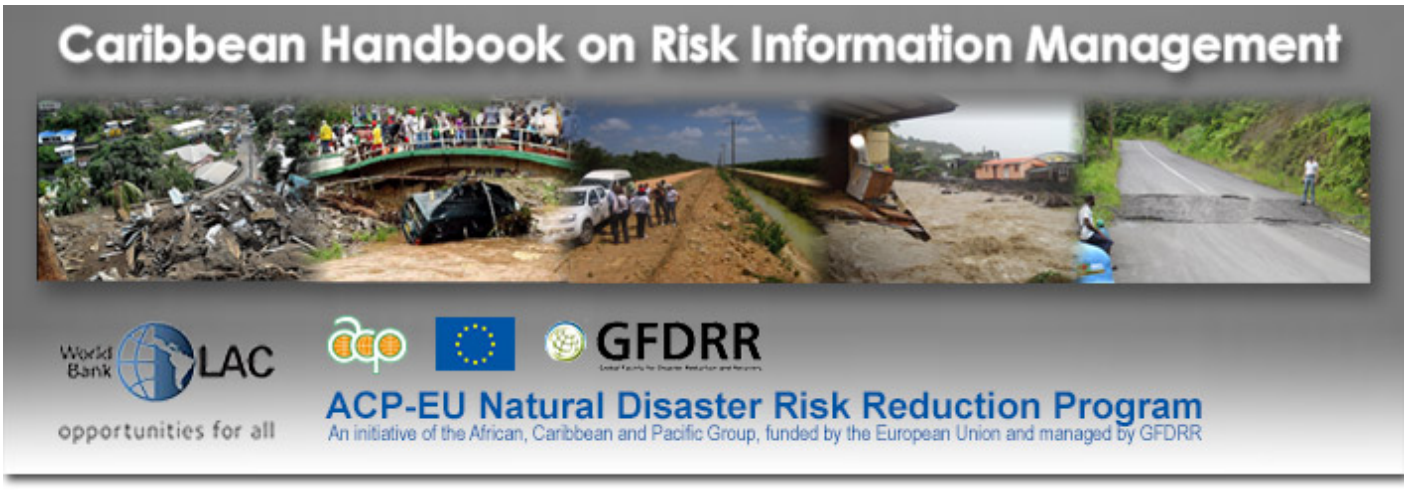

2.3 Guidelines for incorporating landslide and flood hazards in building construction

Summary

It is important to ensure that landslide and flood hazards are considered during the design and construction of buildings and various critical infrastructure that are to be constructed in the hazard prone area.

This use case indicates the overall procedure that should be followed in order to develop guidelines that incorporate landslide and flood hazards during building construction. The building characteristics and the various analysis steps have been illustrated for landslide and flood hazards. For OECS countries building codes have some provisions for earthquake and wind storm but in particular, do not address flood and landslide hazards. Once accepted, the proposed process to develop guidelines can be used by OECS member countries.

Keywords:

Flood risk, landslide risk, building design guidelines, OCES building code

Before you start:	Use case Location:	Uses GIS data:	Authors:
Section 2.1 National land use plan, 2.2 local land use planning and 2.4 Evaluation of relocation options for settlements should be read before this use case.	**OECS member countries**	**No**	**Naveed Anwar**

Introduction:

The aim of developing guidelines for development with consideration of hazard risk is to ensure that hazard risk is taken into account at all stages in the planning process to avoid inappropriate development in areas at risk, and to direct development away from areas at highest risk. Typically both landslide and flooding are site/location based hazards and most of the measures to reduce the risk are related to:

- Avoiding sites and locations in high hazard land
- Macro-level mitigation to protect the sites

The building level measures to mitigate these hazards may prove to be relatively expensive, and often may not be

realistically practical, except for exceptional or special buildings.

Integrating mitigation measures into new construction at initial stages of planning and design is more economically feasible than retrofitting existing structures.

Objectives:

This use case formalizes the procedure to develop guidelines for incorporating landslide and flood hazards into building construction and identifies the required building characteristics that relate to flooding and landslides. It also describes where they differ from the aspects that are generally considered for earthquakes and wind storms. Furthermore, how the existing building codes fit with and can incorporate specific landslide and flood related aspects is elaborated.

Flowchart:

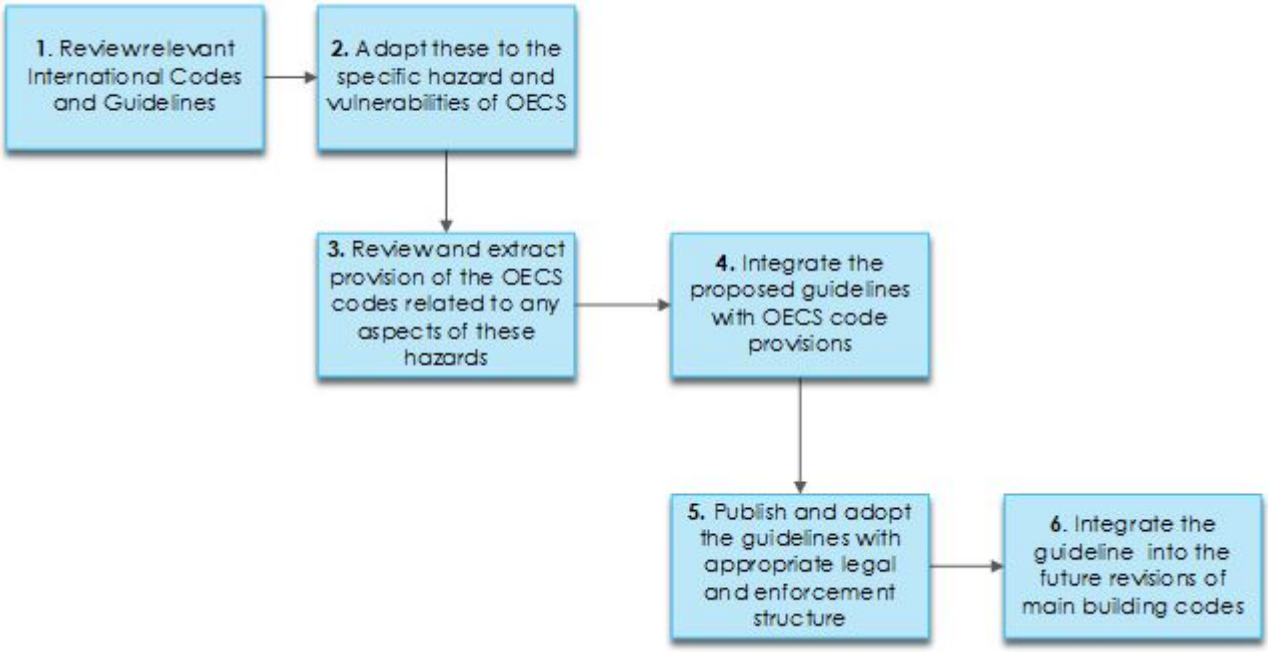

Figure 1: Procedure to develop guidelines for incorporating landslide and flood hazard in building construction

Problems definition and specifications:

Most of the international general building codes and even the special structural design codes do not explicitly address the landslide and flood hazards. There are however, several specific guidelines, policy statements and local regulations in many countries, regions and locations that are explicitly developed for the land use planning, hazard mitigation and for the design of buildings and infrastructures that address the flood and land slide hazards. Some of these are listed in the reference in the end of this use case.

For the case of OCES, the general building code draft, as well as specific adaption to various member states do not address these hazards adequately. The states also may not have resources for considering and adapting the specific provisions to the local conditions, especially the particular intensity of the hazards during hurricane season, which is unique to these areas. Another major hurdle in development of the codes and guidelines will be the estimation of the vulnerability of the traditional housing in the islands, which may be different from other parts of the world where such guidelines are available.

The process proposed in this use case can be used to develop for the initial guidelines that once developed and generally accepted, may be included into the next versions of main code body or adopted by reference.

Data requirements:

The following map data may be required to consider the risk associated with flood and landslide hazard while planning and constructing buildings:

- Land use plans

- Flood hazard maps
- Landslide Inventory maps that show landslide locations and may show the dimensions and geographical extent of each landslide.
- Landslide susceptibility maps describe the relative likelihood of future landslide hazard based solely on the intrinsic properties of a locale or site.
- Landslide hazard maps that indicate the possibility of landslides occurring throughout a given area.
- Information on past event, community knowledge, and experts evaluation should also be consulted if detailed hazard maps are not available

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Analysis steps:

To develop the guidelines for incorporating flood hazard into the building construction the following process and considerations need to be made:

1. Review relevant International codes and Guidelines

The first step is to study the international codes and guidelines that are considered as best practiced and already implemented.

2. Adapt these to specific hazard and vulnerabilities to OECS

a. Identify the relevant landslide hazard types in the region for which the guidelines are being developed. For assessment and other factors related to landslide hazard UC 3.3.1 “landslide Mitigation measures for Buildings” and Methodology book section 8.4 can be referred.

b. For incorporating the flood risk in the guidelines, define the flood hazard levels that may include the prediction and definition of flood levels and hazard, including water pressure, water current velocity, floatation etc. For further details please refer to UC 3.3.2 “Flood mitigation measures for Buildings” and methodology book section 8.4.

It will be useful to classify flood hazard into three levels as adapted in many other countries and develop the requirements accordingly for each level.

Table 1 provides a general description of proposed flood levels for the purpose of defining the hazards levels, and the corresponding expected performance criteria for the buildings.This is based on the similar concept used for definition of earthquakes in performance based design guidelines as ASCE 7[1] and TBI[2].

Flood Level Definition	Hazard Definition	Performance expectations
Service Level Flood (SLF) **Water Level A**	• **Occurs regularly in the area, say with a probability of exceeding every 10 years and may not have enough warning time** • **Has low water flow velocity, less than 2 m/sec**	• **The house, the property, and the occupants must be safe and no damage to the living areas** • **Facility operations should not be hampered for an extended duration**

Design Level Flood (DLF) **Water Level B**	• **Expected to occur every, say every 50 years and due warning may be available** • **Has medium water flow velocity, with flow velocity between 2 to 4 m/sec**	• **This flood may damage the property inside the building, but no extensive damage to the building** • **The occupants must be able to save themselves in the elevated areas within the building and be able to live there for a specified duration**
Extreme Event Flood (EEF) **Water Level C**	• **Expected less than once in a lifetime of the building (a return period of 100 years or more)** • **Has high water flow velocity, greater than 4 m/se.**	• **The building and the property within the building may be damaged by the flood, but the life of the occupant must be saved until rescue arrives or flood subsides**

Table 1: Flood hazard types and performance expectations

3. Review and extract provisions of the OECS codes related to any aspects of these hazards

Some the provisions in the existing OECS and other building codes for earthquake and for wind loads and hurricanes may also be relevant for flood and landslide resilience.Table 3 lists some of these provisions as an example.A more detailed review of the provisions should be useful for developing integrated guidelines for multiple hazards.

Earthquake and Hurricane Consideration		**Relevance to Flood**	**Relevan landslid**
Rules for the Construction of Earthquake Resistant Buildings			
Location of Openings	**The location and size of openings in walls have a significant effect upon the strength of a wall and its ability to resist earthquake forces.**	**Not relevant but height of location will be relevant**	**Relevant of debris**

Design of Masonry Buildings	**An important factor contributing to the earthquake resistance of concrete masonry buildings is the detailing and placing of steel reinforcement. The design of a reinforced concrete frame building should be undertaken by experienced engineers. The reinforcing guide given in this section therefore must only be used for simple single story buildings constructed of good quality concrete blocks.**	**Not directly relevant, except in some cases, can increase in the wall strength to resist water pressure**	**Some of t provision help to re the dama to land sl provide b resistanc reduce vulnerabil**
Rules for Construction of Hurricane Resistant Buildings			
Building Site	**Buildings sited in exposed areas (e.g. on the brow of a hill) are most vulnerable, while those sheltered by natural topography are less vulnerable. Buildings sited in gullies or in river beds are very vulnerable as they are subject to severe damage by floods caused by the heavy rains which often accompany a hurricane.**	**Some of these are useful for improving flood resistance, such as rules for avoiding building locations.**	**Some of t are usefu improving landslide resistanc as buildin location b on topogr**
Roof	**Several provisions for the roof form and details**	**Not so relevant**	**Not so re**
Windows and doors	**Special attention must be paid to the installation of doors and windows, since the loss of a door or window during a hurricane will greatly alter the internal pressure of the building, thus adversely affecting its safety. For this reason, glazed windows and doors should be fitted with wooden shutters.**	**Not so relevant, except these could be used to control access and egress**	**Not so r**

Walls	**Although it may not be common for the walls of concrete block buildings to be destroyed during a hurricane, many concrete block buildings were completely destroyed during the passage of hurricanes David in 1979 and Hugo in 1989. For this reason, it is important that the wall reinforcement be properly anchored at the foundation and the ring beam levels.**	**Useful to improve resistance to flood water and water pressure**	**Not direc relevant, may help improve structura stiffness robustne**
Timber Buildings	**Because of the relatively light nature of a timber building, extra precautions must be taken concerning uplift. The building must not be lifted off of it foundations. Care must therefore be taken to ensure that the entire structure is securely fastened to the foundations.**	**This may be useful to anchor the structure, to reduce likelihood of floating or damage by water flow**	**May help improve structura robustne**
Steel Buildings	**Extensive damage to steel frames has occurred as a result to recent hurricanes in the Caribbean. The damage resulted from, in some cases, under designed sections and in most cases poor maintenance which led to significant reduction in the sizes of critical members and thence to failure.** **.**	**Can help to improve the resistance to water flow and flood waters**	**May help improve structura robustne**

Table 2: OECS existing building codes for earthquake and hurricane and relevance to flood and landslide

Generally, the characteristics of the building that affect the response to earthquake and strong winds are well understood and documented in most structural design and building codes, unlike those for flood and landslide. However, comparing the building characteristics for various hazards can greatly help to understand the effect of these hazards, and to integrate these in the guidelines and code provisions. The Table below gives an overview of the relevance of the various building characteristics for four primary hazards.

Building Characteristics	**Relevance to hazard response**			
	Earthquake	**Wind**	**Landslide**	**Flood**

Location of the building within a region or city or town	**Not critical and governed by seismicity of region, except located on or near fault lines.**	**Somewhat relevant for the shielding effects and terrain and typography or for coastal areas**	**Most critical when located on known hazard zone or prone to hazard due to flood or earthquake**	**Very critical if located in known flood plains, storms or surge zones, down side of dams, and water ways etc.**
Building plan and layout	**This is very critical for good performance and reduction of forces. Regular Symmetric plans are preferred**	**This could be important for wind load**	**Not so relevant**	**Not so relevant**
Design of the roof segment and connection to walls and columns	**This may be important in some cases and overall integrity of the entire system is very important**	**Very critical for proper stability and uplift forces**	**Not so relevant**	**Not so relevant**
Stiffness and strength of the super structure	**Important for the low intensity earthquake. Too much stiffness is not good as it may increase seismic forces**	**Very important for resistance to wind as for stability**	**A certain level of stiffness and rigidity is essential but excess stiffness may lead to large forces due to differential settlement**	**A certain level of stiffness and strength is needed to resist water pressure and flow**
Ductility and energy absorption capacity of main structural system	**Most important for good preparation during strong earthquake. Collapse can be prevent through these measures**	**Not so relevant**	**Somewhat important to reduce the forces accommodate some deformations**	**Not so relevant**
Proper Design of foundation and substructure	**Very important for overall stability**	**Important for overall stability**	**Important for overall stability**	**Important for overall stability**

Elevation or level of habitable floors	**Not so relevant**	**Not so relevant**	**Not so relevant**	**Very important**
Quality of Construction material	**Very important**	**Important**	**Important**	**Important**
Access and Egress	**Very important**	**Important**	**Important**	**Very important**

Table 3: Building Characteristics Relevance to Hazard Response

4. Integrate the proposed guidelines with OECS codes provisions

Once the basic guidelines have been developed for flood and landslide hazards, these can then be integrated and linked with relevant provisions of the exiting building codes, similar to those listed in Table 2.

5. Publish and adopt the guidelines with appropriate legal and enforcement structure

For the guidelines to be useful and enforceable, they will need to be published by the ministries and public works departments, responsible for reviewing the design and issuing the building permits, so that the provisions in the guidelines are part of the design and construction requirements.

6. Integrate the guideline into the future revisions of main building codes

When the new versions of the building codes are developed, the guidelines can either be included by reference or embedded into the relevant sections of the building land use, planning and design requirements, so that flood and landslide hazards are considered with the same level of importance as earthquakes and hurricanes.

Consider various characteristics that are relevant to the mitigation of the landslide risk. The most important of these is the location or sitting of the building with reference to the land slide hazard. Others include the design of the foundations, the split level design to follow the slope lines, flexibility of the structural system to accommodate deformations, use of tie beams, and protections walls.

Define the building characteristics that are relevant to be considered for protection against flood hazard. Most important characteristic is the elevation of the living floor.

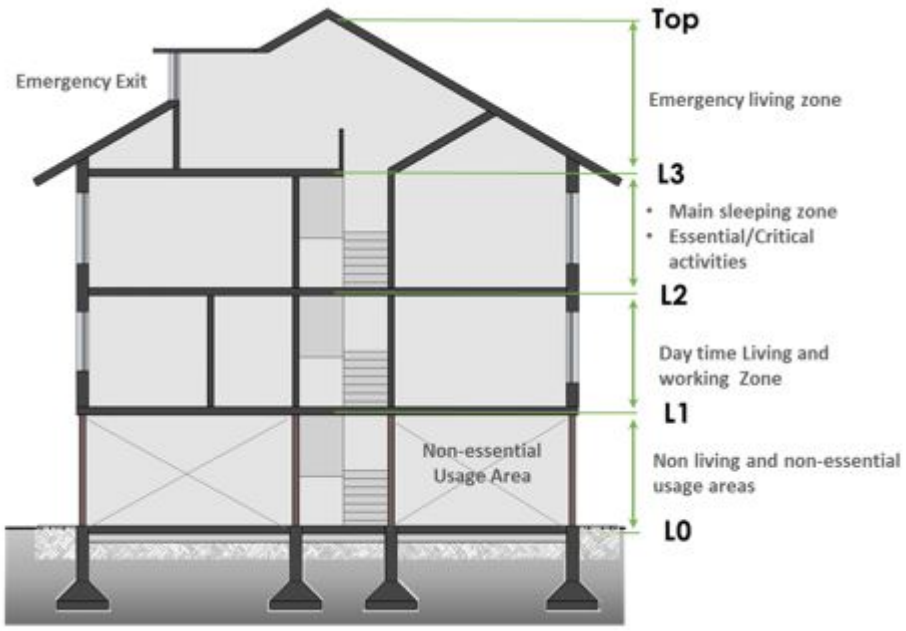

Figure 2: Definition of typical building floors

Relate the defined flood hazard levels to the building characteristics that may be suitable or allowed for each hazard level. The effective handling and design of these characteristics can reduce the vulnerability and hence the risk of flood and landslide hazards. This may limit locations where construction can be done, specify minimum levels/elevations for liveable and essential services areas, regulate extreme event safe houses, etc. Figure 2 represents a typical multi-storey house/ residential building. All individual buildings in the Caribbean may not have all of these levels and spaces, but most houses at least have some of these. The Annex in section 8.4 of the Methodology book contains some pictures of these houses. See also Table 4 below for building design requirements for flood prone structures.

Design Requirements	Explanation
Floor Height Requirements	**Habitable floors should be above the Service Level Flood. Level 1 of the building may be on stilts with nonresidential level 0. Freeboard provisions should be considered. This strategy can be used for primary risk management as well as eliminate residual flood risk.**
Footing System Requirements	**Following points should be considered:** • **Footing system depth:** • **Use of stilts, columns and piles :** • **Use of fill and slabs**
Modification of Ground levels	**This aspect needs to be considered during early design stages. By raising land by civil engineering operations above the level of flood risk, or to reduce the depth of flood water in extreme conditions to acceptable level, risk to the development may be reduced.**

Requirements for enclosures below the hazard level	**These should either be design for full water tightness, water pressure, water proofing and buoyancy, or for water pressure relief through valves and blowout sections**
Development behind flood walls and embankments	**These should be designed for possible failure of the walls, with appropriate warning systems.**
Requirements for Structural Attachments	**Items such as decks and patios must be structurally adequate so as not to cause failure of the main building they are attached to. Any structure either designed to fail or not structurally adequate must be designed to not impact upon the structural adequacy of the building.**
Material Requirements	**Water proof, water resistant and durable**
Building Services	**Utilities include electrical, plumbing, telecommunication, HVAC and similar services. All these utilities and associated equipment should be designed and installed in such way that is should prevent flood water from entering and accumulating.**
Electrical	**All the cables that comes below flood service level should be water proof and all the switches should also be mounted above that flood level.**
Requirements for Egress	**Exit areas of the building should be clearly identified in case occupants needs to be rescued during disaster event. The exit route could be from a balcony, verandah, deck, door or operable window of sufficient size.**

Table 4: Basic building design requirements for flood prone structures [3]

Results:

The expected result of this use case is the development of guidelines for each OECS country for the flood and landslide hazard, to complement the existing building codes where such provisions are not explicitly and adequately addressed. Ultimately, these guidelines can become integral part of the national building codes, and help to reduce the vulnerability and risk to these hazards. The use case is also useful reference for the contents and provisions of such guidelines.

Conclusions:

The procedure to develop specific guidelines for considering the flood and landslide hazards for the planning and design of buildings in the OCES is described. A phased approach is proposed where basic and independent guidelines are developed first, and adopted as an interim document and then integrated and included in the new versions of the building codes when they are updated.

The basic hazards levels performance expectations and the relevant building characteristics for flood and landslide are described that need to be considered for the development of the guidelines and code provisions. The current provisions and design considerations in the building codes for earthquakes and hurricanes, relevant to flood and landslide are also discussed to provide a frame of reference.

References:

[1] ASCE 7-13, Minimum Design Loads for Buildings and Other Structures. http://www.asce.org/templates/publications-book-detail.aspx?id=6725

[2] Peer Tall Building Initiative. http://peer.berkeley.edu/tbi/

[3] Australian Building Codes Handbook, Landslide Hazard 2006 www.abcb.gov.au/education-events-resources/publications/abcb-handbooks.aspx and UK Planning Policy Statement March, 2010, https://www.gov.uk/government/uploads/system/uploads/attachment_data/fil...

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