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"Climate Change Impacts and Adaptation for Coastal Transport Infrastructure in Caribbean SIDS"

Impacts of Natural Hazards on the Transport Infrastructure Sector

By

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Impacts of Natural Hazards on the Transport Infrastructure Sector


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Objectives

The main objectives of this presentation are:

A. To give an overview of the natural hazards that affect transport infrastructure in the Caribbean.
B. To summarize the most common impacts that occur as a result of these, notably hurricanes, earthquakes, extreme rainfall events, tsunami and climate change effects;
C. To provide guidelines relating to adaptation and recovery.

Overview of natural hazards affecting the Caribbean

What are the hazards that affect Caribbean infrastructure?

Hazards that can affect the region include:

- Volcanoes
- Earthquakes
- Landslides/Mudslides
- Tsunami
- Hurricanes (High Winds; Storm Surge; Extreme Rainfall)
- Floods (Land based)
- Anthropogenic/Technological (fire, hazardous spill, etc.)
- Climate Change Induced

Toll of Hazards and their Regional Distribution

Over 300,000 lives lost in the Caribbean basin over the past 30 years due to natural disasters.

Greater Antilles

(Cuba, Jamaica, Hispañola, Puerto Rico)

- Hurricanes
- Floods
- Earthquakes
- Tsunami

Lesser Antilles

(Virgin Islands to Trinidad)

- Hurricanes
- Volcanic Eruptions (Ash fallout)
- Earthquakes
- Tsunamis

All: climate change

Hurricanes in the Caribbean: Historical Account

Records of hurricane damage exist in the archives of the Caribbean for over five centuries;

Since approximately 1900, detailed hurricane records and characteristics have been maintained by the National Hurricane Center (NHC) and NOAA in Florida, USA (records go back to 1850).

These records have improved in accuracy and detail since the 1950's, first with the ability of special reconnaissance aircraft to fly into the eye of these storms, and later, with the aid of satellite imagery.

Hurricanes in the Caribbean: Patterns

- The records over the past century show a wide band of hurricane activity across the Caribbean, with the least activity occurring in the area of Trinidad;
- In general, damage occurs from storm surge, waves, wind and rainfall (leading to flooding), as all of the islands have vulnerable aspects to them;

Hurricanes in the Caribbean: Paths

Damage from Hurricanes

Occurs primarily from:

- Hurricane waves;
- Shoreline erosion;
- Storm surge;
- Land based Flooding;
- High Winds

Hurricane Waves

- Waves resulting from hurricanes can be very damaging. Estimates of extreme (i.e. design) wave heights made throughout the region show a gradient of risk:

Island	1 in 50 year Return period (m)	1 in 100 year (m)
Jamaica	7.6	8.6
Antigua	13.3	14.9
Grenada	8.1	9.6

Trident Hotel, Jamaica

Port Zante, St. Kitts

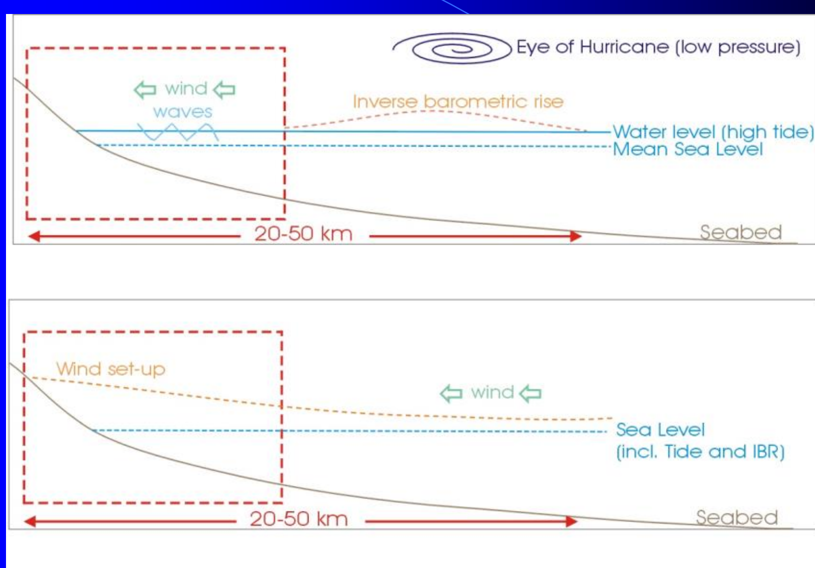
West coast road, Grenada

Shoreline Erosion

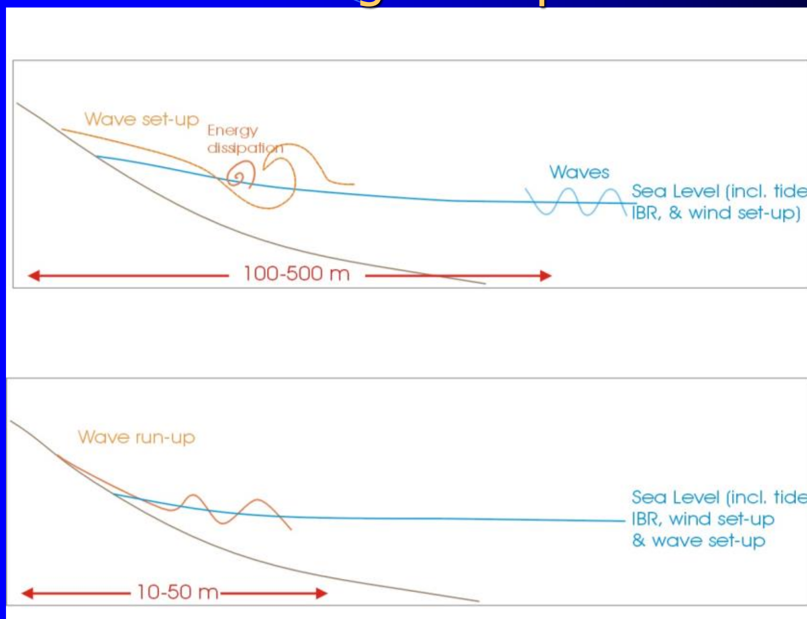
- Storm and swell events, can result in severe erosion of the beach and/or shoreline.

Negril, Jamaica – 1m/year erosion rate

Storm Surge Components



Storm Surge Components



Example of Storm Surge

High storm waves

Inundation of waterfront promenade, Dominica – Approx. 3m of Storm Surge, wave run up

Flooding in the Caribbean: Historical Account

- In the Lesser Antilles, flooding has been associated primarily with tropical waves and hurricanes;
- Flooding may take the form of excessive **ponding**, as occurred in Antigua during Hurricane Lenny, or **flash flooding** as can occur in the more hilly or mountainous islands such as Nevis and Dominica;
- Can trigger **debris flows** that are extremely
- dangerous to human settlements.
- In general, all of the islands and their communities are vulnerable to flooding and drainage systems and river training must be designed to take this into account.

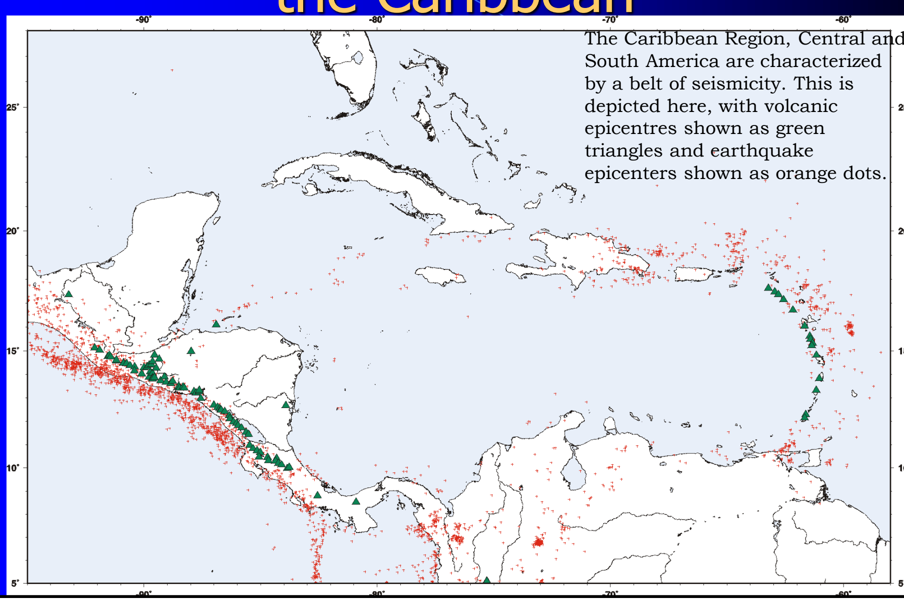
Flooding - Consequences

- Flooding of road infrastructure
- Economic slowdown

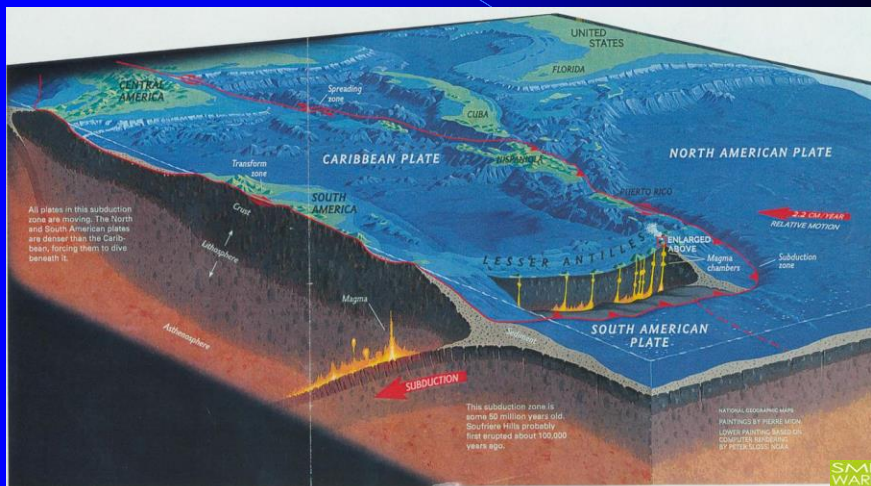
Hurricane Wind Speeds - The Saffir-Simpson Scale

STATUS	WINDS (km/hr)	WINDS (mph)	PRESSURE
Depression	<56	<35 mph	------
Tropical Storm	56-117	35-73 mph	------
Category 1	**118-152**	**74-95 mph**	**966 mb>**
Category 2	**153-176**	**96-110 mph**	**980-965 mb**
Category 3	**177-208**	**111-130 mph**	**964-945 mb**
Category 4	**209-248**	**131-155 mph**	**944-920 mb**
Category 5	**248 +**	**155 mph+**	**<920 mb**

Earthquakes and Volcanoes in the Caribbean



Earthquakes and Volcanoes in the Caribbean



Earthquakes in the Caribbean

- Major Earthquakes
  - Jamaica (1692)
  - Trinidad (1766)
  - Antigua (1843)
  - Haiti (2010)
- Minor Events
  - St. Lucia (1953)
  - Trinidad (1954)
  - Antigua (1974)

Earthquakes in the Caribbean

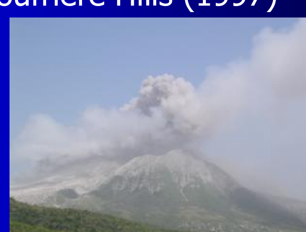
- Port-au-Prince, Haiti 2010

Volcanoes: A source of risk to property and life

Soufriere Hills, Montserrat

A significant Hazard in the Lesser Antilles

- Soufriere (1718, 812, 1902-3, 1979)
- Mt. Pelee (1902, 1929-32)
- Soufriere Hills (1997)

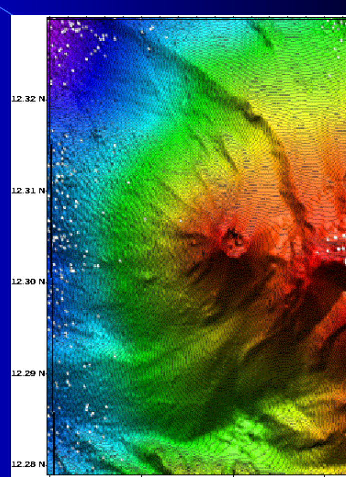


Volcanoes in the Caribbean: Historical Account

- 17 Volcanoes erupted in the Eastern Caribbean.
- 25 Volcanic Centres with the potential to erupt.
- Approx. 40,000 lives lost in 1902 eruptions (St. Vincent and Martinique).
- Warning time has ranged from 14 days to 14 years.
- The famous Port Royal disaster of 1692 was initially caused by an earthquake which liquefied an alluvial plane causing it to slide into the sea, the resulting tsunami was several metres in height and caused over 2000 deaths.

Tsunamis: another source of risk

- Caused by ocean centered earthquakes, volcanic eruptions, or plate movement.
- Some risk presently posed by "Kick 'em Jenny"



SeaBeam image of Kick 'em Jenny constructed from measurements taken from the NOAA Research Vessel Ronald H. Brown on March 12 2002.

Tsunamis in the Caribbean: Historical Account

Date	Location	Comment
1897-Nov-29	West Indies	Large tsunami at Montserrat
1907-Jan-14	Jamaica	Tsunami generated, main damage at Kingston
1918-Oct-11	Puerto Rico	Tsunami caused fatalities and damage at Point Borinquen and Aguadilla; also damage at Mayaguez
1946-Aug	Dominican Republic	Town of Matanzas badly damaged and abandoned; more than 100 persons killed; minor damage on coast of Haiti
1953-May-31	Dominican Republic	Very slight tsunami; amplitude 0.2 ft at Puerto Plata
1955-Jan-18	Venezuela	Tsunami caused damage at La Vela, Venezuela

Transport and related Infrastructure

Infrastructure sub-sectors include:
- Roads and Transport
- Sea Ports and Air Ports

Roads and Transport

- For the small island states of the Caribbean region, the network of coastal roads is a critical one.
- Roads connect main urban centres to rural fishing, agricultural or smaller communities.
- They serve as vital links between these communities.
- They facilitate routes for evacuation when needed.
- Roads also facilitate the distribution of services

North to Middle Caicos Causeway following TS Hanna and Hurricane Ike, 2008

Roads/Transport - Rehabilitation

- Reconstruct to revised minimum standards to include Climate Change projections;
- Allow for retaining walls; coastal revetments; drainage structures, etc.
- Allow for debris clearance (e.g. as happened in Cayman after Hurricane Ivan in 2004)

Sea Ports and Airports

Port Zante, St. Kitts following Hurricane Lenny, 1999

Airplane hanger, Grand Turk, following Hurricane Ike, 2008

Sea Ports and Airports - Damage

Physical damage can include;

- Damage to specific equipment – e.g. perimeter fencing; terminal buildings;
- Damage to aircraft and boats;
- Damage to physical plant – air conditioners; desalination plants; landing and/or navigation equipment; runway damage; warehouse or dock damage;

Summary of **loss** of income:

- Landing charges; berthing and demurrage rates; departure tax; duty free sales.

Sea Ports and Airports Examples

Reconstruction Suggestions

- Proper appreciation of **mechanisms** of damage – *how are the impacts effected*
- Adoption of an acceptable level of **risk** for national infrastructure - *1 in 100 Year?*
- Adoption of techniques or design methods to reduce vulnerability (e.g. assessing WL)
- Use of "Best Value" engineering or rehabilitation techniques to reduce long-term vulnerability

Reconstruction Suggestions

For Design Water Surface Elevations (WSE) for example, we should consider:

- MSL
- Tide amplitude
- Thermal expansion (July – Nov)
- Climate change (GSLR)
- Storm surge (including wave set-up)
- Wave run-up (dynamic component)

Regional Needs?

Better definition (by climate change scientists) of likely extreme event scenarios, to help in the evaluation of what impacts could likely be in 20-50 years from now;

b) Improvement of regional research opportunities to include things such as:

i. The role of different types of coral in attenuating wave energy

ii. Hybrid protection structures incorporating hard structures and ecosystems

c) Incorporation of marine biological considerations in coastal protection design in a more “mainstreamed” manner, to provide true eco-engineered solutions;

d) Collection of up-to-date, accurate, bathymetric and near water topographic data (0m – +5m) LIDAR!!

Regional Needs?

Paradigm shift in design philosophy from Coastal Protection to Protection/Skills Training/Livelihoods/Social Benefit/Ongoing Education.

b) Scenario modelling:

i. Water level variations; Tides; Thermal Expansion; Surges; Sea Level Rise

ii. More severe hurricanes

iii. Multi-event occurrences

c) Ecosystem initiatives such as:

i. Mangrove replanting

ii. Coral replanting

iii. Seagrass clearing guidelines????????

Regional Needs?

a) Better linkage needed between Design – Social Good – Economic Feasibility;

b) Need a “Clearing House” for storage and dissemination of research and general information;

c) Need to properly document work being done, both successes and failures;

d) As the role of coastal structures expands from “Coastal Protection” to “Multi-Use”, the evaluation of the structure performance after construction needs to be similarly expanded (driven by Funding agencies?);

Thank you!