Damage Mitigation Measures
for New and Existing Structures
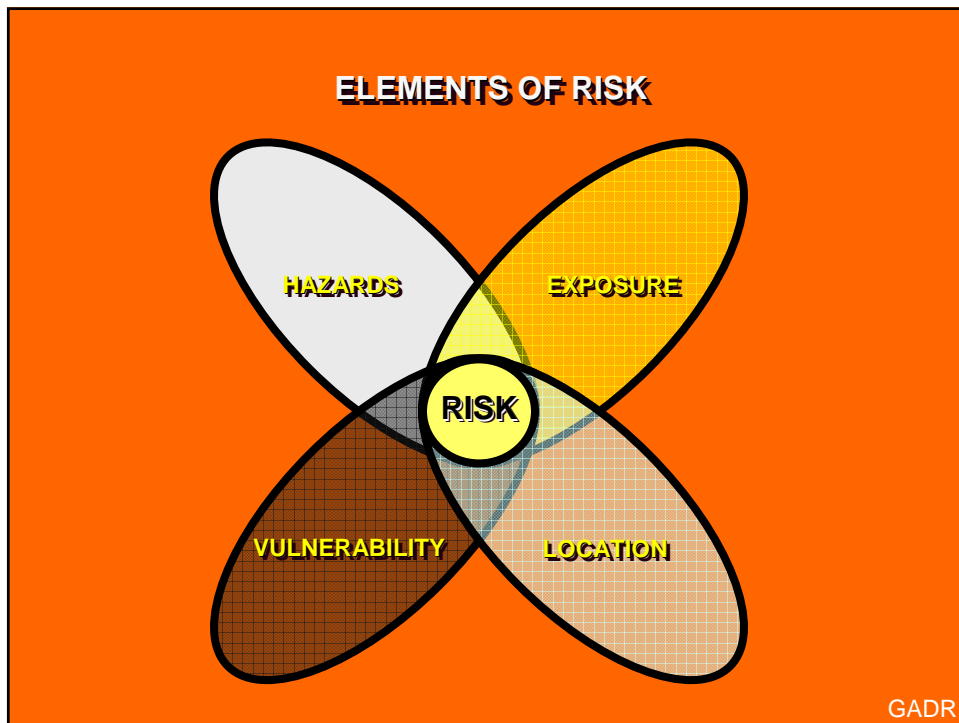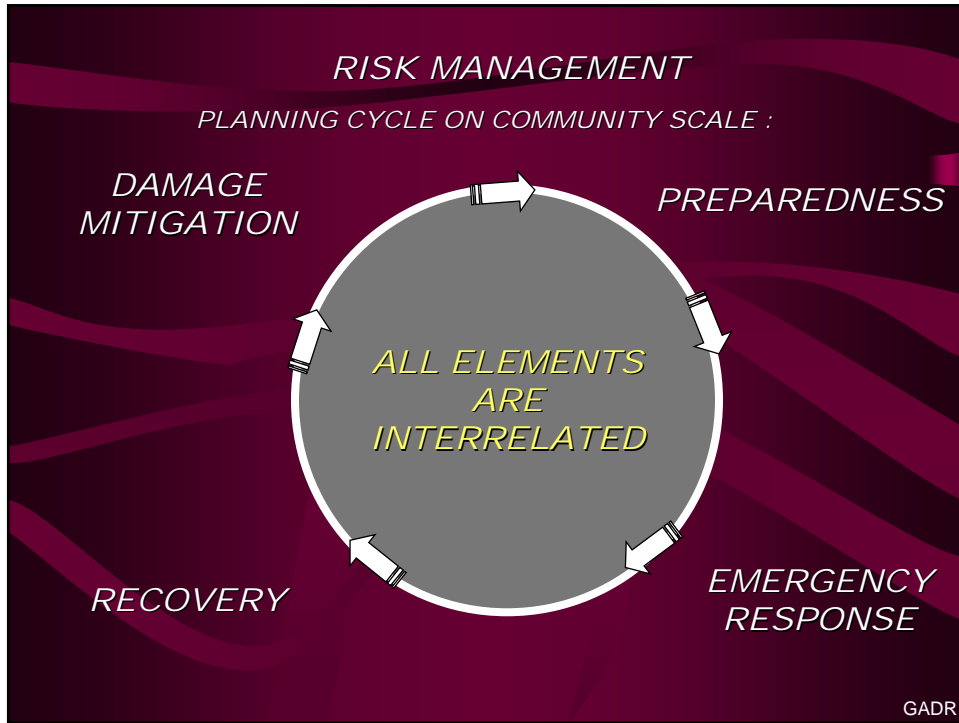
Tony Gibbs
Consulting Engineers Partnership Ltd

Definition

Generally: Hazard . Vulnerability = Risk

Natural Hazard . **High** Vulnerability = **Disaster**

that is a man-made disaster
not a natural disaster

Recommended seismic behaviour objectives
Required behavior

Level of seismic design	Permanent Operation	Immediate Occupation	Protection of lives	Collapse Prevention
Frequent (50% over 30 years)	✖	Unacceptable performance (new facilities)		
Occasional (50% over 50 years)	◆	✖		
Rare (10% in 50 years)	🔴	◆	✖	
Very Rare (10% in 100 years)		🔴	◆	✖

🔴 = Critical security, as in hospitals and fire stations
◆ = Essential or hazardous facility or component, such as telephone switchboards and buildings with toxic materials stored inside
✖ = Basic or conventional facility, such as offices or homes

PAHO

Vulnerability Surveys

a) qualitative assessments

b) analytical evaluations

**Qualitative Assessments
by persons other than engineers**

a)   structure
   -      wind

b)   non-structure
   -   earthquake
   -      wind

**Pan American Health Organization
DIPECHO**

**Health Services Facilities
in the
Eastern Caribbean**

**Terms of Reference for Consultants
and
Standards
(with particular reference to
Natural Hazards)**

July 2000

Prepared for the Pan American Health Organization
under the Disaster Prevention, Mitigation and Preparedness Programme
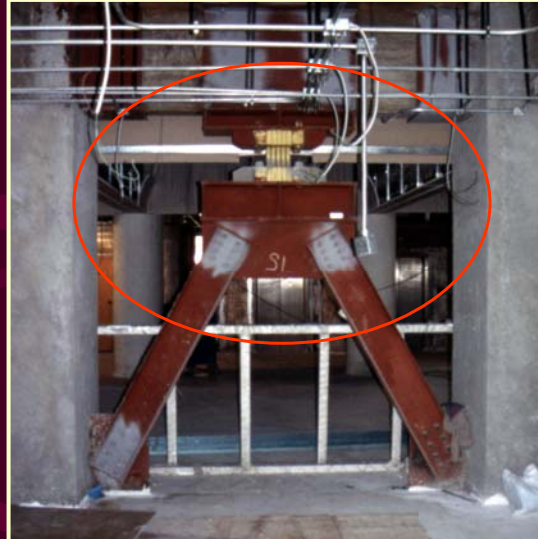of the European Community Humanitarian Office

Plan irregularities

Examples of irregularities in elevation
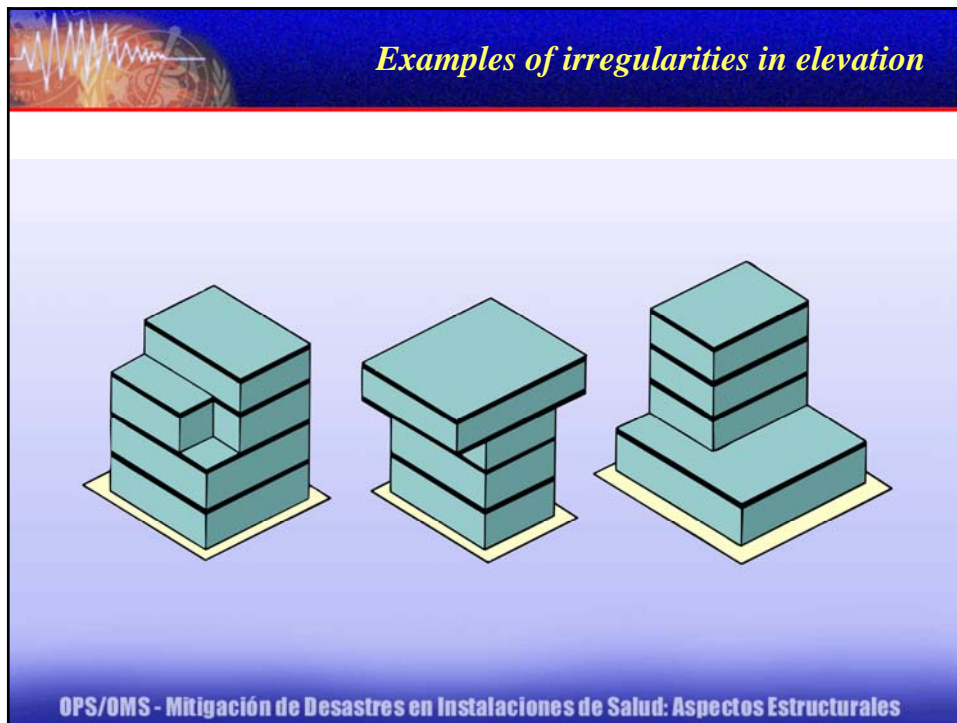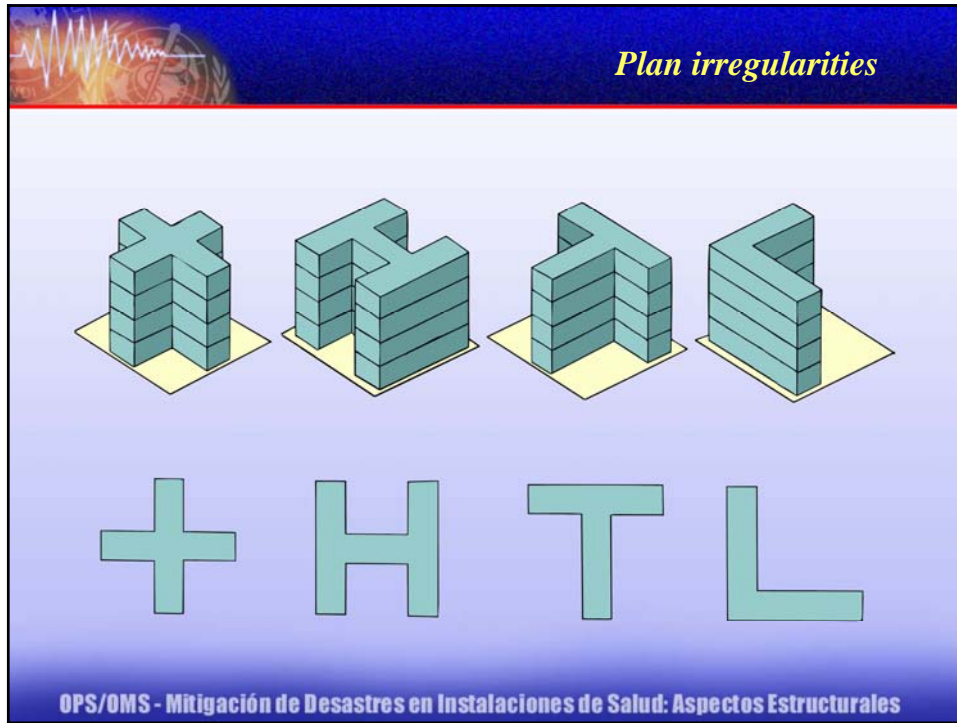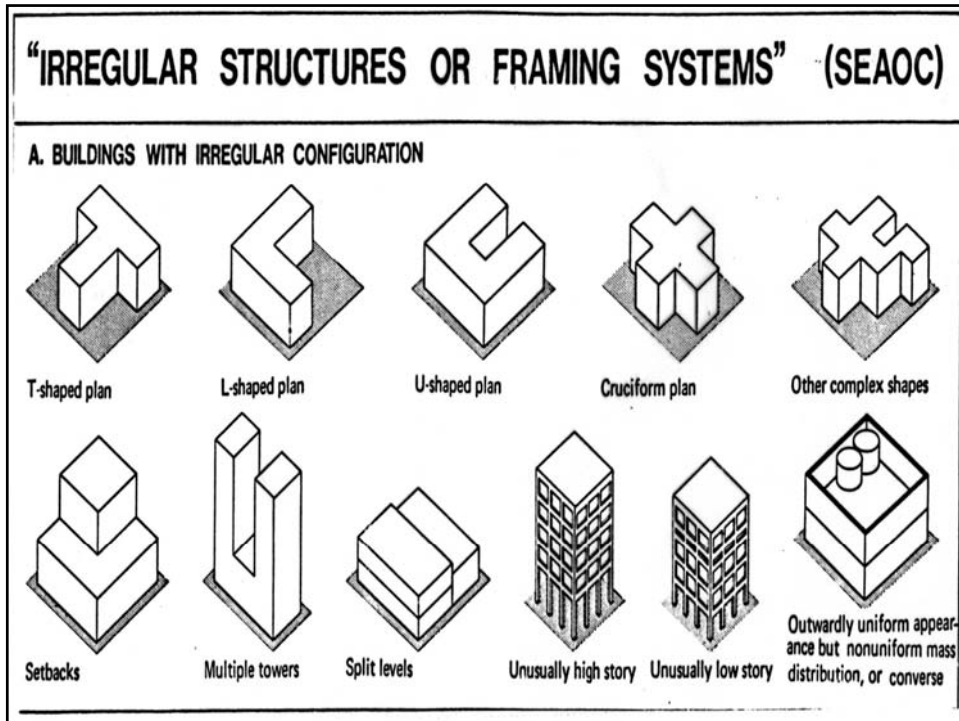
Retrofitting

Method of "strengthening":
Dissipation of energy used in the central offices of
Instituto Mexicano del Seguro Social-México (PAHO)

Method of strengthening:
Perimeter structural frames used in the Hospital México
of the Caja Costarricense del Seguro Social, Costa Rica (PAHO)

M. Cruz

Method of strengthening:
Buttresses used in the Hospital de Cardiología
del Instituto Mexicano del Seguro Social (PAHO CD-ROM)

Reinforcement method: addition of (interior or exterior) walls

PAHO

Reinforcement method: External diagonals or braces

O.D. Cardona

JN France Hospital post-George

Wall strengthening

Strengthening internal partition

Roof framing completed

HIP ROOF CONSTRUCTION

Non-structural elements

OPS/OMS - Mitigación de Desastres en Instalaciones de Salud: Aspectos no Estructurales

Suspended ceilings
are particularly vulnerable during earthquakes. (PAHO)
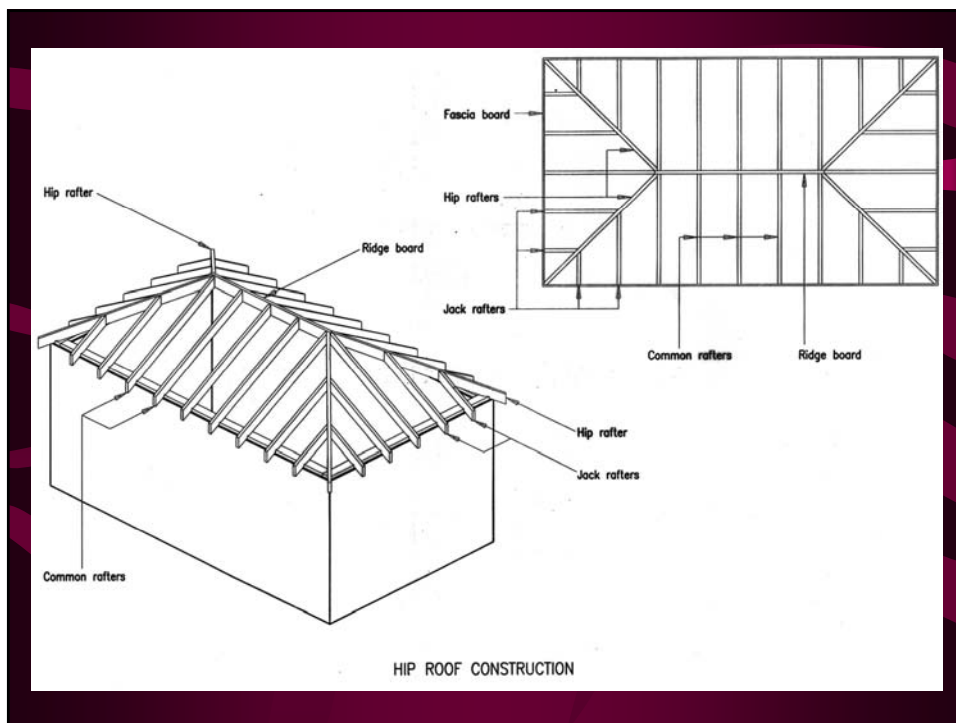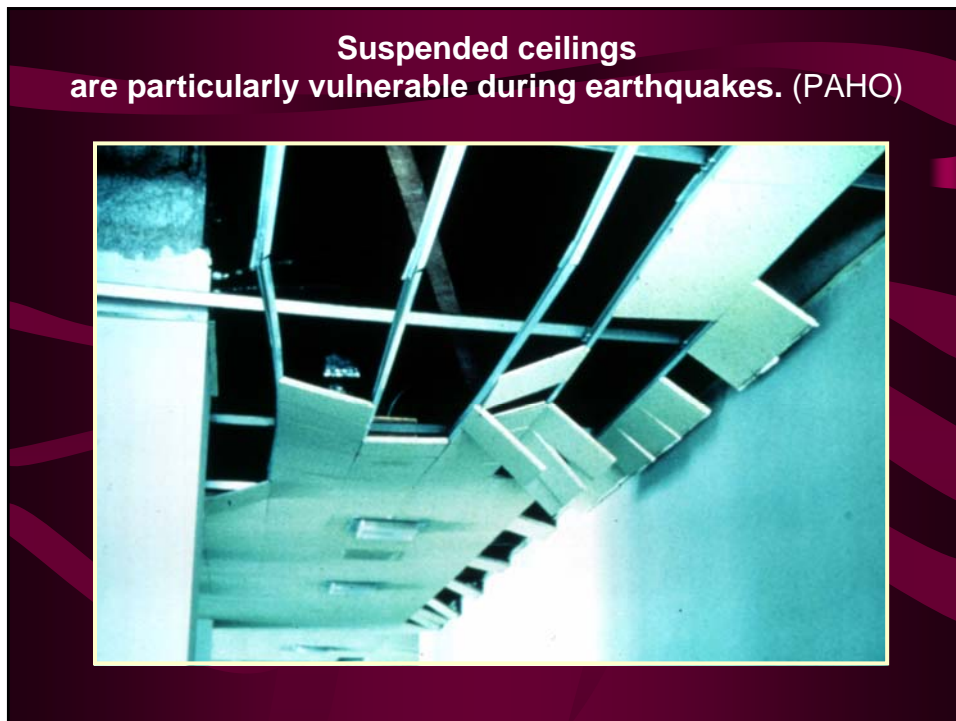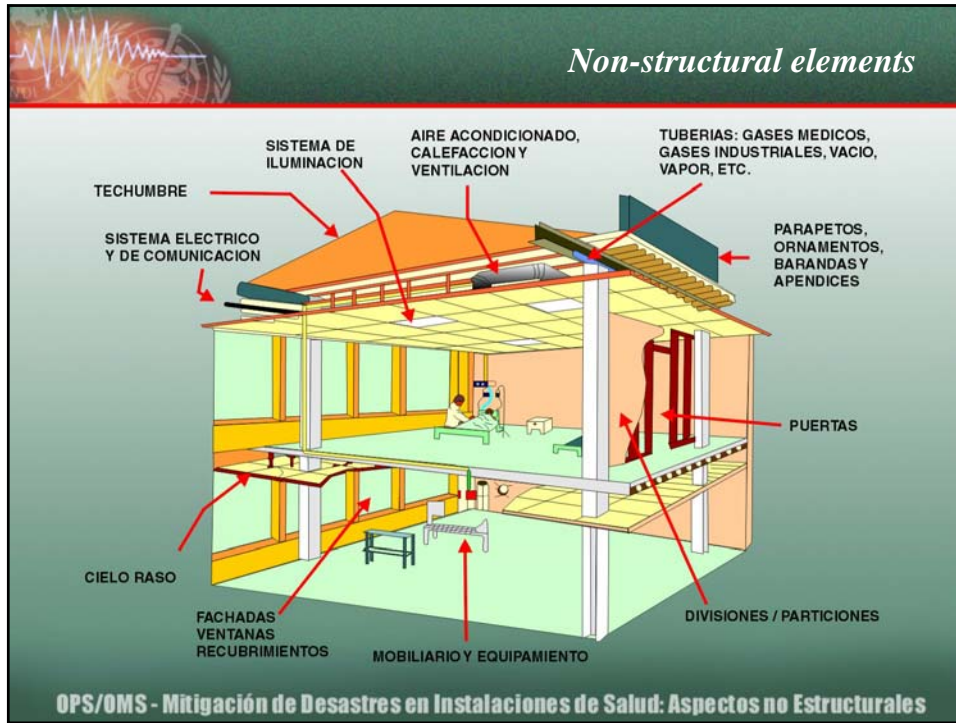
Recommended arrangement of restraints for suspended ceilings, light fixtures and ducts (PAHO)

Hospital infrastructure should be appropriate to safeguard its advanced technological equipment so as to reduce its vulnerability. (PAHO)

Restraints and fasteners for smaller equipment

PAHO/WHO - Disaster Mitigation in Health Facilities: Nonstructural Issues

The breakage of containers of chemicals and biological materials during an earthquake may lead to fires or contamination. (PAHO)

There should be made available the means to prevent the shifting or tipping over of essential supplies. (PAHO)

The disruption of *clinical documents* neccesitates the use of human resources for cleanup when they are required for priority tasks in the aftermath of an earthquake. (PAHO)

Furniture supports

SHELF LIP

ATTACHMENT TO WALL

WIRE OR ELASTIC STRAP

STEEL ANGLE

ATTACHMENT TO WALL

BRACING

TYING PLATE

BOLTED ANCHOR

PAHO/WHO - Disaster Mitigation in Health Facilities: Nonstructural Issues   33

Photo 33 - Blood Bank
Unrestrained gas cylinder is vulnerable to toppling in the event of an earthquake.
<<<<<<<<<
<<<<<<<<<
<<<<<<<<<
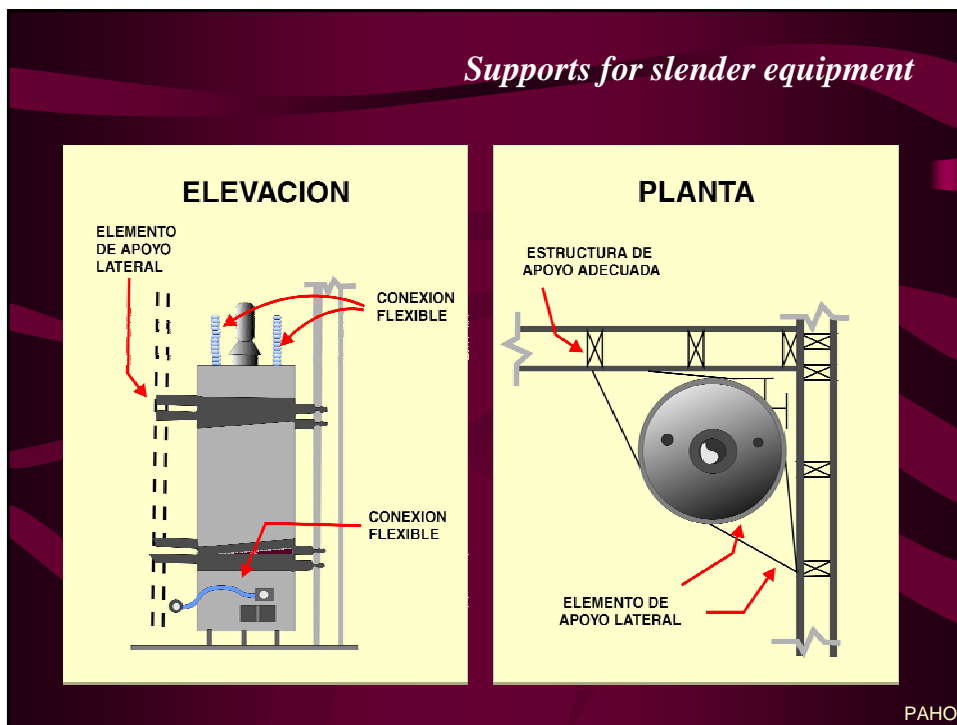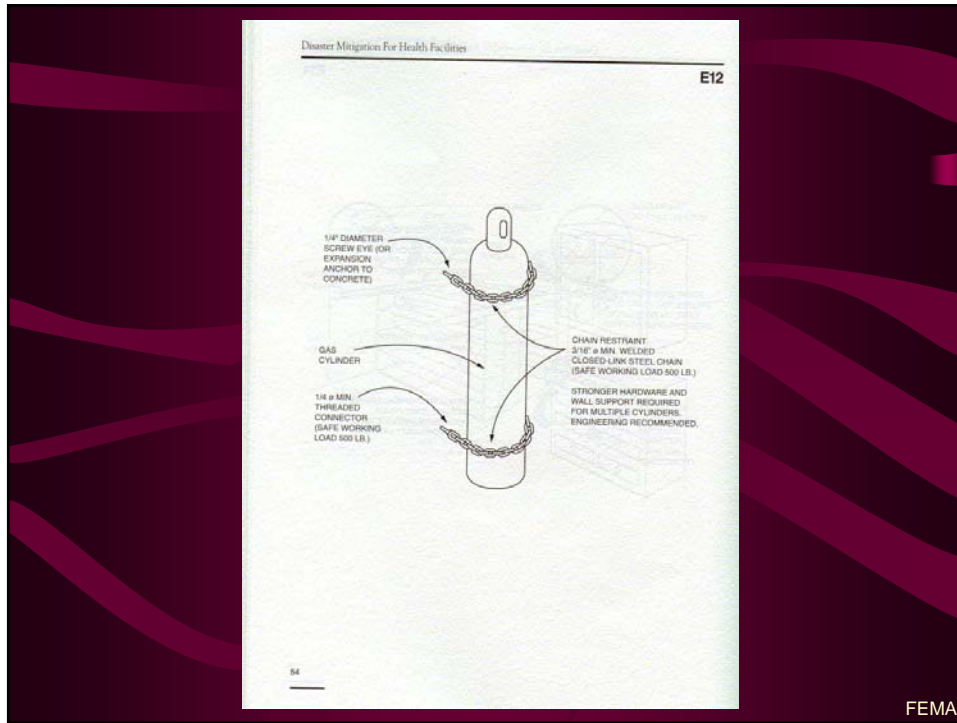
Diesel Fuel Tank

a)   Is the tank securely attached to the supports?

b)   Are the tank supports cross-braced in both directions?

c)   Is the bracing attached with anchor bolts secured to a concrete pad?

Supports and connections for important equipment

CONEXION FLEXIBLE

CONEXION SOLDADA O APERNADA

PERNO DE ANCLAJE

FUNDACION ESTABLE

ARRIOSTRAMIENTO

OPS/OMS - Mitigación de Desastres en Instalaciones de Salud: Aspectos no Estructurales

Pipes damaged because of the absence of a flexible connection.

PAHO
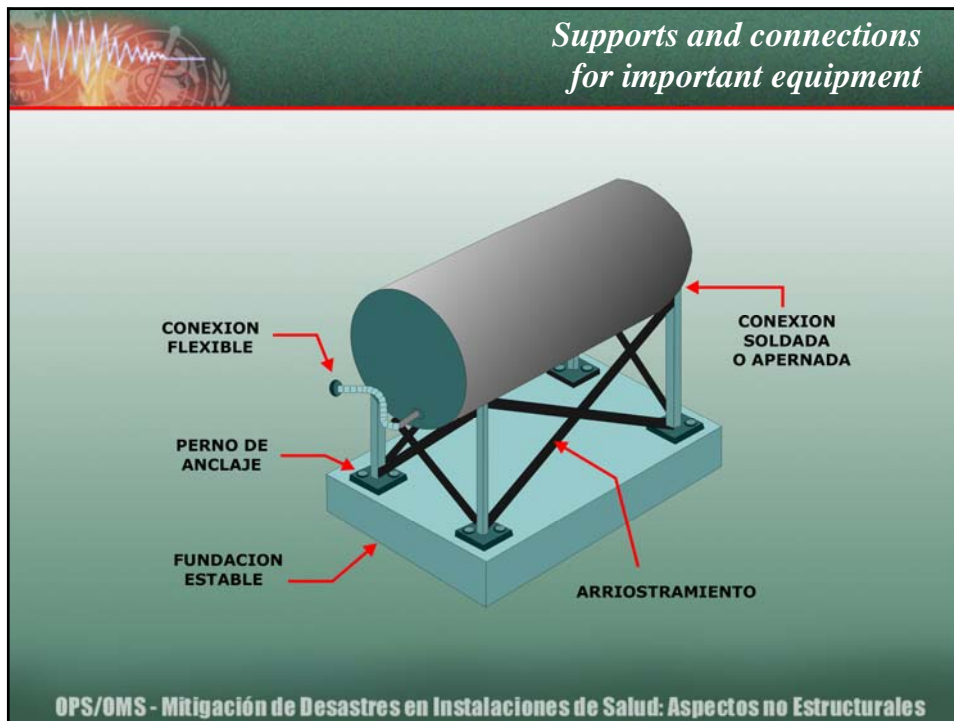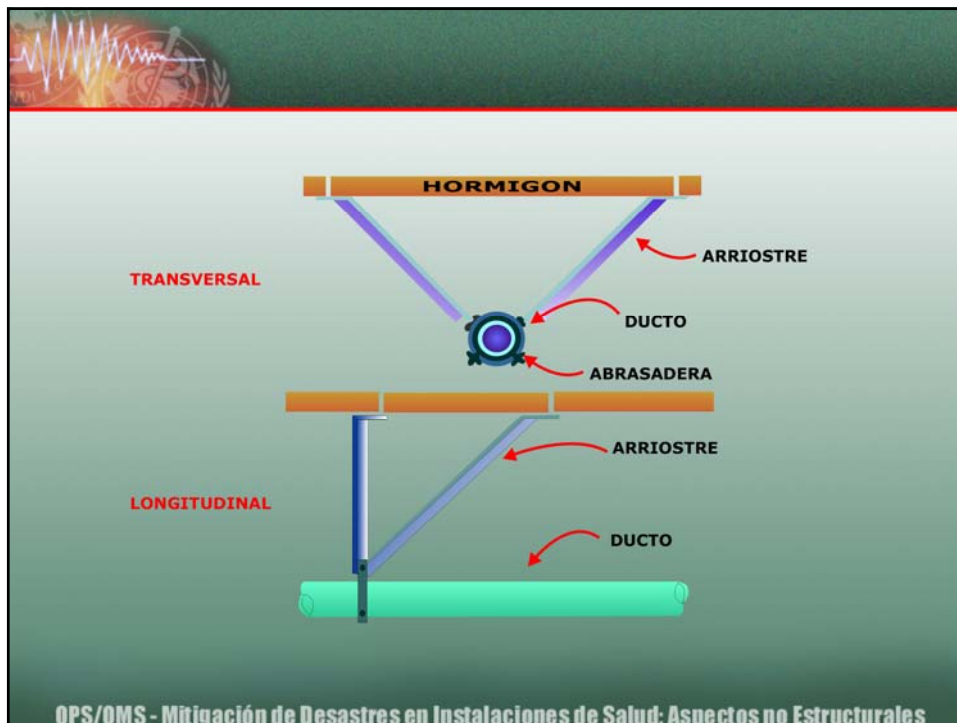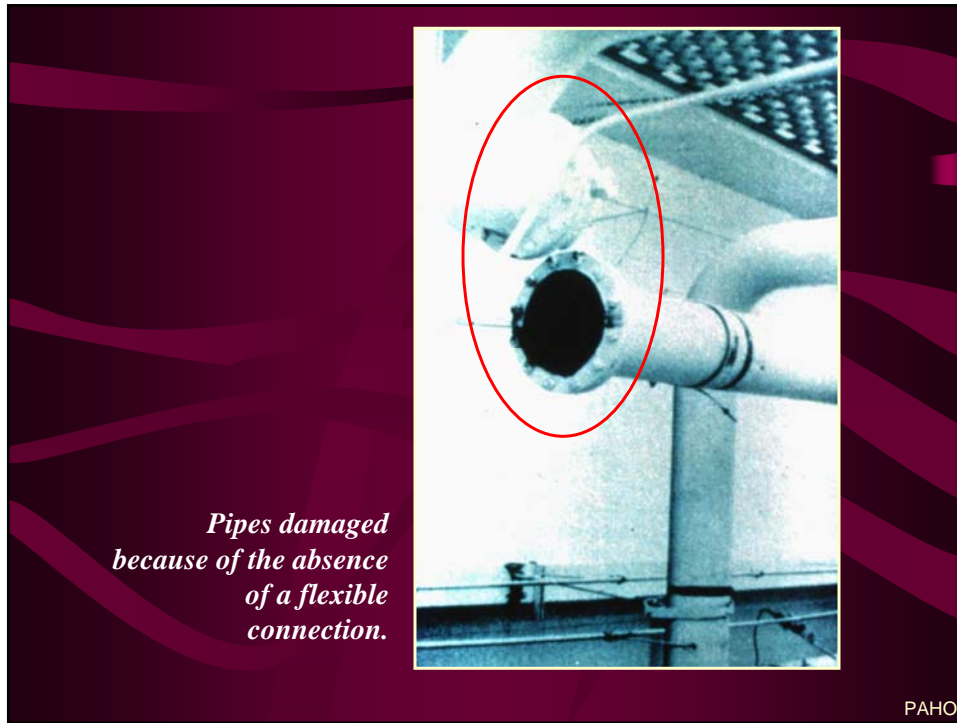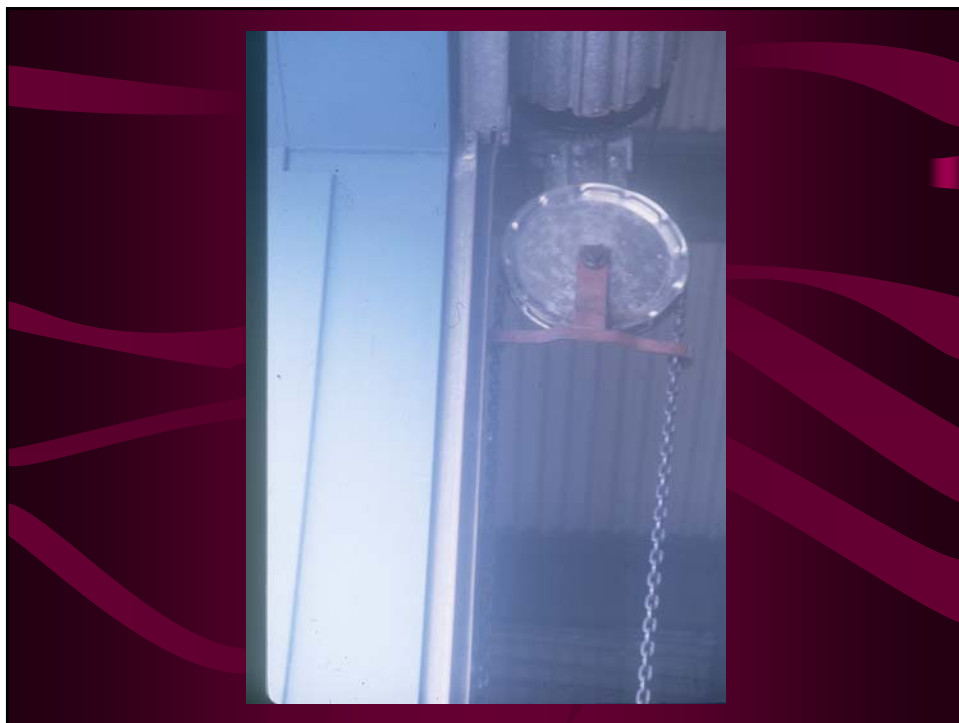
Impact-resistant windows

Protection shutters against the penetration of flying objects and water

Comarazamy

hospitals require convenient protection against penetration of airborne debris and water

Comarazamy

Present Standards and Codes

- CUBiC and national codes
  - Barbados
  - Belize
  - Guyana
  - Jamaica
  - Trinidad & Tobago
  - OECS (9 states)
- Bahamas - SFBC
- Cayman – SBCCI
- TCI – hybrid (USA and CUBiC)

Status

Country	Standards	Laws	Enforcement
Anguilla	Y	Y	Y
Antigua	Y	Y	Y ?
Bahamas	Y	Y	Y
Barbados	Y	N	N
Belize	Y	N	N
BVI	Y	Y	Y ?
Cayman	Y	Y	Y
Dominica	Y	Y ?	N
Grenada	Y	Y	Y ?
Guyana	N	N	N
Jamaica	N	Y	Y
Montserrat	Y	Y	Y
St Kitts	Y	Y	Y ?
St Lucia	Y	N	N
St Vincent	N	N	N
TCI	Y	Y	Y
Trinidad	N	Y	Y

The New CUBiC (or CUBiS)
to be based on the I-codes

CUBiS countries:

Barbados

Belize

Guyana

Jamaica

Trinidad & Tobago

OECS (9 states)

Other similar countries

Bahamas – SFBC >> IBC

Cayman – SBCCI >> IBC

TCI – hybrid >> IBC

Dominican Republic >> IBC approach

Components
(agreed by CCEO & CARICOM in March 1999)

1   Caribbean Application Document
     (CAD) based on the **I**-codes

2   Caribbean
     Residential Design Standards

3   Model Laws and Regulations

Overall Programme

Multi-hazard Design

Multi-hazard Design
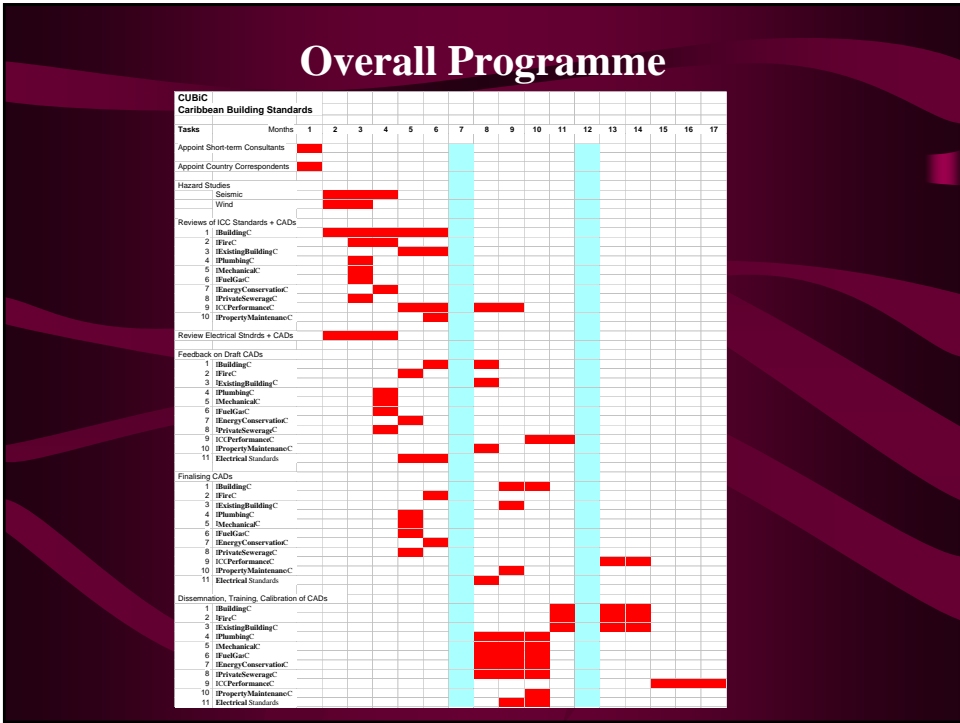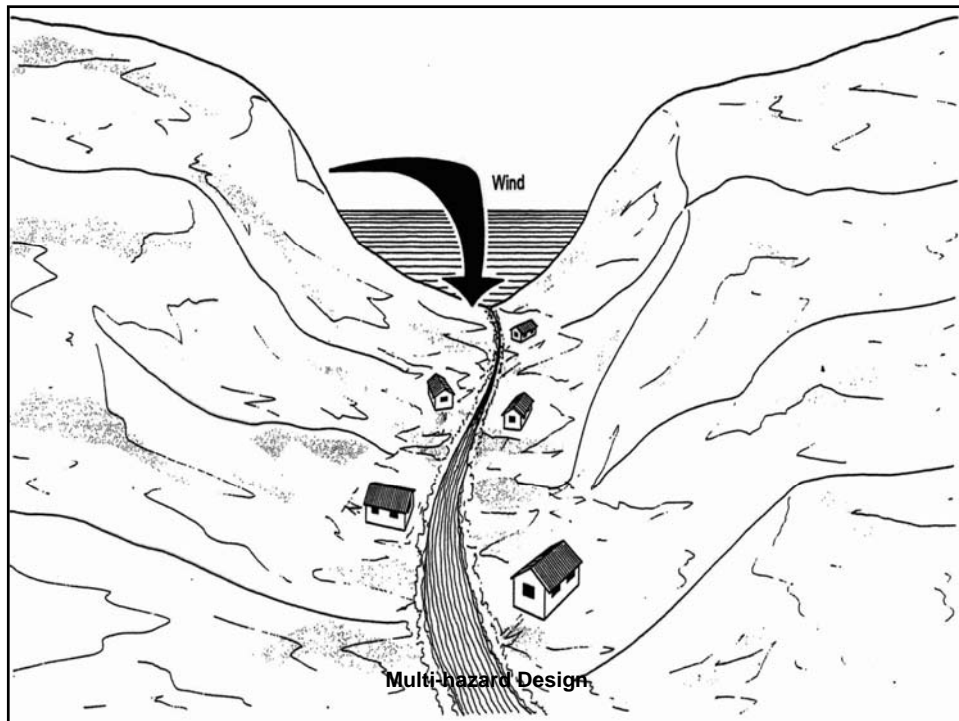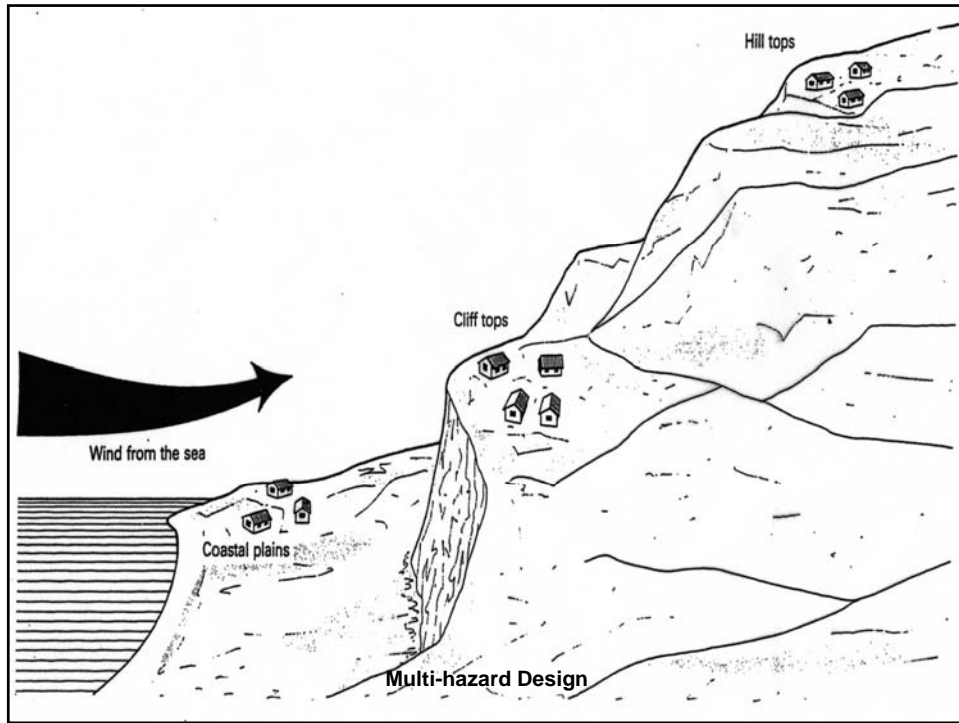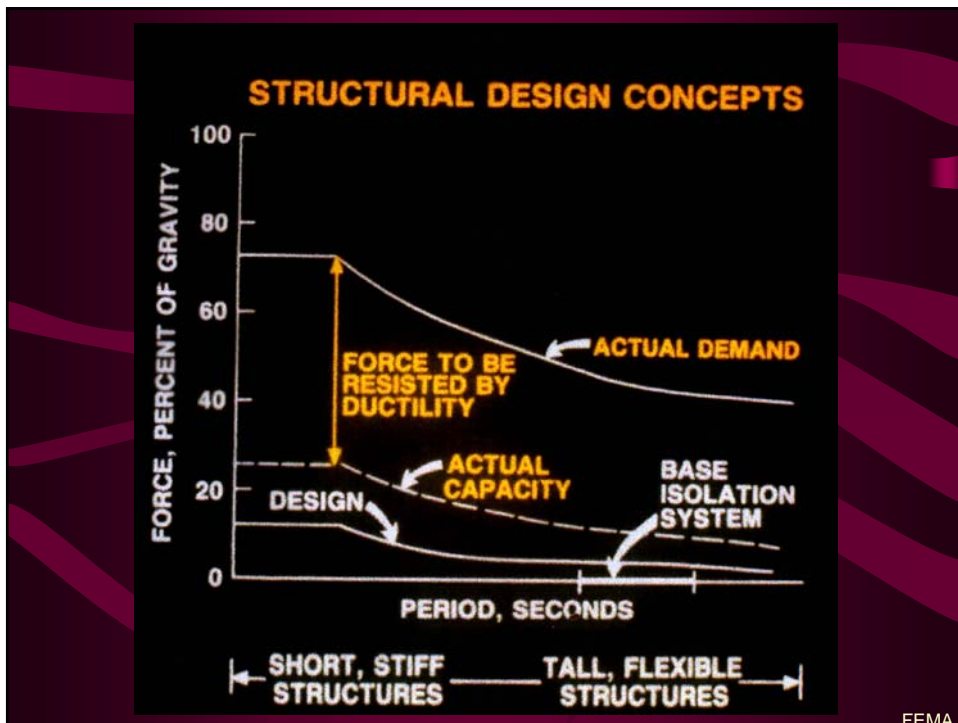
Gaius Plinius Secundus, Naturalis Historia :

"Grecae magnificentiae vera admiratio extat templum Ephesiae Dianae
CXX annis factum a tota Asia.
In solo id palustri fecere, ne terrae motus sentiret aut hiatus timeret,
rursus ne in lubrico atque instabili fondamenta tantae molis locarentur,
calcatis ea substravere carbonus, dein velleribus lanae".

Paestum
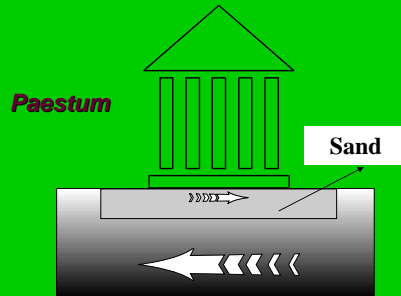
Sand

Ancient Greek temples, Chinese monasteries, temples and bridges,
as well as temples erected in Italy in the past
appear to be protected by seismic isolation systems.

The Use of Check Consultants
in
Design and Construction
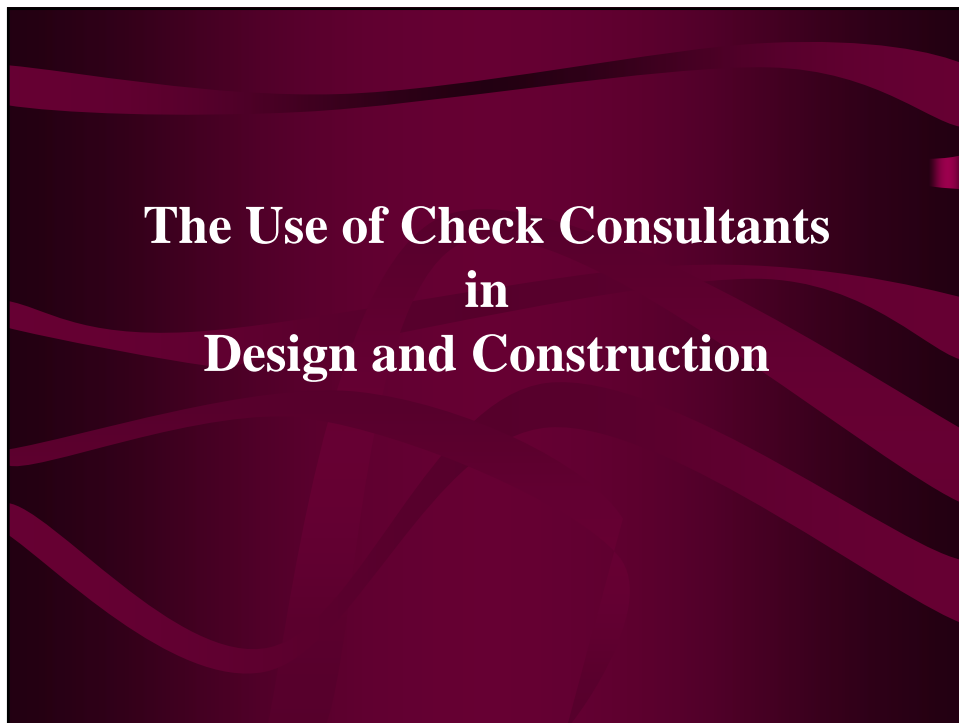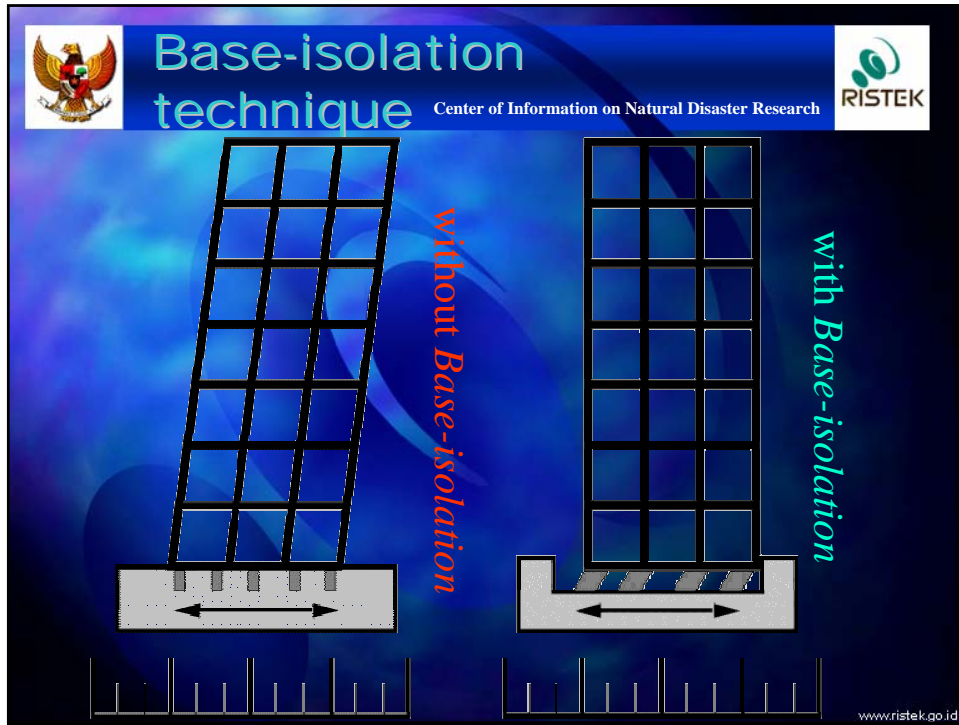
Hurricane Luis
in
Dutch **Sint Maarten**
and
French **Saint Martin**

Dutch side:
Catastrophic damage
- 100% GDP direct
- 100% GDP indirect

French side:
Not much damage

Regulatory Regime on the **Dutch side:**

- a variety of standards
  - * Dutch
  - * home base of designer
  - * other "equivalent" standards
- checking by PWD
  - * normally by in-house staff
  - * rarely by hired consultants

Regulatory Regime on the **French side:**

- French standards or "norms"

- *bureau de contrôle* checks:
  - * design
  - * construction quality assurance mechanisms

Dutch side:
A wide range of standards

French side:
"We have to do it right."

The differences outlined by those familiar with construction on both sides of the border include:

*   Better attention to conceptual design on the French side;

*   Greater consistency and uniformity of standards of design for earthquakes and hurricanes on the French side;

*   The involvement of *bureaux de contrôle* on the French side.

The *bureaux de contrôle*:

* Independent firms licensed by the state

* Pay well and attract, and keep, some of the best talent

* Check designs and also make occasional site visits during construction

* Involvement in projects is necessary if decennial (10-year) insurance cover is to be obtained [Spinetta Act of 1978]

* Lending agencies also demand the certification of a *bureau de contrôle*.

Peter Rice's book: The Engineer Imagines

"It is no accident of time that both the La Villette and IBM projects first appeared in France where there exist the most intelligent and knowledgeable checking authorities that I have come across. The large centralized controlling offices, *bureaux de contrôle* (Socotec, Veritas, CEP and others), each have at their head engineers who are equal in ability to any I have encountered in the best design offices, as Centre Pompidou amply demonstrated." - page 113

Peter Rice's book: The Engineer Imagines

"Others not so closely involved must also be asked to review the project, to question the assumptions and demand explanations. .... The presence of a competent, dedicated and sceptical checking authority is also very important in this respect." - page 123

Other Countries

* United Kingdom - dams, tunnels and bridges
* Germany - *pruf ingenieurs*
* Japan - advocates and review jury
* Mexico City - engineers licensed by exam for 3 years
* Colombia - *diseñador* (the designer) and *interventor* and *curador* (the checkers)
* California
* Vancouver

Roles of the Review Consultant

1. To assist a design consultant in achieving a better and more reliable project by providing independent assessments of the work

2. To reduce the incidence of errors or of unsatisfactory designs and construction

3. To identify sub-standard work (vital for the fundamental well being of the project, for the protection of the client and for providing security for the funding agency and insurance underwriter)

4. To assist in the development of the construction industry

Consequences of Introducing the System

* Better information on the hazards
* Improved standards documents
* More appropriate conceptual designs leading to lower construction costs
* Improved quality of tertiary education for architects and engineers
* Better organised post-graduation formation of professionals
* Self-financing CPD programmes

CEP Ltd for PresTcoN
Atlantic LNG Train-4 Jetty-2

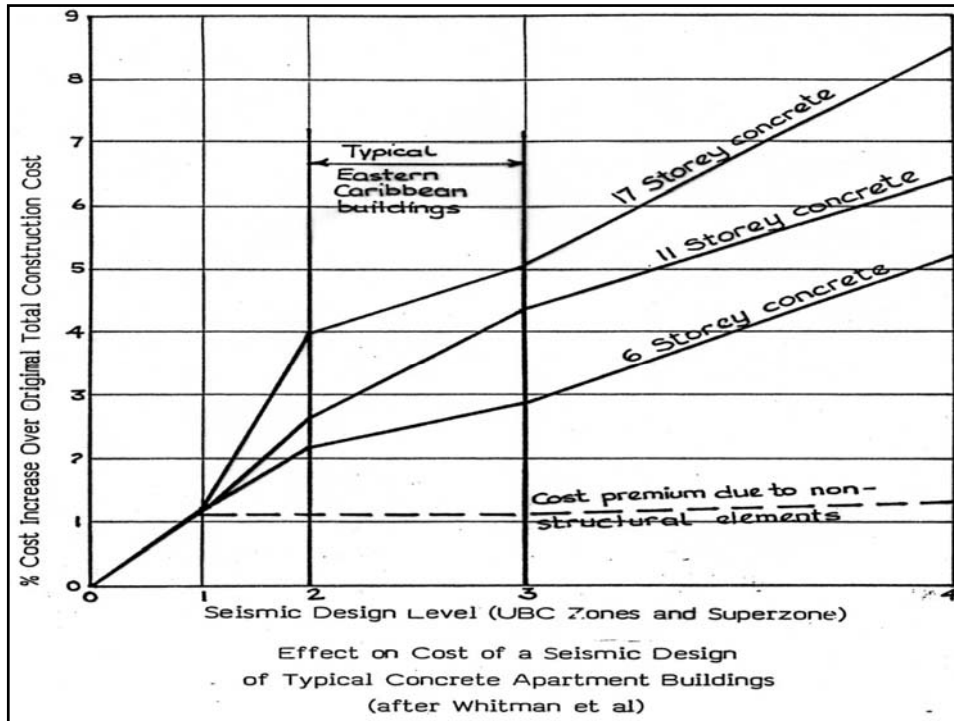### 4 layers of checking:

*   Internal at CEP
*   Bectel
         - Strict adherence to the standards quoted in the contract
         - Approval of variations through expert opinions
         - Specifications for calculations, approval of software and hardware
*   Independent engineers hired by Bectel
*   Insurers

Atlantic LNG Train-4 Jetty-2

06.09.2005 11:42

PresTcoN

Effect on Cost of a Seismic Design
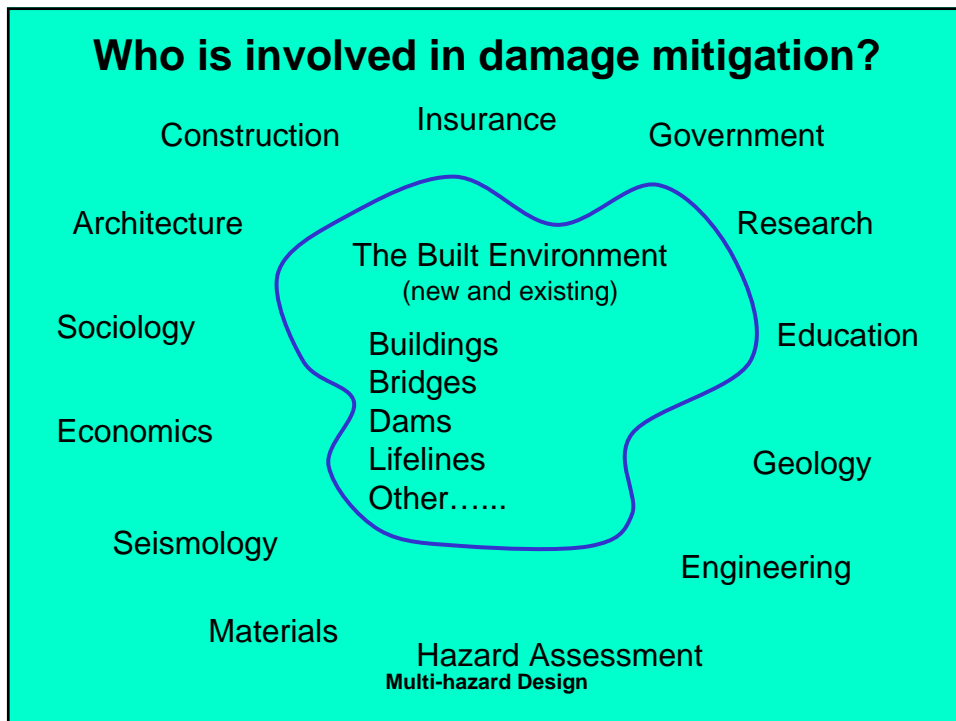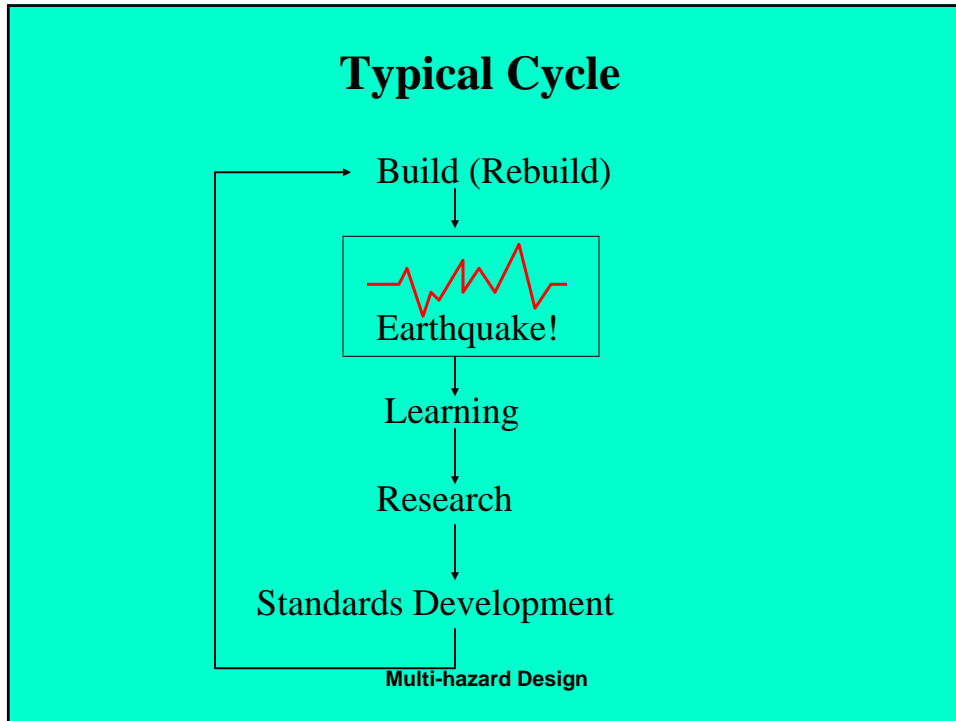of Typical Concrete Apartment Buildings
(after Whitman et al)

PERCENTAGE INCREASE * IN CONSTRUCTION COST FOR MODEL DWELLINGS
INCORPORATING SEISMIC OR WIND DESIGN RECOMMENDATIONS **

SEISMIC OR WIND LOADING	'A'	'A' 1.5 x O.T.	'A-1' Sliding door	'A-1' Window	'B'	'B-1'	'C'	'C-1'	'C-2'	E	F
Zone 3	0.3		0.37	0.37	0.42	0.45	0.81	0.74	0.74	0.48	1.4
	0.24		0.29	0.29	0.33	0.35	0.63	0.58	0.58	0.38	1.1
Zone 2	0.28		0.36	0.36	0.29	0.29	0.31	0.28	0.27	0.48	0.24
	0.22		0.28	0.28	0.23	0.23	0.24	0.22	0.21	0.38	0.18
15 psf wind	0.31	0.57	0.41	0.39	0.44	0.61	1.3	1.2	1.2	0.48	0.24
	0.25	0.45	0.32	0.31	0.34	0.47	0.98	0.90	0.95	0.38	0.19
25 psf wind	0.59	1.1	0.60	0.59	0.92	1.0				0.48	0.71
	0.46	0.85	0.47	0.46	0.72	0.79				0.38	0.55
40 psf wind	2.00	2.2	1.6	1.4	2.2	1.9				1.3	1.9
	1.57	1.7	1.2	1.1	1.7	1.5				1.0	1.5

* Estimated upper and lower bounds given
**Design recommendations as given in the report titled " A Methodology for Seismic Design and Construction of Single-Family Dwellings".

The most expensive building is the one that fails.

What we need:

**better designs
not better accounting**

Typical Cycle

Build (Rebuild)

Earthquake!

Learning

Research

Standards Development

Multi-hazard Design

Who is involved in damage mitigation?

Construction

Insurance

Government

Architecture

Research

The Built Environment
(new and existing)

Sociology

Education

Buildings
Bridges
Dams
Lifelines
Other…...

Economics

Geology

Seismology

Engineering

Materials

Hazard Assessment
Multi-hazard Design

Winds of Change

"Ever since the break up of the Roman Empire, one of the constant factors of political life has been the emergence of the independent nations. *The wind of change is blowing through this continent* and whether we like it or not this growth of national consciousness is a political fact. We must all accept this fact and our national policies must take account of it."

- Harold Macmillan in Cape Town, South Africa in February 1960 –

We speak here not of literal winds, but of the metaphorical "winds of change".

From *Diario de la Marina* on the San Francisco de Borja Hurricane of 10-11 October 1846 (from Luis A Pérez's book "Winds of Change"):

"Numbers of hospitals were in ruins, ……………. At the moment of greatest medical need, La Habana found itself with limited capacity to care for the thousands of injured habaneros. *'All my work has been lost...'* despaired the director of the Real Hospital de San Lázaro. *'The principal entrance has collapsed......Various wards and the new infirmary building have suffered much damage; all the roofs are ruined.'* "

Here we speak not of metaphorical winds, but of the literal "winds of change".

The name

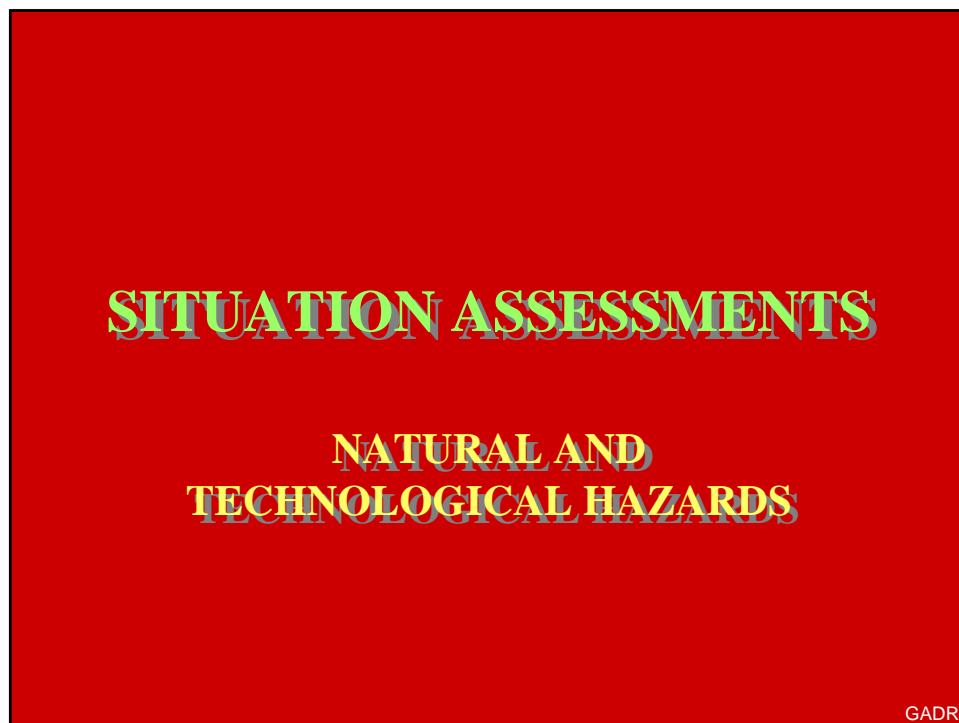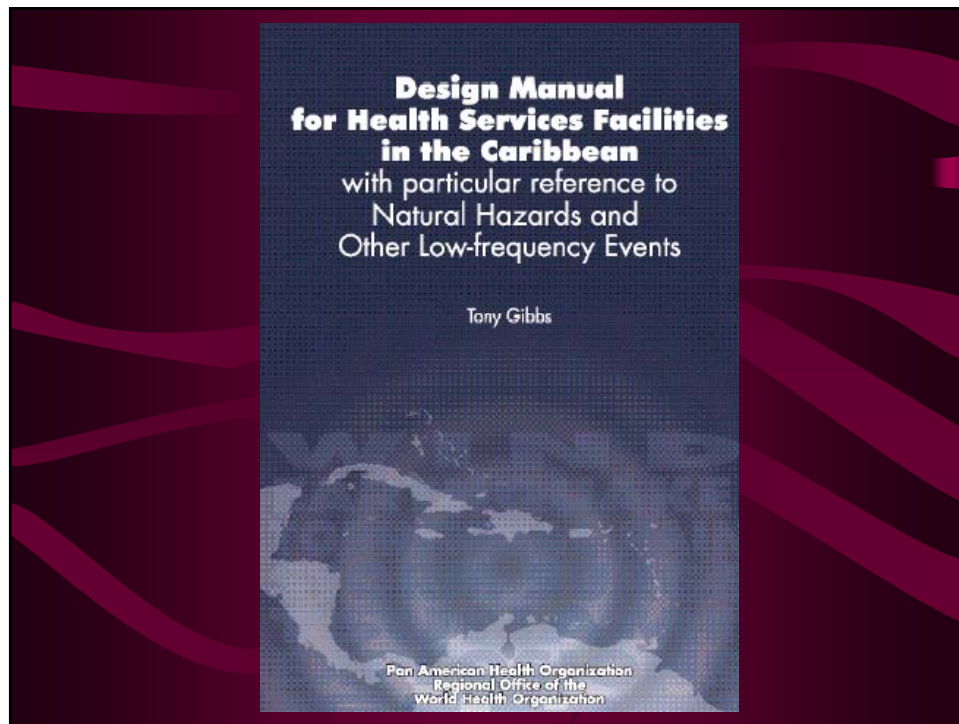a   *Di*saster *M*itigation *A*dvisory *G*roup for Health Facilities

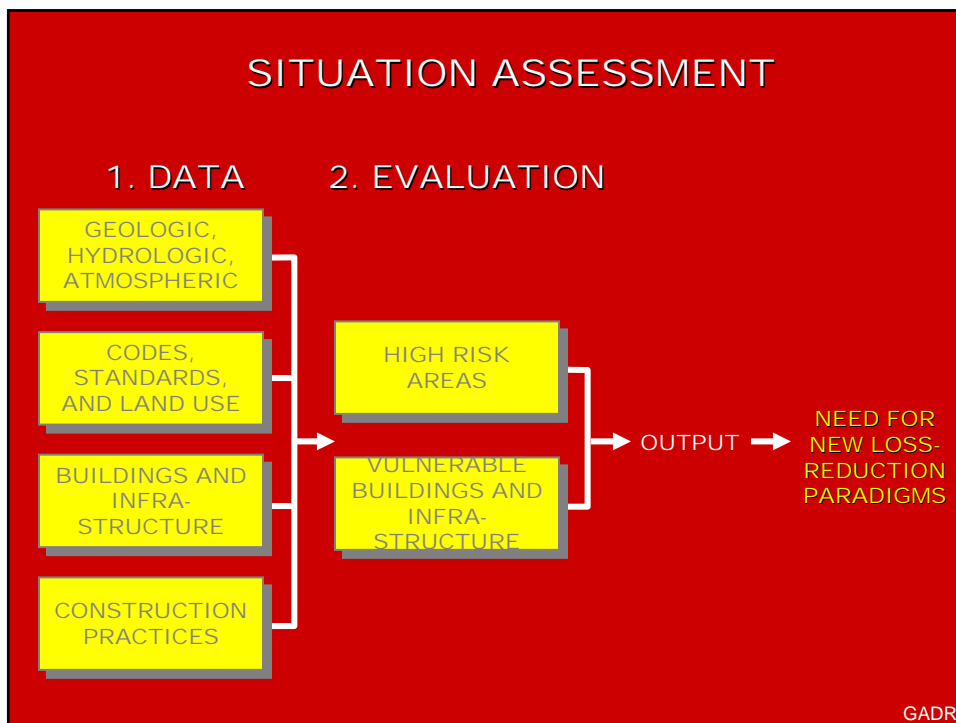b   *DiMAG/GAMiD*
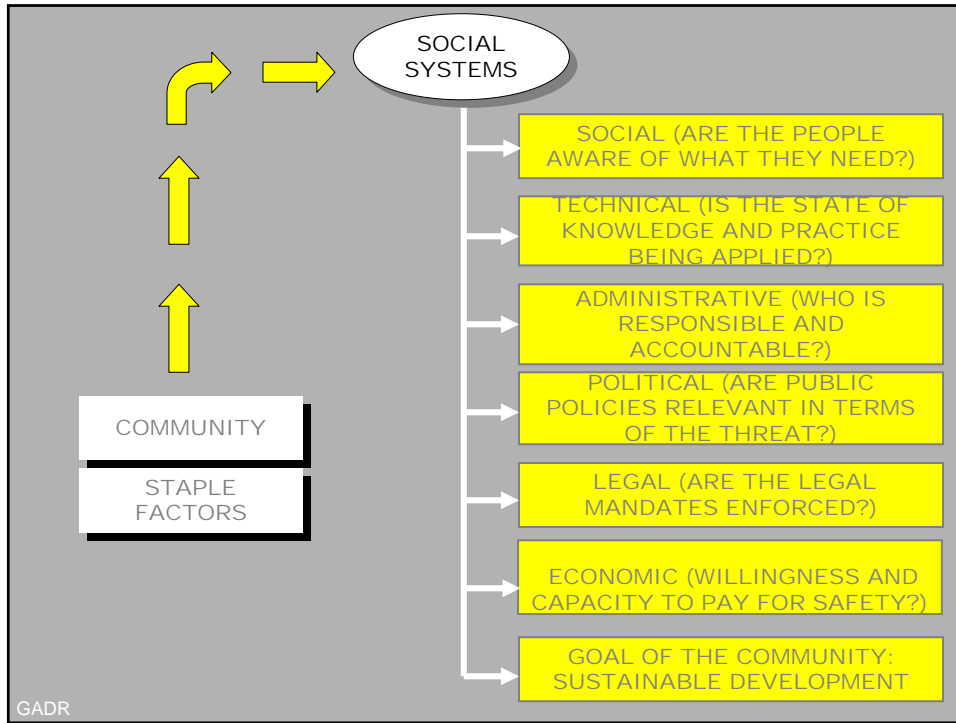
c   *G*rupo *A*sesor de la *Mi*tigación de *D*esastres para las Instalaciones de Salud

PAHO aims to:

o   create a platform for others to build on;

o   generate a *wind of change* in the area of
         design and construction of safer
         healthcare facilities and other institutional
         buildings.

Design Manual
for Health Services Facilities
in the Caribbean
with particular reference to
Natural Hazards and
Other Low-frequency Events

Tony Gibbs

Pan American Health Organization
Regional Office of the
World Health Organization

SITUATION ASSESSMENTS

NATURAL AND TECHNOLOGICAL HAZARDS

GADR

NEW PARADIGMS REQUIRE INTEGRATION OF KNOWLEDGE AND EXPERIENCE

REDUCTION OF COMMUNITY VULNERABILITY ESSENTIAL FACTORS

BUILT ENVIRONMENT
- BUILDINGS
- LIFELINE SYSTEMS

HAZARD ENVIRONMENT
- GEOLOGIC
- HYDROLOGIC
- ATMOSPHERIC
- TECHNOLOGICAL

POLICY ENVIRONMENT
- MITIGATION
- PREPAREDNESS
- EMERGENCY REPONSE
- RECOVERY
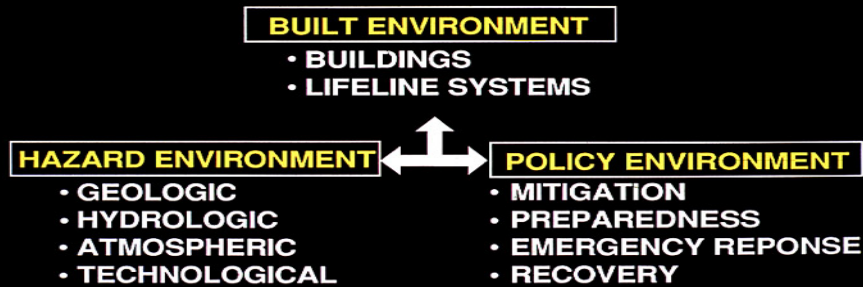
GADR

SITUATION ASSESSMENTS

- WHAT HAPPENED?
- WAS IT A DISASTER? WHY?
- WHAT VULNERABILITIES WERE EXPOSED DURING THE EVENT?
- IN WHAT WAYS DID THE COMMUNITY'S STAPLE (I.E., THE SOCIAL, TECHNICAL, ADMINISTRATIVE, POLITICAL, LEGAL, AND ECONOMIC) FACTORS EXACERBATE THESE VULNERABILITIES?

GADR

SITUATION ASSESSMENTS

- CAN ANY OF THE SOCIAL, TECHNICAL, ADMINISTRATIVE, POLITICAL, LEGAL, AND ECONOMIC FACTORS BE CHANGED TO MAKE THE COMMUNITY MORE RESILIENT TO POTENTIAL DISASTERS? WHICH ONES?

- WHAT ARE YOUR RECOMMENDATIONS FOR IMPLEMENTING THESE NEW PARADIGMS?

GADR