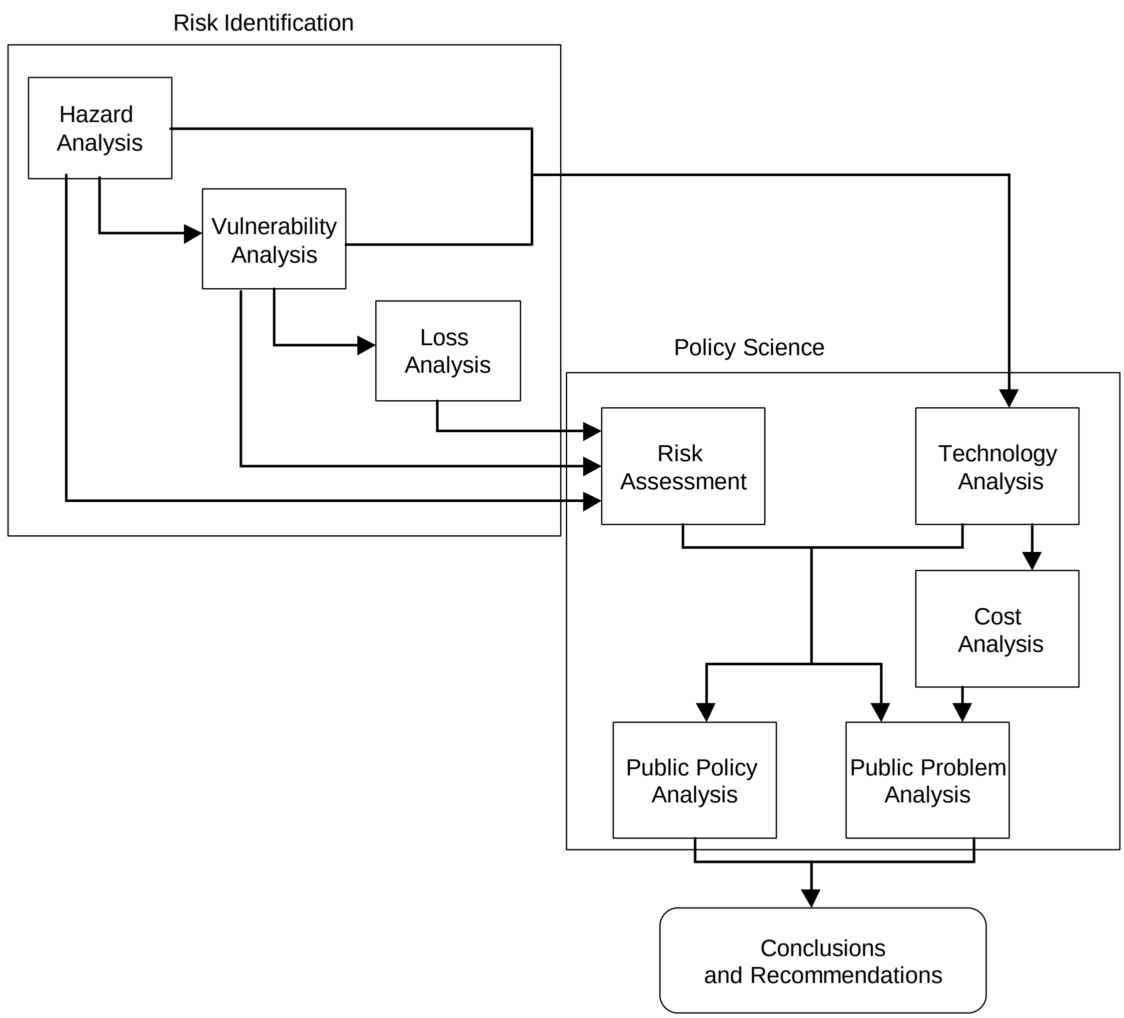

## Question 7: Level 2 Individual Risk and Societal Risk

Given the destruction of a building of a particular class what is the probability of lethality for a person within this building?

# Similar Approach was Follow by Petak and Atkisson (1982):

Comprehensive Natural Hazard risk assessment comparing 9 different natural hazards in one model:

1. Earth Quakes
2. Landslides
3. Expansive Soils
4. Riverine Flooding
5. Storm Surge
6. Tsunami
7. Tornado
8. Hurricane



## Hazard Analysis:

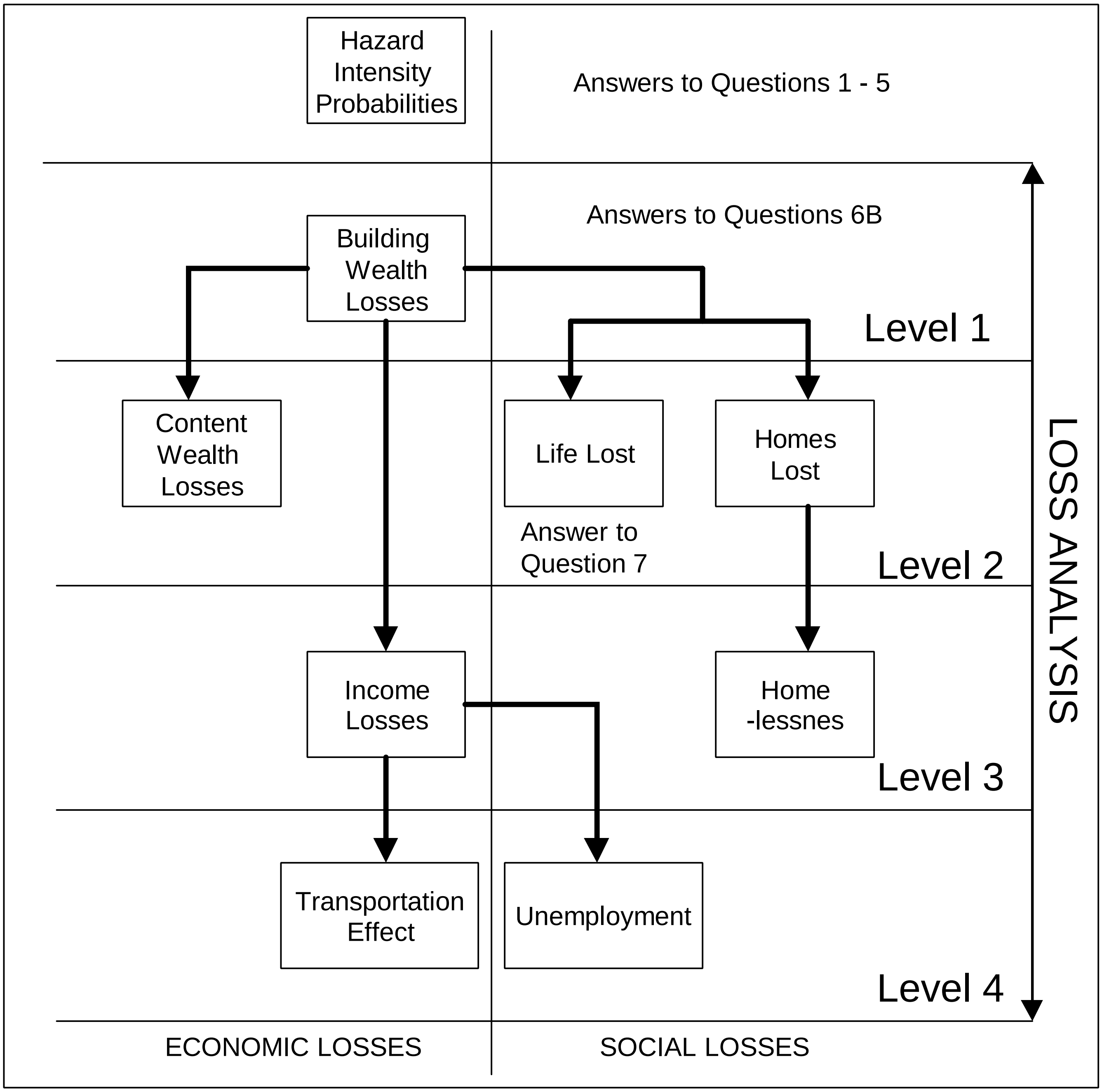
Identification and description characteristics, geographic distribution and potential effect of nine hazardous natural events within the US. **Answers:** Question 1 to 5.

## Vulnerability Analysis:

Assessment of the vulnerability of several classes of building and their occupants to each hazard. **Answers:** Question 6B.

## Loss Analysis

Identification of the primary and second order effects to be associated with the exposure by major geographic area, of buildings and there occupants to these hazardous natural events. **Answers:** Question 6A and 7


Hazard Intensity Probabilities
Answers to Questions 1 - 5
Answers to Questions 6B
Building Wealth Losses
Level 1
Content Wealth Losses
Life Lost
Homes Lost
Answer to Question 7
Level 2
Income Losses
Home -lessnes
Level 3
Transportation Effect
Unemployment
Level 4
ECONOMIC LOSSES
SOCIAL LOSSES
LOSS ANALYSIS

**Problem Analysis:**

- Identification and explication of the major candidate public problems associated with the effects of the nine natural hazards
- Identification of the major effects and candidate public problems that might be generated by the use of selected technologies to mitigate the effects of the nine natural hazards.

**Technology Analysis:**
Identification of the costs and characterisitics of the major types of technologies appropriate for mitigating the effects induced by the exposure of buildings and their occupants to the nine natural hazards.

**Cost Analysis:**
Estimation of the economic costs and other effects associated with the use of selected technologies to mitigate the effects of selected natural hazards.

**Public Policy Analysis:**

- Identification and description of the major type of public policies that may induce the application of hazard mitigating tehcnologies.
- Identification and evaluation of the major-solving strategies and the major problem solving strategies and public policies relevant to the problems identified in the **problem analysis**

# INTRODUCTION TO NATURAL HAZARDS

## SOURCE:

- Multihazard, Identification and Risk Assessment Report, FEMA publication
- National Geographic, Vol. 194, No. 1, July 1998
- Natural Hazard Risk Assessment and Public Policy, Petak & Atkisson
- Environmental Hazards, Keith Smith, Assessing Risk and Reducing Disaster.

# 1. EARTH QUAKES

- Involve Moving and Shaking of the Earth's Crust

**Causes:**
- Release of stresses accumulated as a result of rock rupture along fault planes in the earth's outer crust.
- Continuous collision between 10 major and several minor plates comprising 10 - 50 mile thick outer crust and the floating crust.

**Measurement**: In terms of Richter Scale (9 point logarithmic scale). One unit increase corresponds to a tenfold change in vibrational amplitude and 31.5 change in energy release.

**Seismic Effects:** Direct and Indirect effects of Earth Quakes reflect quake's intensity. Measured in Modified Mercalli Intensity (MMI) scale.

**Damage:** Proportional to Energy Released, the distance from Epicenter, local rock and soil characteristics, and vulnerability of property.

**Hazard:** Based on complex interrelationships between earth quake faults, weak geological materials and human activity.

# 2. LANDSLIDES

- An event in which surface masses of slope-forming earth move outward and downward from their underlying and stable floors in response to gravity**.**

**Causes:** Landslide occurs when "shear resistance" is exceeded by "shear stress".

## TRANSITIONAL or ROTATIONAL SLIDES

- Transitional or Rotational Slides: Mass movements that involve a distinct surface rupture or zone of weakness separating the earth slide material from more stable underlying material.

**Causes**:

- Slope that are sufficiently steep
- Underlying zone of weakness at a potential surface of rupture
- An introduction of a natural or man-made disturbing factor.

# 3. EXPANSIVE SOIL

- Excessive shrik-swell behavior of soils producing the craking and/or failure of building walls, foundations, slabs and veneers.

**Causes:**

- Soil and rock containing clay materials with the capacity of undergoing significant volumetric changes when subjected to variances in water content. Degree of shrink-swell related to proportion of clay contained in the soil.

**Measurement: COLE**, coefficient of linear extensibility developed by U.S. Soil Conservation Service.

**Identification:** Tentatively by visual observation and positively by laboratory testing. See Table 2-4.

## EXPANSIVE SOIL - MITIGATION

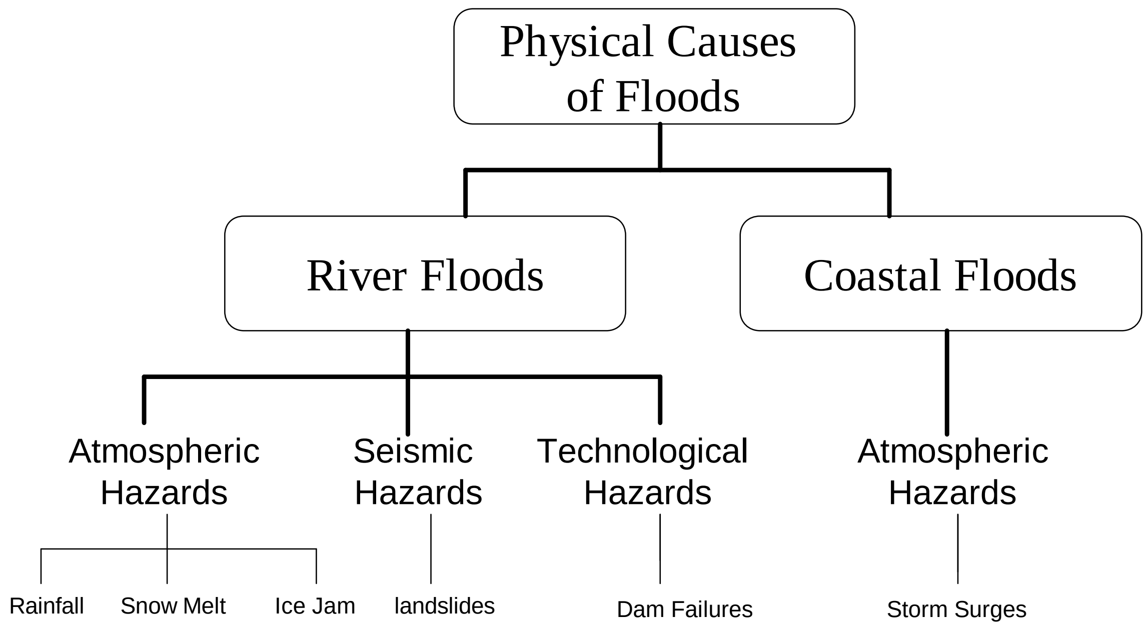
- Use of soil stabilization and moisture control techniques
- Engineered foundation design
- Well-planned site-drainage systems
- Landscapping to enhance drainage
- Careful attention to interior construction details.

# 4. RIVERINE FLOODING

- Periodic flooding of lands adjacent to streams and rivers

**Causes:**

- Function of precipitation levels and water runoff colume within in the watershed of the stream or river.




**Measurement:**

- Average Time Interval, in years, between the occurrences of a flood of a specified magnitude.
-
- Portion of streams floodplain that will be inundated by spillover waters is referred to by the name of the frequency interval.

HYDROLOGIC HAZARDS: FLOODS

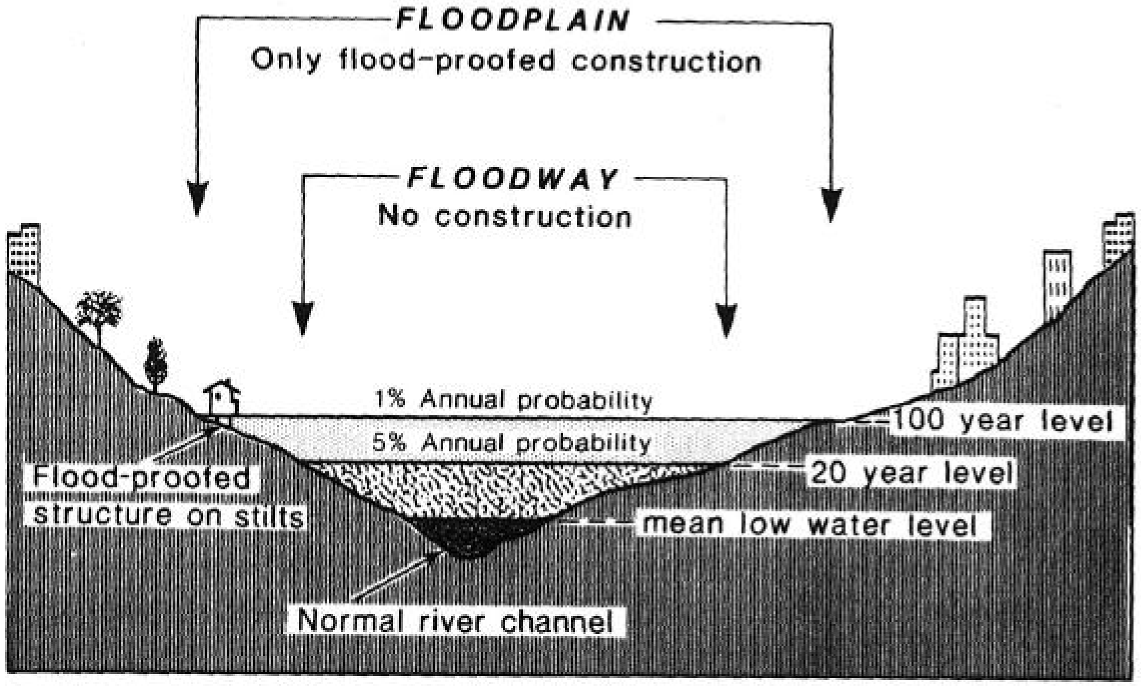



*Figure 11.5* The delimitation of hazard planning zones on a hypothetical floodplain. Such zonation is intended to restrict encroachment and vulnerable development in the most hazardous areas through the application of building legislation.

**Damage depends on:**

- The type, strength and elevation of structures
- The depts of the floodwaters during the epizide
- The force exerted against the structure by mooving floodwaters
- Impacts of floating debris against the structures
- The adverse effects of "wetting" on the structures and their contents as a result of the intrusion of flood waters.

**Table 4-2.** Number of Urban Places with Flood Problems

| City size | Number of places with flood problems (incorporated municipalities) |
|---|---|
| Greater than 100,000 | 140 |
| 50,000 – 100,000 | 204 |
| 25,000 – 50,000 | 390 |
| 10,000 – 25,000 | 903 |
| 5,000 – 10,000 | 992 |
| 2,500 – 5,000 | 1,098 |
| 1,000 – 2,500 | 1,812 |
| Total | 5,539 |

Source: U.S. Army Corps of Engineers, 1967.

**Table 4-3.** Distribution of Dwelling Units by Flood Hazard Zone

| Hazard zone | Return period of flood (years) | Fraction of dwellings on 100 year floodplain[a] | |
|---|---|---|---|
| A | 2–5 | .135 | |
| B | 5–10 | .150 | |
| C | 10–25 | .200 | $\Sigma = 1.0$ (A–E) |
| D | 25–50 | .245 | |
| E | 50–100 | .270 | |
| F | more than 100 | 1.000 | |

[a]There are as many dwelling in Zone F as in Zone A to E inclusive.

# RIVERING FLOODING - MITIGATION

- Structural Mitigation that involve the construction of area protecting dams, dikes, levees an/or deepening or improvement of the normal watercourse

- Avoidance mitigation that prevent or deter the oocupancy of flood plain lands

- Building mitigations such as the elevation, strengthening, and/or floodproofing of structures locateds within the flood plain.

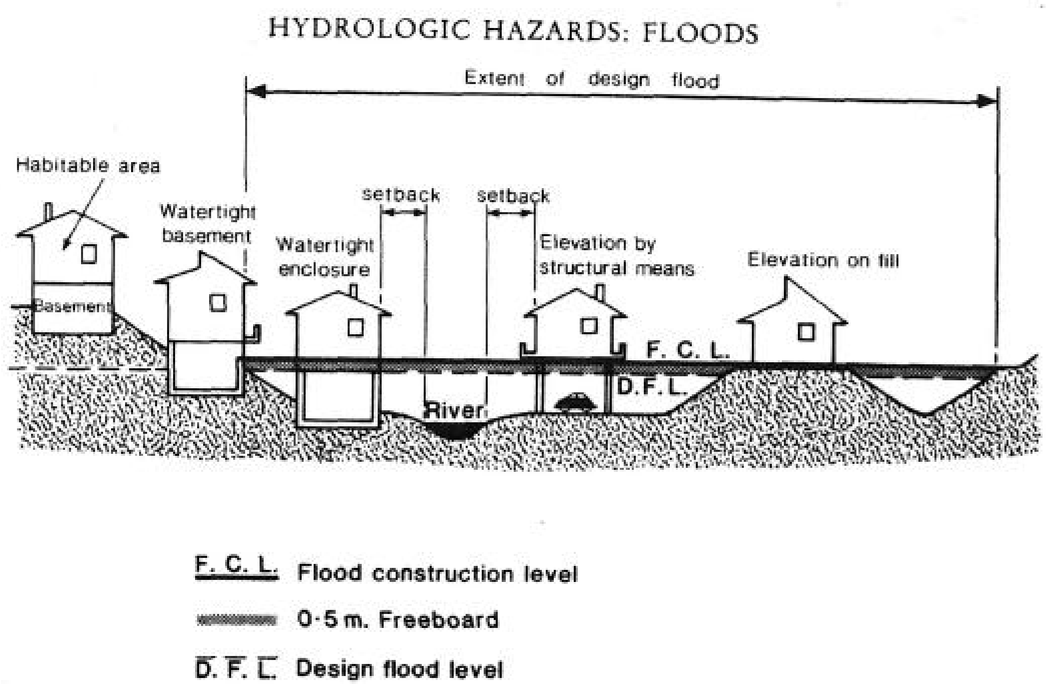



*Figure 11.6* The location and design of flood-proofed new residential buildings on an idealised floodplain. Habitable areas are raised above the flood construction level. In turn, the flood construction level allows 0.5 m of freeboard above the predicted maximum height of the design flood, e.g. the 1:100 year event.
*Source:* Modified from Rapanos (1981)

# 5. STORM SURGE

- An event in which coastal waters rise above the level associated with normal tidal action. Most affected Areas:Atlantic, Gulf Costs.

**Causes:**

- Hurricanes + Tropical Storm
- Nothern Atlantic Coast Line: Extratropical Winters "Northeasters"

**Extreme Waves:**

- Superimposed on high waters when storm approaches land.
- Depth, size of the surge depends on interaction of storm path, speed, and size, as well as configuration of sea bottom and coast line.

Tropical Weather Storms potential for storm surges classified in three categories:

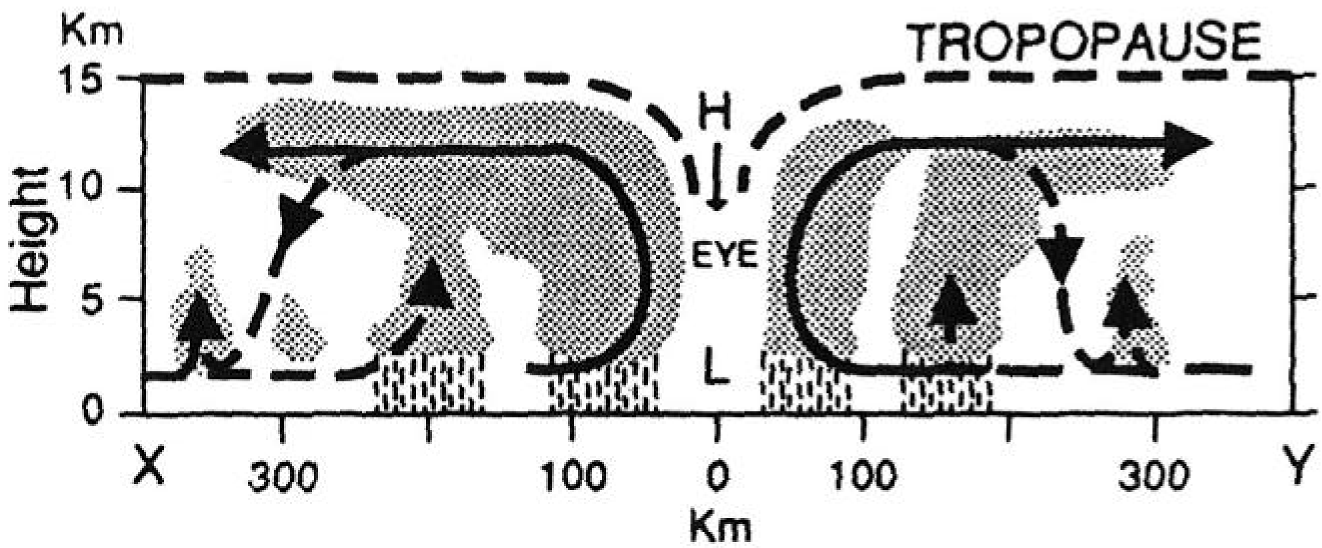
- Tropical Depressions with max windspeed < 40 mph
- Tropical storms with max windspeed of 40 to 73 mph
- Huricanes with max windspeed in excess of 73 mph

**Damage:**

- Still water effects associated with the simple inundation of structure or land
- Wave Action Effect induced by the pounding of waves against a structure

Most devastating storm surges are cause by hurricanes. The normal water level may be altered by five distrinct processes:

- The Pressure Effec.
- The Onshore Wind Effect.
- Coriolis Effect: Related to Earth's Rotation
- Wave Effect
- Rainfall Effect.




**STORM SURGE - MITIGATION:** Same as Riverine Flooding

# 6. TSUNAMI

- Seismic sea wave, a larg ocenaic wave produced by an earth quake, submarine volcanic eruption, or large submarine landslide. Waves are formed in groups having great length from crest to crest and long periods. In deep, oceans wave lengths may be **100 miles or more**, while wave heights are **only a few feet**. Nevertheless, the intrisic wave energy is enormous.

- As a tsunami enters shallow waters wave felocity decreases, height increases. Waves following the intitial wave can crest at heights of **more than a 100 feet** and strike with devastating force.

## Damage:

- Still water effects associated with the simple inundation of structure or land
- Force excerted on the structure by the impacting wave.

In the last 50 years, more lives have been lost due to tsunamis than directly from seismic activity. 1946, 173 people killed in Hawaii. 1964, 126 people killed in Alaska.

# TSUNAMI - MITIGATION

Forces associated with Tsunamis are so great that the only positive means of protection for most structures is to avoid areas subject to tsunami impact.

THE EXPERIENCE AND REDUCTION OF HAZARD

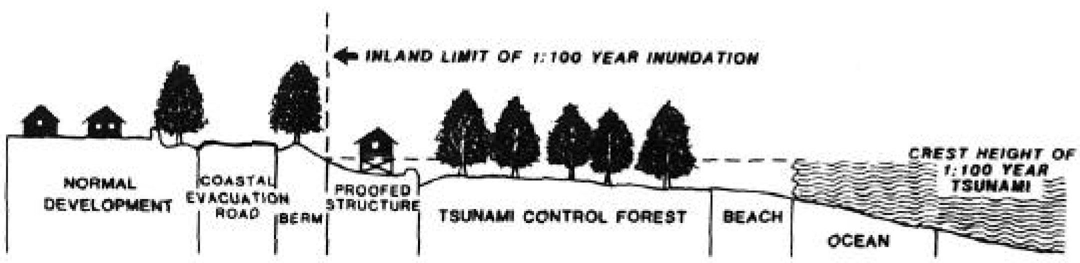



*Figure 6.10* Coastal land use planning designed to mitigate tsunamis. The beach and the forest are used to dissipate the energy of the onshore wave whilst development and the coastal evacuation route are located above the predicted height of the 1:100 year event. *Source:* After Preuss (1983)

# 7. TORNADO

- Violently rotating columns of air that are in contact with the ground. A tornado is visible as a cloud base or rotating dust cloud rising from the ground.

Comes from Spanish "tornada" = thunderstorm. Derived from Latin "tornare"=make round by turning.

- Most violent weather phenomena known to man. Rotating at velocities up to **500mph**, ranging from **1/4 to 3/4 of a mile wide** and **upward of 16 miles long**.
- Extreme Events have been known to travel over areas of one mile wide and 300 miles long.
- No other disaster strikes with the suddenness of a tornado.

**Measurement:** Fujita Classification and Pearson Scale. Later classifies tornadoes by their path width and length.

**Damage:** Increases as the Fujita Scale increases. Tornado are local low pressure systems. The pressure inside a building will greatly exceed the outside pressure**. It is better to open a window.** Tornado's **number 1 natural disaster killer** in US.

# TORNADO - MITIGATION

- Event is random, little can done to keep population and structure out of path

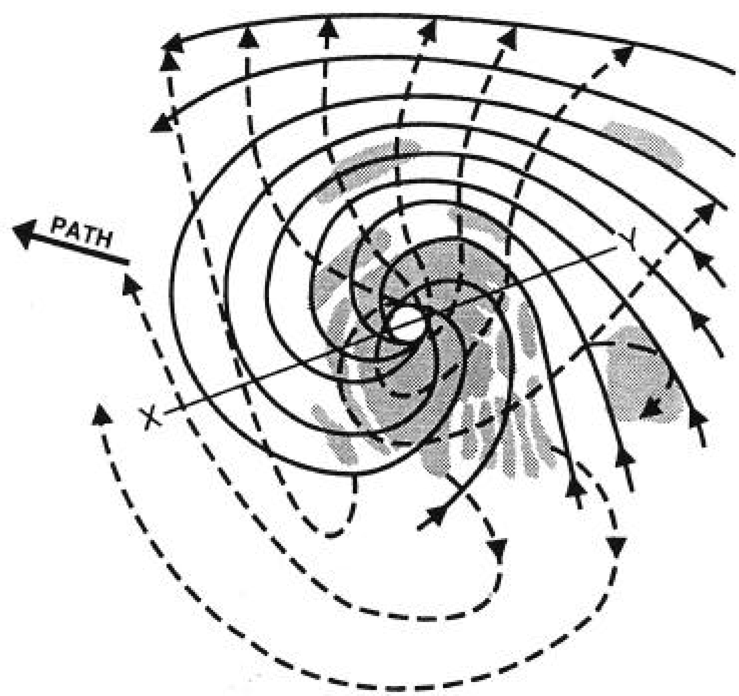
- Vulnerability of structures exposed to tornadoes can be reduced through the use of building strengthening technologies. Mitigation should concentrate on improved structural design

- Storm cellars, Old Buildings reinforced, Mobil homes tied down, windows boarded up, Framed Construction, Fasten Roof and Floor to supports.

# 8. HURRICANE

- An event involving devastating winds, flood producing rain, and sometimes lethal storm surges

- Large Cyclones of Air in which the counterclockwise spiraling wind moves around a relatively calm center at speeds of 73 mph or more.



- Formed in the tropics hurricane systems measure about **400 miles in diameter**, moves forward at a speed **of 15 mph**, and has an **average life span of 9 days**.

- Highest wind speeds are measured approximately 20 to 30 miles from the center. Max Speed recorded: 197 mph (Hurricane Inez).

- Gusts between 73-120 mph can be expected to extend 40-100 miles from the center.

**Hurricanes differ from Tornadoes:**

- Change in pressure from center is gradual. Has little effect on structure.
- Hurricane Winds are generally smaller than those of a tornado.
- While both windstorms are rotating air masses, the hurricane rotating air mass covers a much greater area.

## HURRICAN - MITIGATION

- Similar to Tornadoes