Evaluación de Riesgos Naturales
- América Latina -
Consultores en Riesgos y Desastres

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CAPRA

CENTRAL AMERICA PROBABILISTIC RISK ASSESSMENT

EVALUACIÓN PROBABILISTA DE RIESGOS EN CENTRO AMÉRICA

BELIZE

TASK IV

HAZARD, RISK MAPS AND RISK MANAGEMENT APPLICATIONS

TECHNICAL REPORT SUBTASK 4.2B

DISASTER RISK ASSESSMENT FOR BELIZE CITY

CEPREDENAC

Estrategia Internacional
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LIMITATIONS AND RESTRICTIONS

This application is illustrative, and has limitations and restrictions due to the level of resolution of available information. The final user should be aware of this, so that he will be able to make appropriate and consistent use of the results obtained, taking account of the type of analysis made, the type and quality of data used, the level of resolution and precision, and the interpretation made. Therefore, the following should be noted:

- Models used in the analysis contain simplifications and suppositions in order to facilitate the calculation which the user of which the user should be aware. They are described in detail in the related technical reports.
- The analyses have been developed with the best information available, within limitations of reliability and currency. It is possible that better and more complete information exists, but that we did not have access to it.
- The information used and the results of the analysis of hazards, exposure and risk are associated with a level of resolution, depending on the unit of analysis used, and this is explained in the descriptive document of the example.
- The use which the final user makes of the information does not in any way involve liability on the part of the authors of the study is made, who present this example as a something which could be feasible, if reliable information with appropriate degrees of precision were made available.
- It is the user´s responsibility to understand the type of model used and its limitations, resolution and the quality of data, limitations and assumptions for analysis, and the interpretation made in order to give these results appropriate and consistent use.
- Neither those who developed the software nor those who promoted and financed the project, nor the contractors or subcontractors who took part in applications or examples of the use of the models, assume any liability for the use which the user gives to the results presented here, and therefore they are free of all liability for loss, damage, or effects which may be derived from the usual interpretation of these demonstrators examples.

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1 Introduction

Belize City, the former capital of Belize, has approximately 59,000 inhabitants (2000 census, projected to 2008), about 20% of the total population of the country, which is 274,590. It stands at the mouth of Belize River, on the Caribbean coast, where the country's principal port facilities, industries and financial centre are concentrated. The city has around 19,140 buildings, mostly 1-2 stories, mainly constructed of wood, simple masonry, or reinforced masonry.

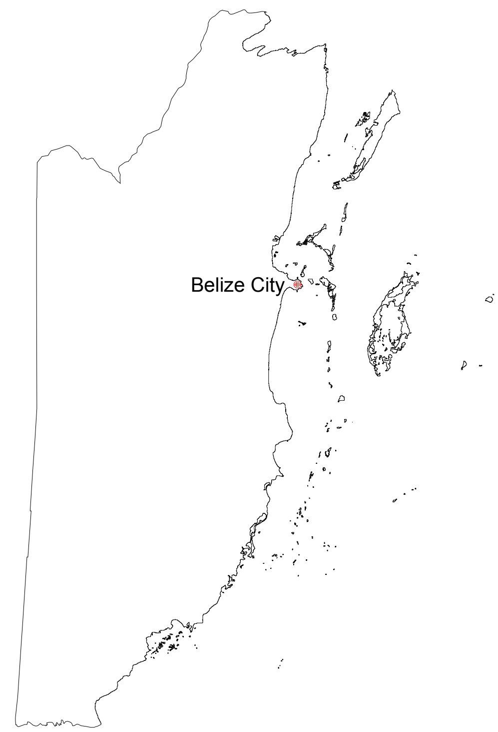

Figure 1-1
Geographical location of Belize City

Historically, Belize, and particularly Belize City, has suffered a series of natural disasters which have cost major economic losses and lives; this accentuates the physical and social vulnerability of the country as a whole. The disasters are related principally to the passage of hurricanes in the Atlantic basin, which affect the region of the north Atlantic an average of 10 times a year, accompanied by one or more of the following phenomena: strong winds, cyclones over the sea, and torrential rain.

In 1961, Hurricane Hattie, category 5 on the Saffir-Simpson scale, affected the Atlantic side of Belize, and caused the destruction of 75% of houses and shops in the city. The rain left damages estimated at US$60 million, and some 275 people lost their lives. In 1974, Hurricane Carmen, category 4 on the Saffir-Simpson scale, caused damage of US$ 4 million in Belize, and some 70,000 people were affected. In 2000, Hurricane Keith, category four on the Saffir-Simpson scale, caused some US$10 million of damage, and 11 people lost their lives.

In the process of the discovery and evaluation of the risks derived from the occurrence of extreme events, the local conditions referring to the exposure of human and physical assets and their geographical distribution must be established, along with physical and population vulnerability, and the potential damage and loss which may be suffered. A procedure of this type should make it possible to rely on useful information in decision-making by public servants responsible for planning and development, since they will be able to estimate the magnitude of an economic and social in impact on the city and the country. In the same way parameters can be set to draw up plans as part of the ex-ante-and ex-post management of the disaster risk.

The purpose of the simulation presented here is to evaluate the potential risk to Belize City for seismic events and the transit of hurricanes, and to express that risk in terms of average annual losses (AAL), probable maximum loss (PML), and direct effects on the population. The analysis is conducted in probabilistic terms for the hazards of earthquake and hurricane.

The results of the simulation are presented so that they can be used for subsequent detailed analysis and as inputs for the preparation of a contingency plan for attention to emergencies, the drafting of plans to reduce physical vulnerability and to propose possible strategies for financial protection.

2 Methodology for risk assessment

For the evaluation of the disaster risk in Belize City the methodology proposed in the context of the CAPRA initiative was followed, described in detail in report ERN-CAPRA-T3.2 (Method of probabilistic analysis of risks, ERN 2010), and in the website www.ecapra.org.

The methodology for the evaluation of risk in terms of seismic and hurricane hazards including the following considerations:

(a) Evaluation of seismic hazard: this is conducted by using a probabilistic seismic hazard analysis -PSHA- which provides results related to the annual expected loss for each of the assets and for the portfolio in general.

(b) The evaluation of the hazard from hurricane winds and storm-surges: these are invaded by probabilistic analysis, which allows results to be obtained in relation to average annual losses for each of the assets and for the portfolio in general.

(c) Inventory of exposed assets: Since it was not possible to obtain detailed cadastral register information, a survey was made of the inventory of exposed assets based on observations from satellite images and their interpretation. Official information and published indicators allowed approximate values to be established, along with indicators of occupation.

(d) Vulnerability functions: The various types of construction identified in the area are characterized with a vulnerability function which takes account of the capacity of the building to withstand the action of various events considered. These vulnerability functions represent the probable or expected behavior of the buildings of each particular structural type, since its use is adequate in statistical terms when there is a large inventory of exposed assets. The analysis uses the vulnerability functions determined according to the methods and tools proposed in the ERN-vulnerability module (ERN, 2010).

(e) Risk assessment: risk assessment is made by associating the hazards considered and the inventory of exposed assets with related vulnerability functions. For this purpose, the risk assessment tool - CAPRA-GIS (ERN 2010) was used. An evaluation is then made of the percentage of damage expected in each of the buildings exposed for each of the scenarios proposed, and for the integral probabilistic analysis. The allocation of value to the risk is presented in terms of estimates of the following:

- Percentage of physical effects on constructions
- Direct economic losses, approximated, per property
- Probable maximum economic losses
- Annual expected losses expected

3 Seismic hazard

The modeling of the hazard is presented in detail in the report ERN-CAPRA-T1.3 (Probabilistic modeling of natural hazards, ERN 2010). The theoretical basis of the model for the hazard is presented in the report ERN-CAPRA-T1-.2 (Hazard evaluation models, ERN 2010). All of this information is also described in detail in the website www.ecapra.org.

The territory of Belize is located on the North American plate. The principal tectonic characteristics which provide a hazard to this country is the interaction of the Caribbean and North American plates, which is of a transcurrent type, with important fault systems such as Motagua in Guatemala, and the underwater Walton fault, to the southeast of the country. Both of these can generate earthquakes of a high magnitude (>7). The subduction zone or Meso-American trench does not represent an important seismic source for Belize, since it is of some 400 km to the west of the country.

The purpose of the simulation presented here is to dimension the consequences which may be caused by a strong earthquake affecting Belize City, taking the most up-to-date possible information about the hazard as the basis, with available digital information on exposed elements or assets in Belize City.

3.1 Historical events

On May 28th, 2009, a strong earthquake magnitude 7.5 (Ml) shook the coast of Honduras and Belize, and the epicenter was 225 km from Belize City. There were power blackouts, some five buildings were destroyed, and some 25 more were damaged.

3.2 Hazard assessment

The seismic hazard for Belize City was calculated using advances presented in the regional project RESIS II (NORSAR et al, 2008), which is the most up-to-date study so far in relation to seismic hazard evaluations in Central America. Based on the seismic tectonics of the area, and the seismicity recorded on a historical basis, a series of seismic sources were defined which cover the entire territory of Central America, and maintain the general conditions of seismicity and regional variation.

Based on this information, and using the methodology explained in detail in the report ERN.CAPRA.T1.3 (Probabilistic modeling of natural hazards, ERN 2010), and the website www.ecapra.org a catalogue of stochastic events was built up to represent the seismic hazard of the region.

14,796 scenarios were determined, according to the methodology presented in the report ERN-CAPRA-T1.2 (Hazard evaluation models, ERN 2010), each of them associated with a defined frequency of occurrence, and with a magnitude corresponding to the characteristics of the seismic sources. Figure 3-1 presents the seismic hazard, in terms of the peak ground acceleration for different return periods.

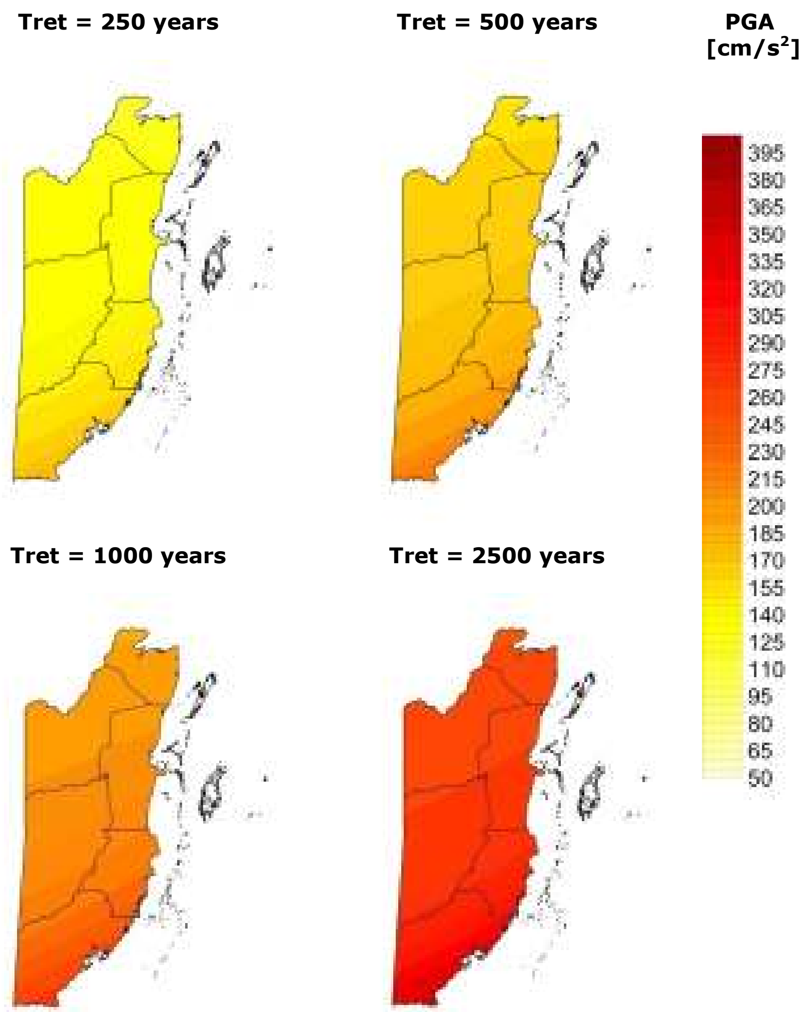

Figure 3-1
Peak ground acceleration maps [cm/s²] for different return periods

On the other hand, Figure 3-2 presents the hazard curve for a representative point in the city.

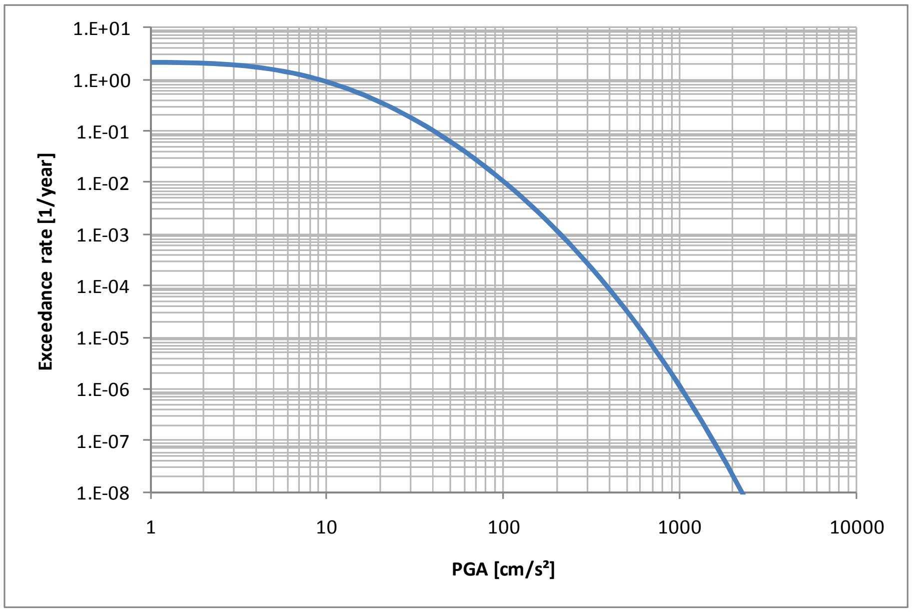

Figure 3-2
Seismic hazard curve of Belize City for peak ground acceleration

4 Hurricane hazard

The modeling of the hazard is presented in detail in the report ERN-T1.3 (Probabilistic modeling of natural hazards, ERN 2010). The theoretical basis of the model of the hazard is presented in the report ERN-CAPRA-T1.2 (Evaluation models for natural hazards, ERN 2010). All this information is also described in detail in the website www.ecapra.org

4.1 Historical events

Table 4-1 presents a summary of the hurricanes which have most strongly affected mainland Belize City. This information is presented in greater detail in the report ERN-T1.1 B. (Review of historical events, ERN 2010).

Table 4-1
Major hurricanes affecting Belize City area
(Fuente: http://weather.unisys.com/hurricane/atlantic/index.html)

Name	Dat6e	Winds (knots)	Pressure (mb)	Category	Description and effects
Hurricane HATTIE	27/10/1961	140	920	5	Hattie cost 319 deaths and damage of US$440 m. Its passage through Belize damaged 75% of housing and shops. The damages costed an estimated US$60m and 275 lives.
Hurricane CARMEN	29/8/1974	130	928	4	Rains caused US$4m of damage and some 70,000 people affected.
Tropical storml HERMINE	20/9/1980	60	993	-	30 lives were lost and 175,000 were affected. There was extensive damage to crops. The wind began to blow on October 20, 1980 and then became a tropical store Hermine south of Jamaica. At 1200GMT that same day the wind formed a depression and formed a tropical storm at 0600GMT on September 21, with its centre 80 nautical miles east of Honduras. The storm then moved along the coast of Honduras without touching land until, it struck north Belize on September 22, at 1200GMT.
Tropical storm KEITH	17/11/1988	65	945	-	Caused US$2m of damage and the death of 11 people.

4.2 Hazard assessment

The hazard from hurricane is evaluated in a temporality jointly with hurricane winds and storm-surges. The analysis is made based on the trajectories and characteristics taken from available historical records. The stochastic events were generated in a simulation using a random-walk technique, which involves sampling of historical distributions in the location of the generation of the storm, to calculate the speed of advance which would allow the storm to move forward, and sampling the distribution in the new location for the next time interval, and so on. Each simulated trajectory is different from each other simulated trajectory or historical trajectory, but the set simulated events remains the same statistical properties as the set of historical events. This methodology is explained in detail in the report ERN-CAPRA-T1.2 (Evaluation models for natural hazards, the in 2010), and the website www ecapra.org.

For modeling the hazard, survey information was taken at resolution of 30m, obtained from NASA-STRM. The method explained in detail in the report ERN-CAPRA T1.3 (Probabilistic modeling of natural hazards, ERN 2010) was used, as was the website www.ecapra.org, and a catalogue of stochastic and historical hurricanes was constructed to represent the overall hazard to Belize.

For the probabilistic analysis, a total of 102 scenarios were calculated for hurricane winds, using the method presented in the report ERN-T1.2 (Evaluation of models for natural hazards, ERN 2010), each of them associated with a given frequency of occurrence, and which corresponds to simulations based on historical events. Figure 4-1 presents the hurricane hazard map in terms of maximum hurricane-force wind velocities, for different return periods.

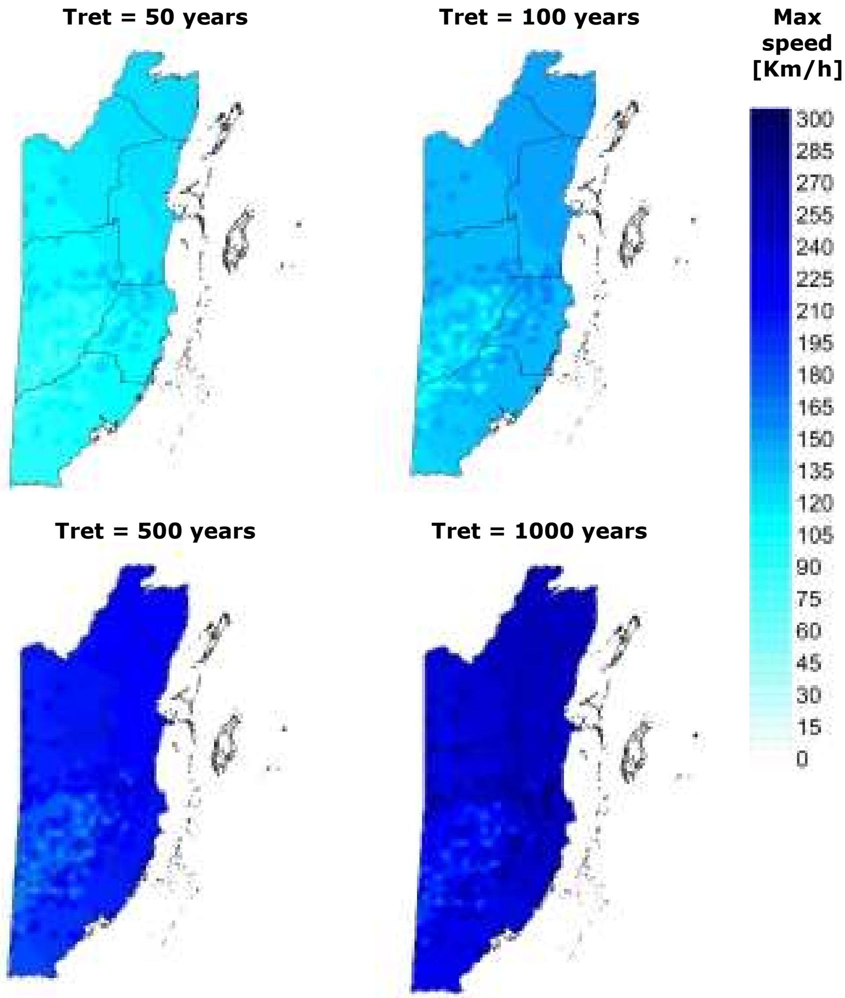

Figure 4-1
Maximum speed maps [km/h] for different return periods

Figure 4-2 presents the wind speed hazard curve for a representative point in the city.

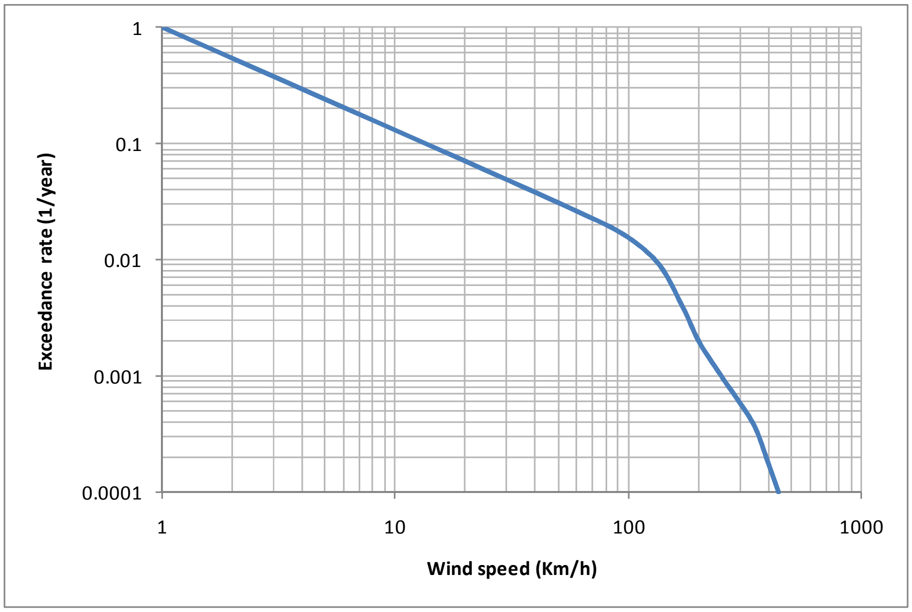

Figure 4-2
Hazard curve for hurricane wind in Belize City [km/h]

On the other hand, Figure 4-3 presents the storm-surge hazard curve, for a representative point within the city.

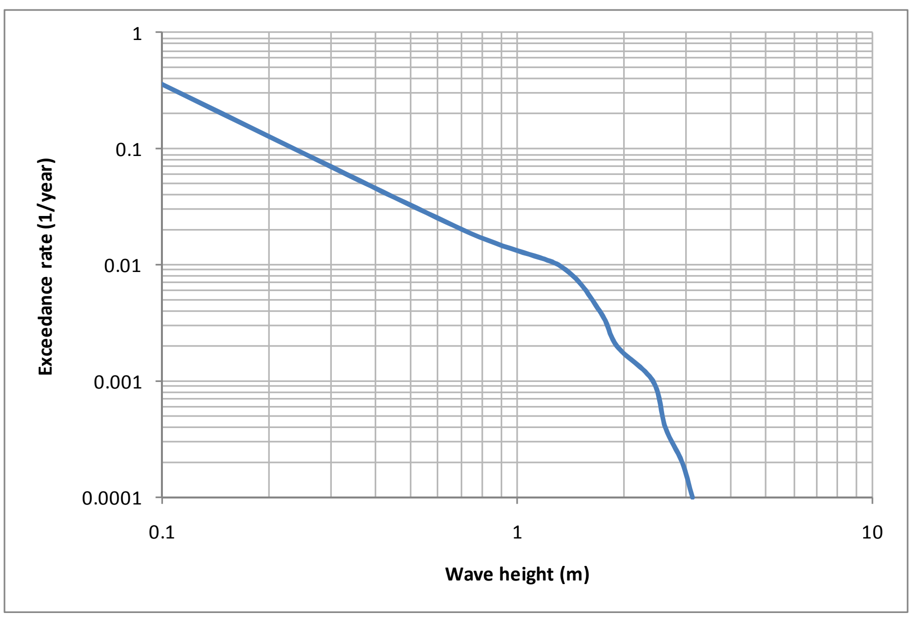

Figure 4-3
Hazard curve for hurricane storm-surge in Belize City [m]

5 Inventory of exposed elements

5.1 Survey of basic information

There is a population census for Belize City which provides the number of inhabitants, but not their spatial distribution or economic activity. Furthermore, there is no a cadastral database, or information related to construction systems, areas of construction, exposed values, construction dates or other data which are useful in determining economic, structural and human exposure and vulnerability.

Therefore, we proceeded to form a database for exposure of buildings, based on a digital survey taken from satellite images, complemented by population statistics, photographs, official indicators and the recommendations of local experts. This information, like any other approximated model of information, is open to improvement, and can be updated and cleaned up using intense fieldwork, or by having detailed property register information available. The quality and resolution of information in an exposure survey defines the reliability and resolution of the results of the risk analysis.

Figure 5-1 presents an image of city blocks, digitalized using the web tool for urban zoning, by homogeneous blocks, (Available in www.ecapra.orgh/zonhu.php for Belize City). The tool allows the identification of blocks to be made with homogeneous exposure on Google Maps satellite images, that is, blocks which can be identified to have conditions of use or levels of occupation, cost and densities of construction, which are similar. Each block is then classified in terms of percentages identified for each type of construction, in relation to observations identified in the survey.

These homogeneous blocks were then split up, to simulate properties around the city. This process of splitting up consists of making a random allocation of points in each homogeneous block, assigning to each point a cost and occupation consisting of values identified in the block, and a type of construction as a function of the percentages previously defined. The total number of properties located per block is consistent with the density of construction identified in the survey.

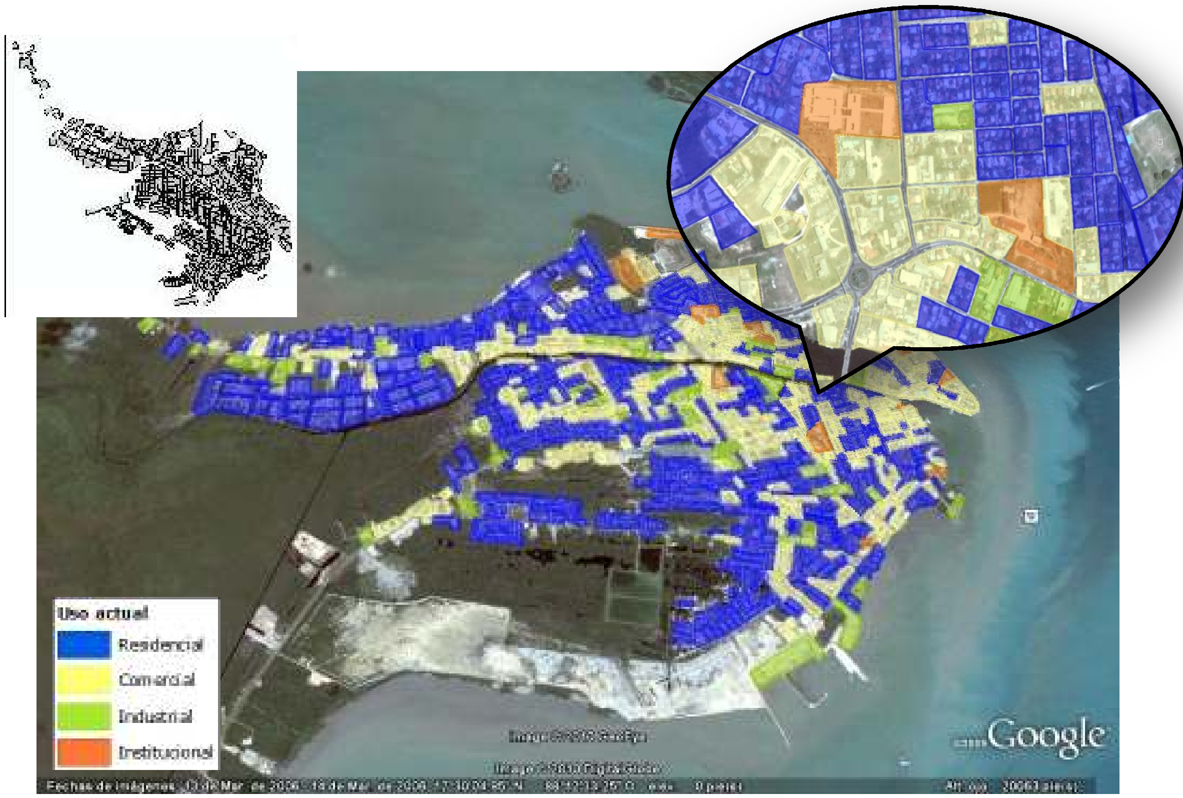

Figure 5-1
Map of homogeneous blocks in Belize City
(Image generated with Google Earth)

5.2 Information of property exposures

The conditions of exposure in Belize City, measured in terms of replacement value of the number of occupants of buildings, was assigned through the approximated methods mentioned above.

Table 5-1 presents certain general indicators used to generate the database for exposure of buildings for this population

Table 5-1
General indicators for building exposure

Indicator	Unit	Value
Estimated population	Pop	58,100
Area of urban land	km^2	13.60
Population density	Pop/km^2	4,270
No. of buildings		19,140
Área constructed	m^2	$3,830 \times 10^3$
Density of urban construction	m^2/m^2 urban land	0.28
Total value of buildings	US$ millions	1,280
Average value per sq m constructed	$US\$/m^2$	330

Below some statistics are shown which are the results of a process of formation of the building's exposure database. Table 5-2 and Figure 5-2 and Figure 5-3 present the general distribution of values exposed, and the occupation of buildings, with different types identified structural systems. The detailed description of the structural systems and distribution in the city is to be found in the report ERN-CAPRA-T2.2 (Proposal for vulnerability functions and indicators, ERN 2010).

Table 5-2
Exposed values and occupation by structural systems

System	System's code	Constructed area [m²]	Exposed value [US$ millions]	Occupation [Hab]
Wooden walls	W-SLFB-1	582,703	190.02	9,136
	W-FLFB-2	418,507	133.55	6,267
Simple masonry	MS-SLSB-1	573,164	184.54	10,190
	MS-RLSB-2	356,706	117.09	6,003
Confined masonry	MC-SLSB-1	150,106	50.03	2,126
	MC-RCSB-1	28,701	9.22	389
	MC-RLSB-2	112,999	36.68	1,655
Reinforced masonry	MR-SLSB-1	300,164	104.35	4,141
	MR-RLSB-2	1,041,542	365.69	14,338
Concrete frames	PCR-RLSB-2	198,181	64.26	2,741
	PCR-RCSB-2	29,267	10.42	436
Steel frames	PAA-SLSB-B	35,880	14.63	676
Total		**3,827,921**	**1,280.48**	**58,098**

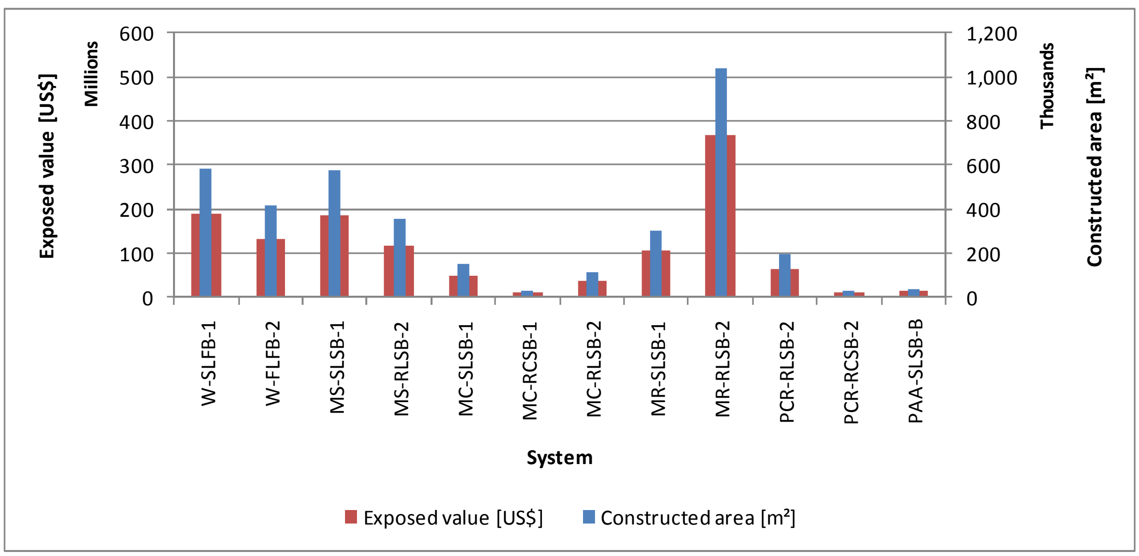

Figure 5-2
Exposed values and constructed area distribution by structural systems

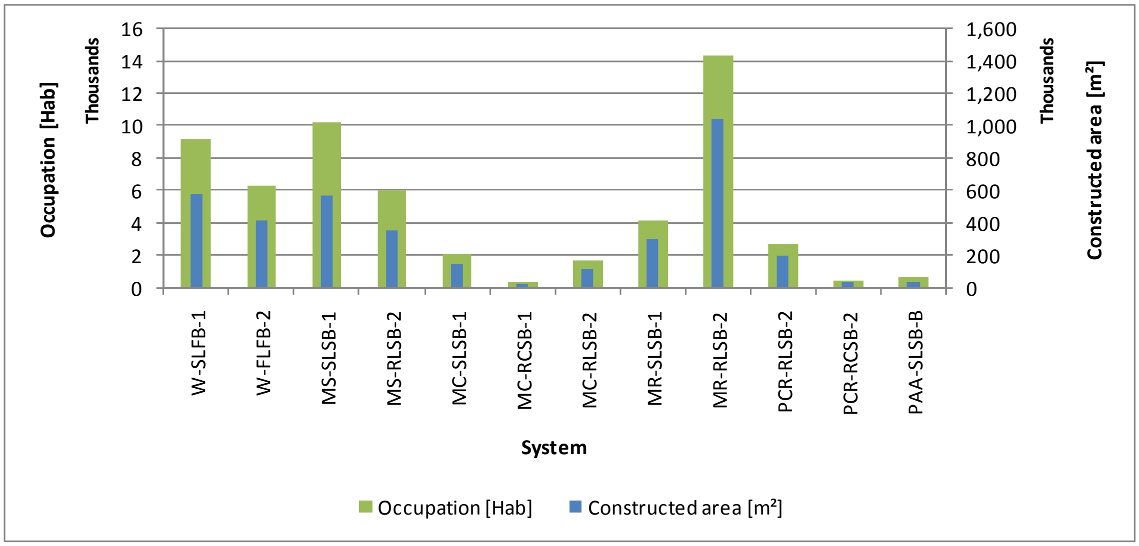

Figure 5-3
Occupation and constructed area distribution by structural systems

Furthermore, Table 5-3 and Figures 5-3, 5-4 and 5-5 show the distribution of exposed values and occupation as a function of the number of floors in the buildings included.

Table 5-3
Exposed values and occupation by number of stories

No of stories	Constructed area [m²]	Exposed value [US$ millions]	Occupation [Hab]
1	1,920,475	615.16	33,712
2	1,280,086	442.29	16,402
3	528,253	191.07	6,848
4	14,619	2.99	240
5	9,528	5.43	146
6	74,960	23.54	750
Total	**3,827,921**	**1,280.48**	**58,098**

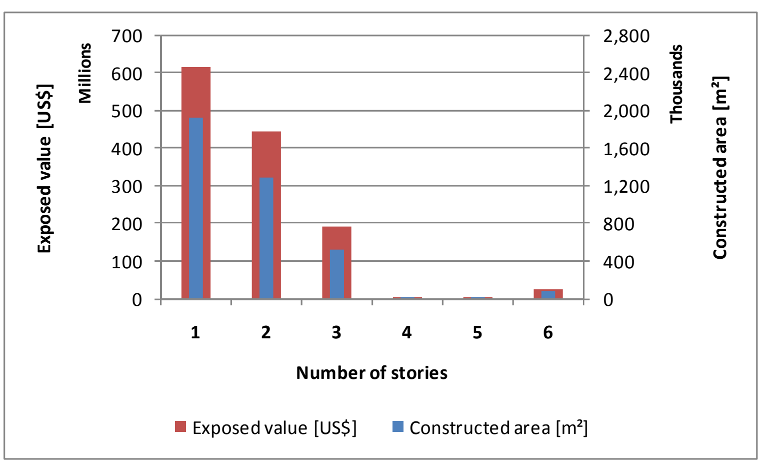

Figure 5-4
Exposed value and constructed area distribution by number of stories

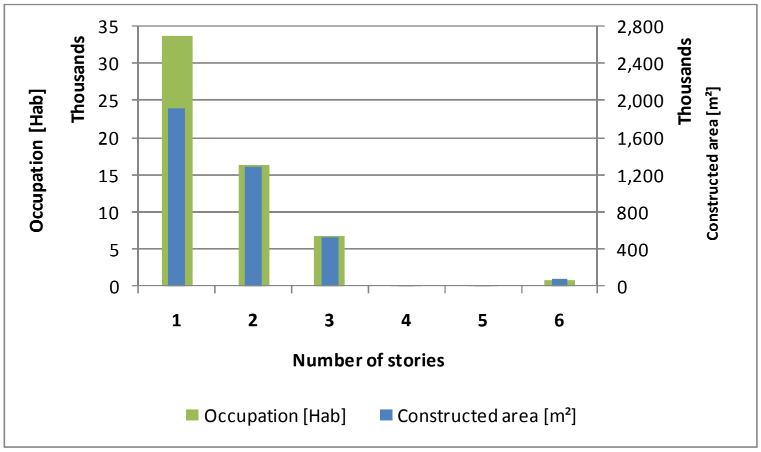

Figure 5-5
Occupation and constructed area distribution by number of stories

5.3 Vulnerability information

The structural types contained in the database correspond to those presented in Table 5-4.

Table 5-4
Employed vulnerability curves

Material	Earthquake curve	Wind curve	Surge curve	No Stories	Exposed value [US$ millions]	Occupation [Hab]
Wood						
W-SLFB-1	S_W-SLFB-1	V_LF1	I_W1	1	190.02	9,136
W-FLFB-2	S_W-FLFB-2	V_LF2	I_W2	2	133.55	6,267
Simple masonry						
MS-SLSB-1	S_MS-SLSB-1	V_LS1	I_M1	1	184.54	10,190
MS-RLSB-2	S_MS-RLSB-2	V_LS2	I_M2	2	117.09	6,003
Confined masonry						
MC-SLSB-1	S_MC-SLSB-1	V_LS1	I_M1	1	50.03	2,126
MC-RCSB-1	S_MC-RCSB-1	V_CS1	I_M1	1	9.22	389
MC-RLSB-2	S_MC-RLSB-2	V_LS2	I_M2	2	36.68	1,655
Reinforced masonry						
MR-SLSB-1	S_MR-SLSB-1	V_LS1	I_M1	1	104.35	4,141
MR-RLSB-2	S_MR-RLSB-2	V_LS2	I_M2	2	365.69	14,338
Concrete frames						
PCR-RLSB-2	S_PCR-RLSB-2	V_LS2	I_C2	2	64.26	2,741
PCR-RCSB-2	S_PCR-RCSB-2	V_CS2	I_C2	2	10.42	436
Steel frames						
PAA-SLSB-B	S_PAA-SLSB-B	V_LS1	I_C2	1-3	14.63	676
Total					**1,280.48**	**58,098**

Table 5-5 and Figures 5-6 to 5-8 show the number of records that would represent the structural types employed and the related vulnerability associated with them.

Table 5-5
Exposure by vulnerability curve

System	Exposed value [US$ millions]	Number of records
W-SLFB-1	190.02	2,873
W-FLFB-2	133.55	2,015
MS-SLSB-1	184.54	2,860
MS-RLSB-2	117.09	1,794
MC-SLSB-1	50.03	737
MC-RCSB-1	9.22	135
MC-RLSB-2	36.68	557
MR-SLSB-1	104.35	1,507
MR-RLSB-2	365.69	5,320
PCR-RCSB-2	10.42	155
PCR-RLSB-2	64.26	970
PAA-SLSB-B	14.63	214
TOTAL	**1,280.48**	**19,137**

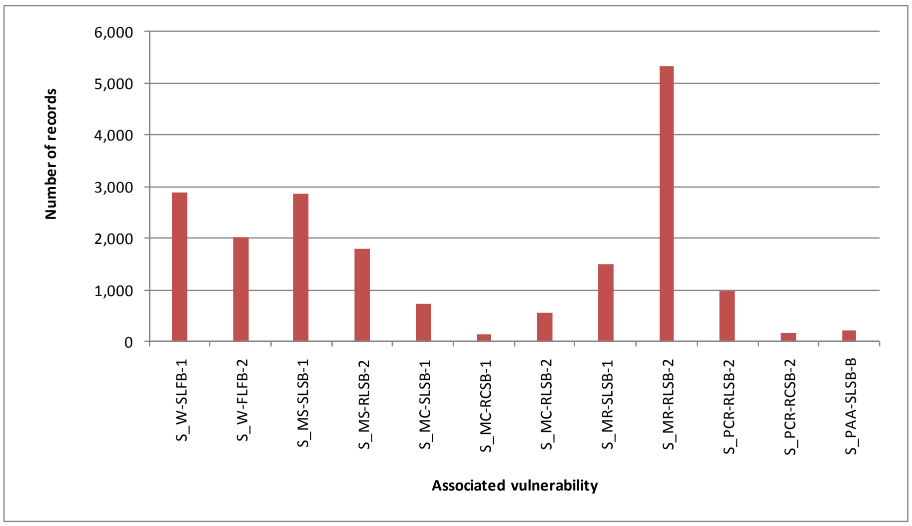

Figure 5-6
Number of records associated with earthquake vulnerability curve

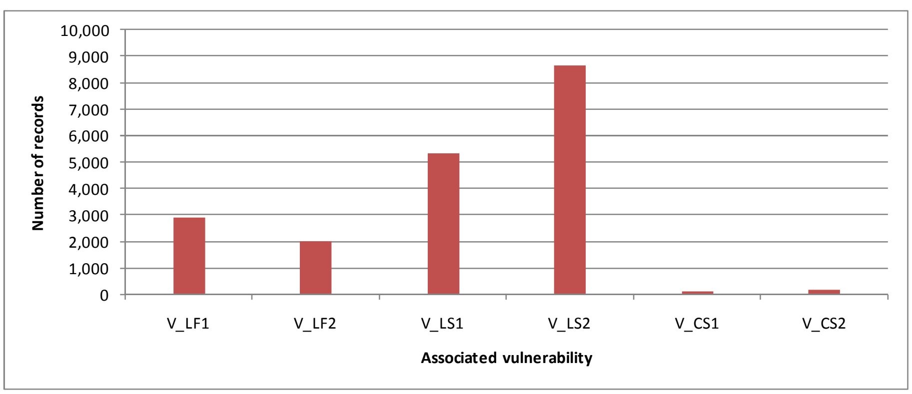

Figure 5-7
Number of records associated with wind vulnerability curve

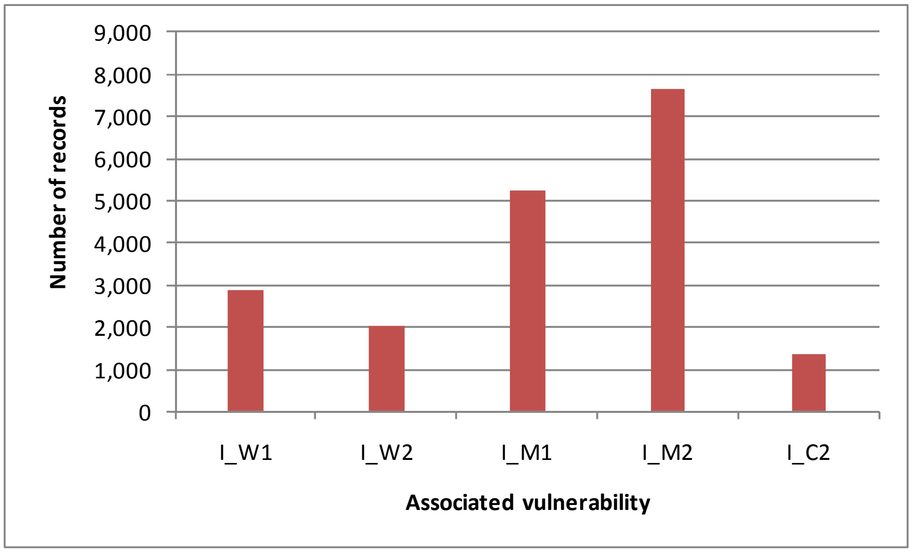

Figure 5-8
Number of records associated with flooding vulnerability curve

The structural types are characterized by the vulnerability functions to physical loss presented in Figures 5-9 to 5-11.

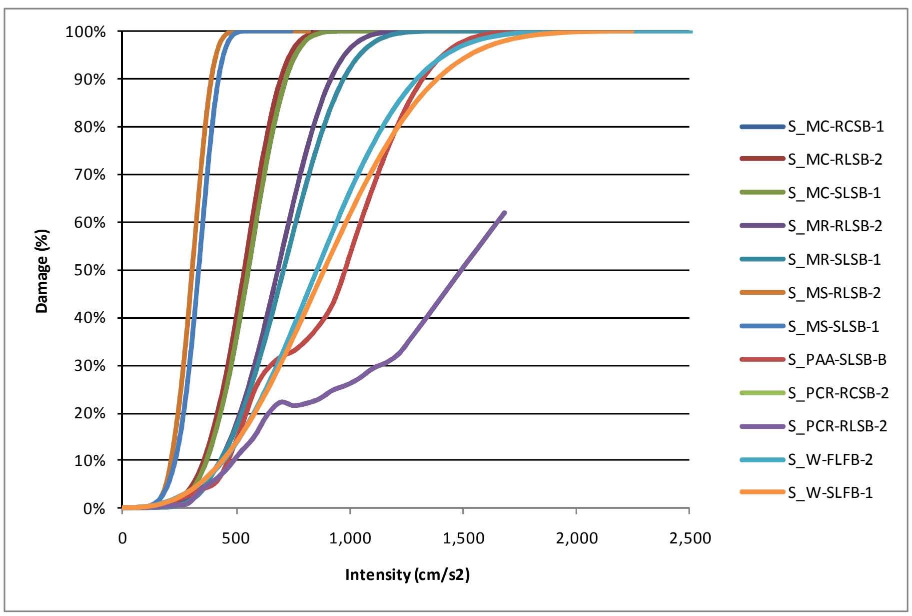

Figure 5-9
Employed earthquake vulnerability curves

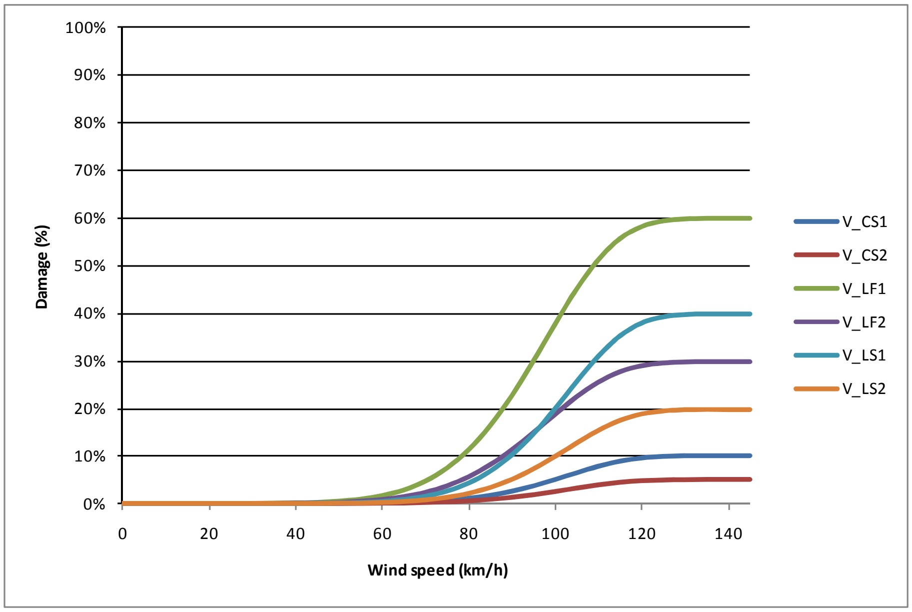

Figure 5-10
Employed wind vulnerability curves

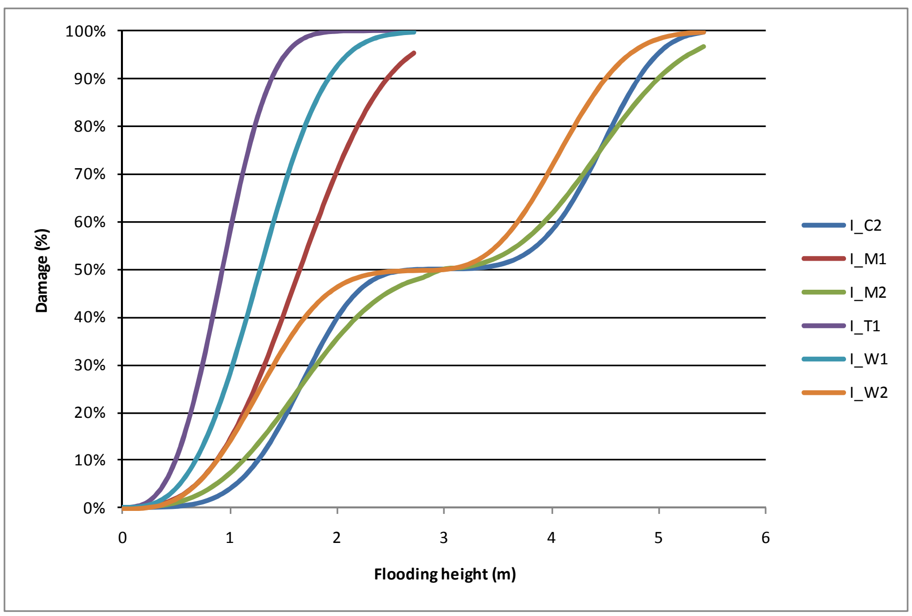

Figure 5-11
Employed flooding vulnerability curves

6 Results of the evaluation

The results of the risk analysis were produced using the methodologies explained in detail in report ERN-CAPRA- T3.2 (Model for probabilistic evaluation of risk, ERN 2010), and the website www.ecapra.-org, and these may be consulted in detail for the method of loss evaluation employed in this study.

6.1 Probabilistic assessment of disaster risk

The probabilistic assessment for disaster was conducted for the temporalities presented in Table 6-1. Each temporality is defined as a set of hazards which occur simultaneously.

Table 6-1
Temporalities used in the assessment

HAZARD	TEMPORALITY	
	1	2
Earthquake		
Hurricane - Wind		
Hurricane – Storm surge		

We now present the results obtained in the probabilistic assessment of earthquake and hurricane losses for Belize City. Details of the method of evaluation for losses used in this study can be consulted o the website www.ecapra.org .

6.1.1 *Results for earthquake*

Table 6-2 and Figure 6-1 summarize the results of the risk for seismic hazard.

Table 6-2
General results

Results		
Exposed value	US$ x10^6	1,280.48
Average Annual Loss	US$ x10^6	0.60
	‰	0.47‰
PML		
Return period	**Loss**	
years	**US$ x10^6**	**%**
250	27.29	2.13%
500	47.44	3.71%
1,000	75.02	5.86%
1,500	95.16	7.43%

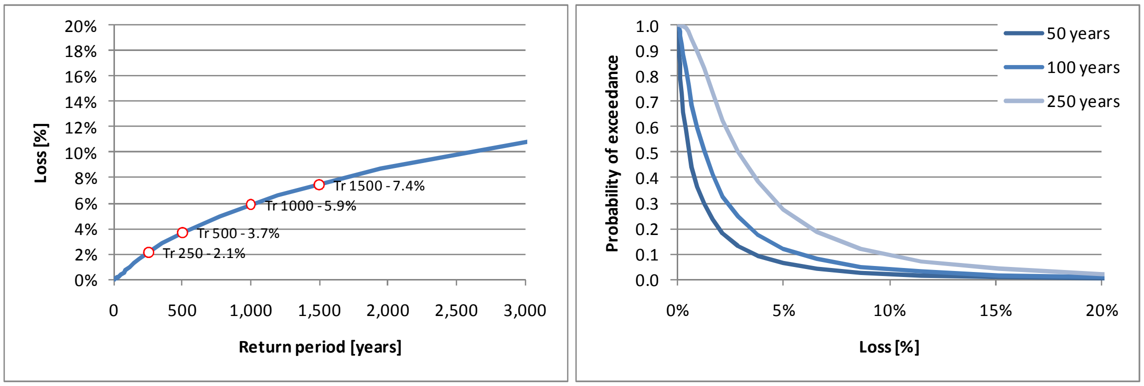

Figure 6-1
Analysis results for earthquake
(Left: Probable maximum loss curve, Right: Exceedance loss probability for different exposition timeframes)

Table 6-3 and Figures 6-2 to 6-5, present the results for seismic risk grouped according to structural system, number of stories, group of use, and the socio-economic category.

Table 6-3
Results by structural system (exposed values and average annual loss)

System	Exposed value		Expected anual loss	
	[US$]	[%]	[US$]	[‰]
MC-RCSB-1	9,217,728	0.72%	638	0.07‰
MC-RLSB-2	36,676,333	2.86%	16,470	0.45‰
MC-SLSB-1	50,029,935	3.91%	3,462	0.07‰
MR-RLSB-2	365,690,353	28.56%	97,727	0.27‰
MR-SLSB-1	104,349,118	8.15%	3,319	0.03‰
MS-RLSB-2	117,090,105	9.14%	240,487	2.05‰
MS-SLSB-1	184,543,890	14.41%	79,293	0.43‰
PAA-SLSB-B	14,634,419	1.14%	4,487	0.31‰
PCR-RCSB-2	10,421,682	0.81%	1,462	0.14‰
PCR-RLSB-2	64,264,916	5.02%	9,023	0.14‰
W-FLFB-2	133,547,157	10.43%	50,996	0.38‰
W-SLFB-1	190,017,572	14.84%	97,552	0.51‰
TOTAL	**1,280,483,209**	**100%**	**604,917**	**0.47‰**

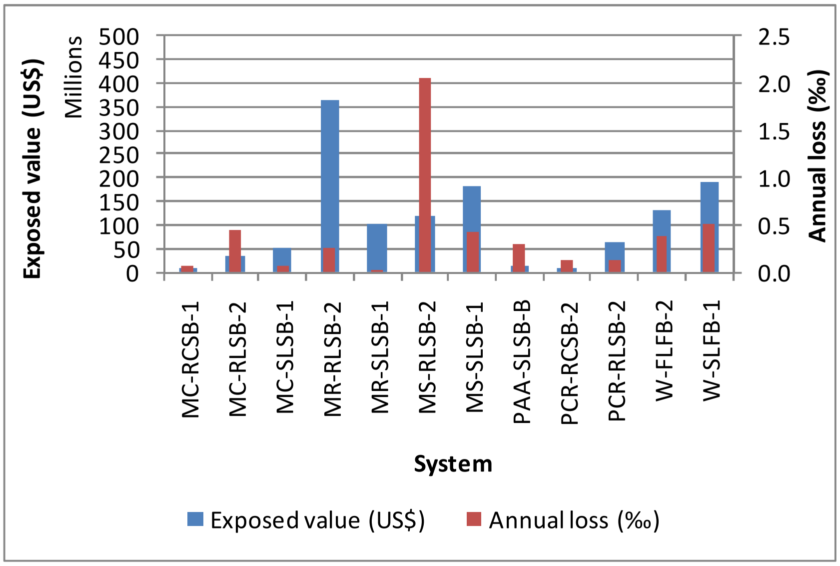

Figure 6-2
Exposed value and average annual loss by structural system

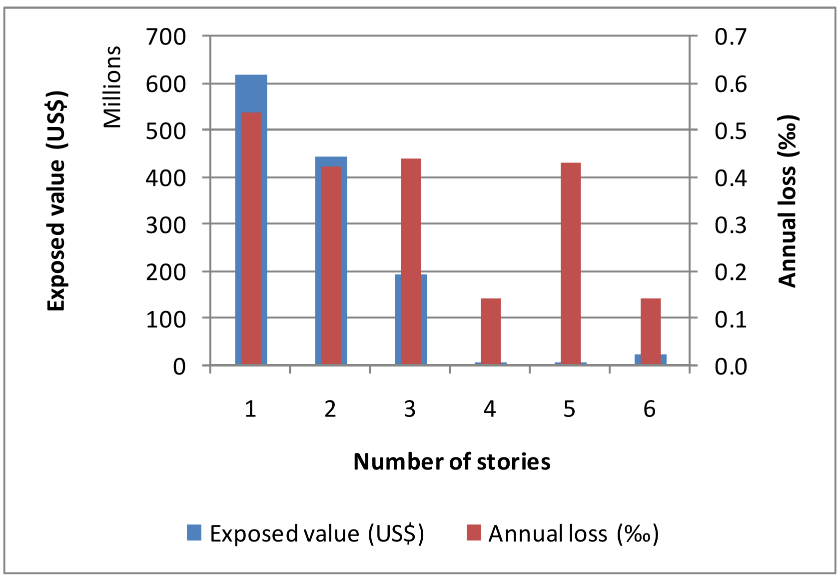

Figure 6-3
Exposed value and average annual loss by number of stories

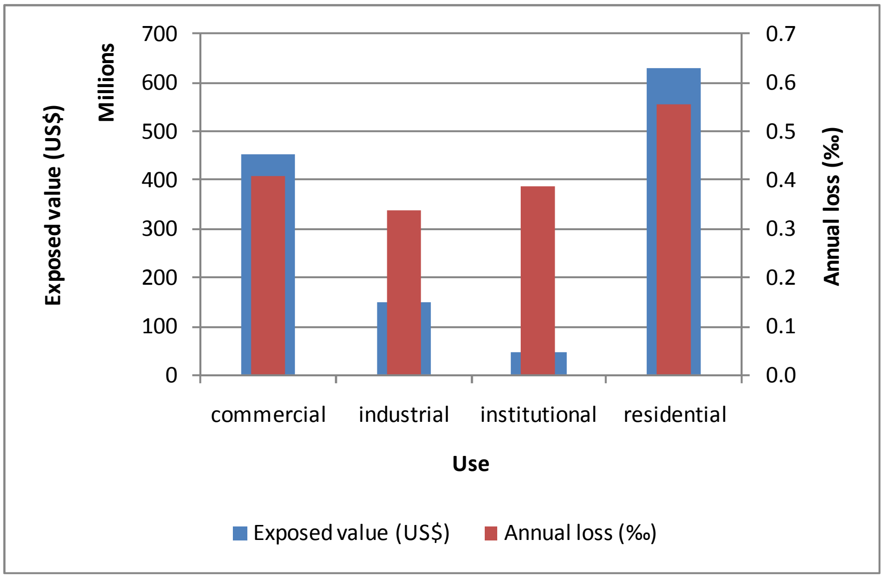

Figure 6-4
Exposed value and average annual loss by use

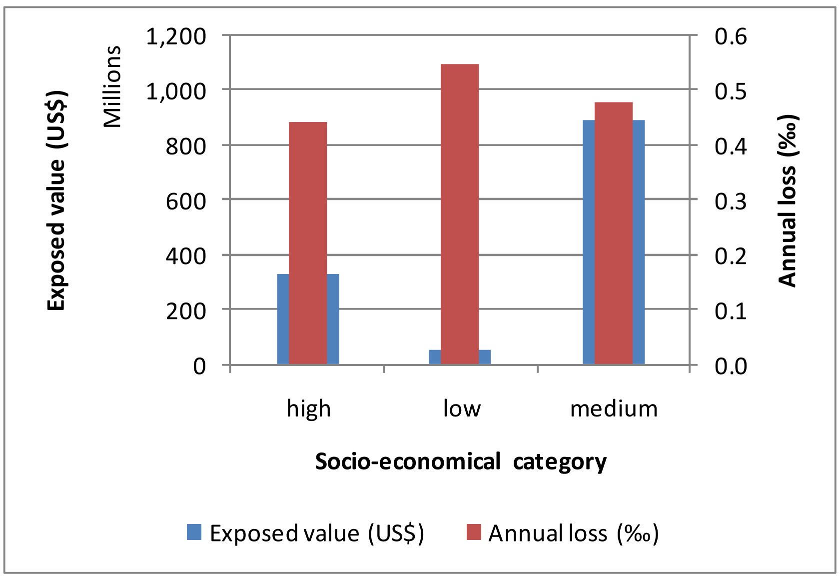

Figure 6-5
Exposed value and average annual loss by socio-economic category

6.1.2 *Results for hurricane (hurricane wind and hurricane storm-surge)*

Table 6-4 and Figure 6-6 summarize the results of risk for hurricane wind and storm-surges.

Table 6-4
General results

Results		
Exposed value	US$ $x10^6$	1,280.48
Average annual loss	US$ $x10^6$	36.76
	‰	28.71‰
PML		
Return period	**Loss**	
Years	**US$ $x10^6$**	**%**
50	273.48	21.36%
100	341.49	26.67%
250	412.25	32.20%
500	460.95	36.00%
1,000	502.85	39.27%
1,500	544.75	42.54%

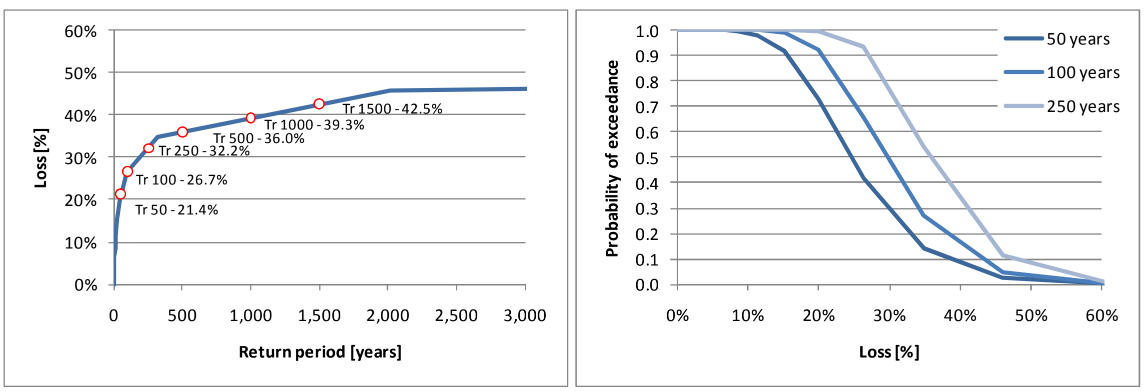

Figure 6-6
Analysis results for wind and storm-surge
(Left: Probable maximum loss curve, Right: Exceedance loss probability for different exposition timeframes)

Table 6-5 and the Figures of 6-7 to 6-10 present the risk results for hurricane winds and storm-surges by structural system, number of stories, type of use, and socio-economic category.

Table 6-5
Results by structural system (exposed values and average annual loss)

System	Exposed value		Average annual loss	
	[US$]	[%]	[US$]	[‰]
MC-RCSB-1	9,217,728	0.72%	173,104	18.78‰
MC-RLSB-2	36,676,333	2.86%	635,113	17.32‰
MC-SLSB-1	50,029,935	3.91%	1,732,208	34.62‰
MR-RLSB-2	365,690,353	28.56%	6,621,536	18.11‰
MR-SLSB-1	104,349,118	8.15%	3,606,099	34.56‰
MS-RLSB-2	117,090,105	9.14%	1,974,095	16.86‰
MS-SLSB-1	184,543,890	14.41%	6,071,597	32.90‰
PAA-SLSB-B	14,634,419	1.14%	706,060	48.25‰
PCR-RCSB-2	10,421,682	0.81%	74,439	7.14‰
PCR-RLSB-2	64,264,916	5.02%	1,065,759	16.58‰
W-FLFB-2	133,547,157	10.43%	3,704,971	27.74‰
W-SLFB-1	190,017,572	14.84%	10,393,060	54.70‰
TOTAL	**1,280,483,209**	**100%**	**36,758,042**	**28.71‰**

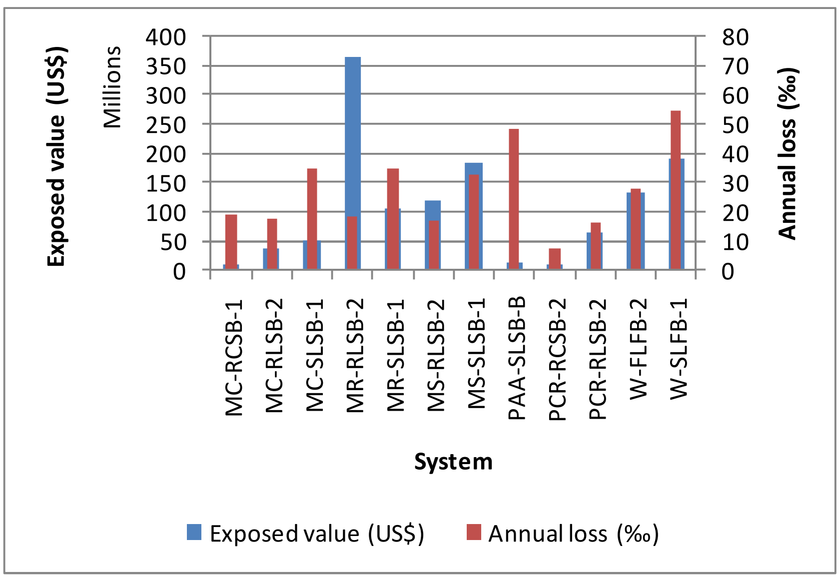

Figure 6-7
Exposed value and average annual loss by structural system

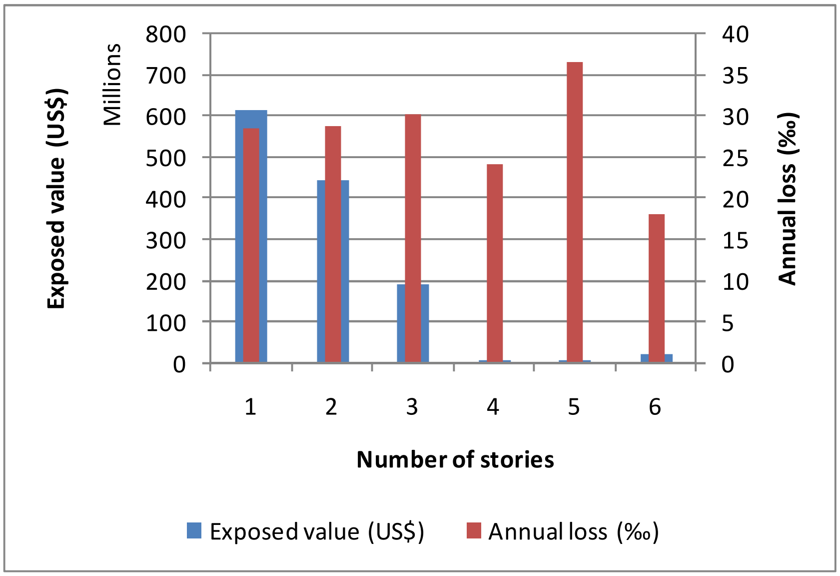

Figure 6-8
Exposed value and average annual loss by number of stories

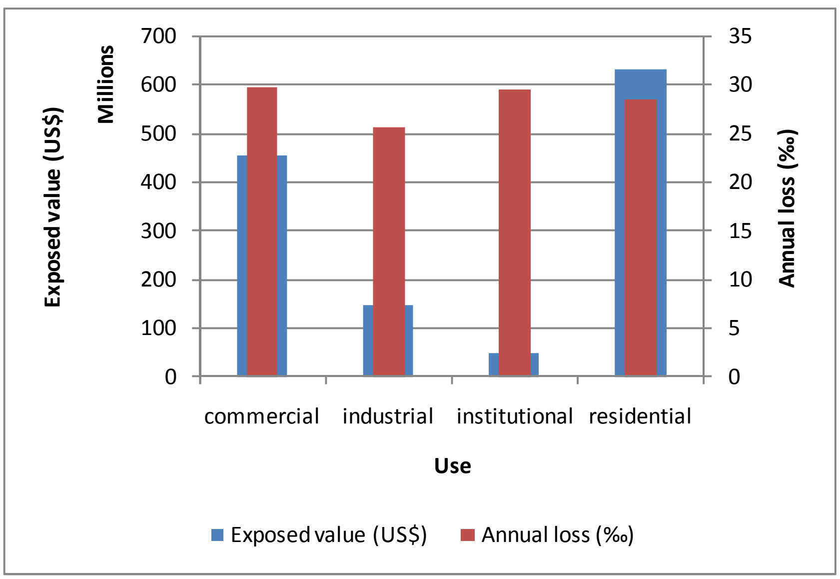

Figure 6-9
Exposed value and average annual loss by use

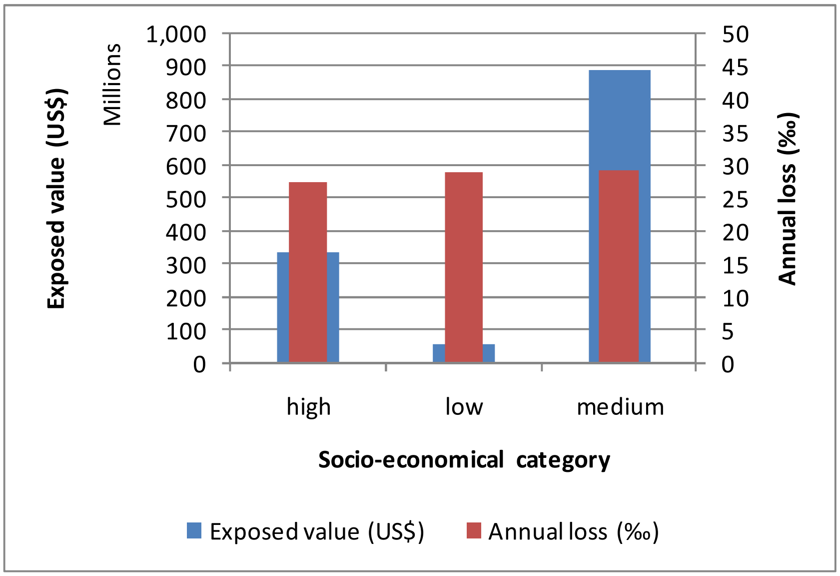

Figure 6-10
Exposed value and average annual loss by socio-economical category

6.1.3 *Grouped results*

Table 6-6 and Figure 6-11 present the results for all temporalities analyzed together. The result corresponds to the sum of the loss exceedance rates of the exceedance curve obtained for each timeframe in the calculation.

Table 6-6
General results

Results		
Exposed value	US$ x10^6	1,280.48
Average annual loss	US$ x10^6	37.36
	‰	29.18‰
PML		
Return period	**Loss**	
years	**US$ x10^6**	**%**
250	412.59	32.22%
500	461.10	36.01%
1,000	503.18	39.30%
1,500	545.25	42.58%

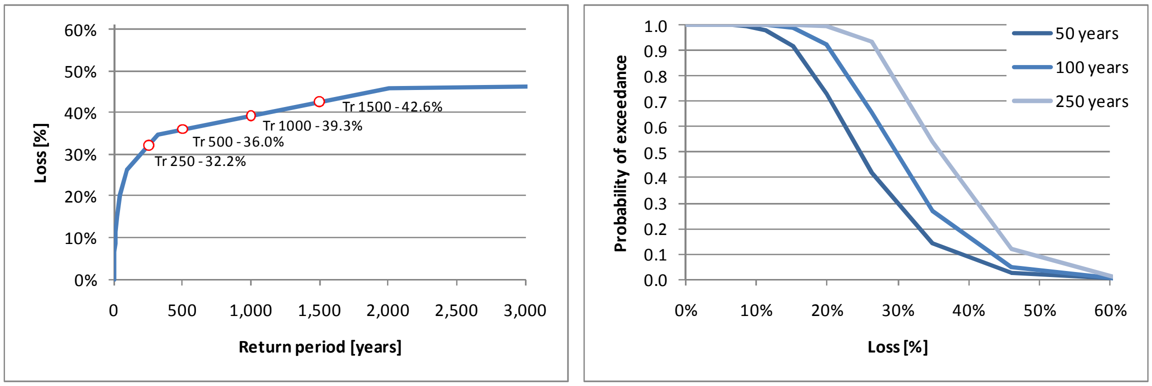

Figure 6-11
Analysis results
(Left: Probable maximum loss curve, Right: Exceedance loss probability for different exposition timeframes)

6.1.4 *Risk maps*

This information is better visualized in risk maps, in which there is a presentation of the geographical distribution for the average annual loss for each element exposed. The results are presented in terms of cost of replacement value, and in physical value. The risk maps for Belize City are the following:

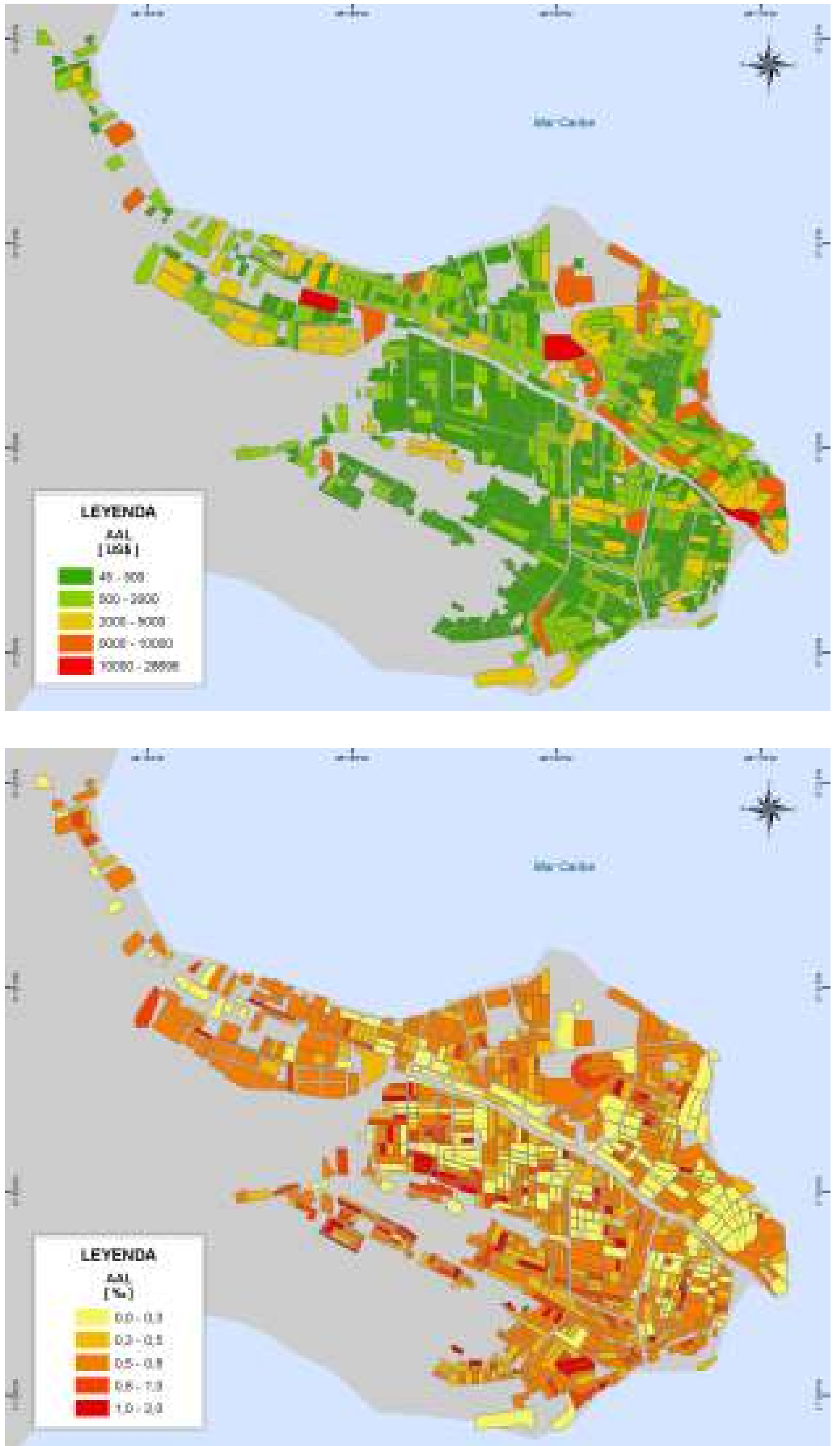

Figure 6-12
Average annual loss by blocks for earthquake
(Top: value, US$; Bottom: Thousand of exposed value)

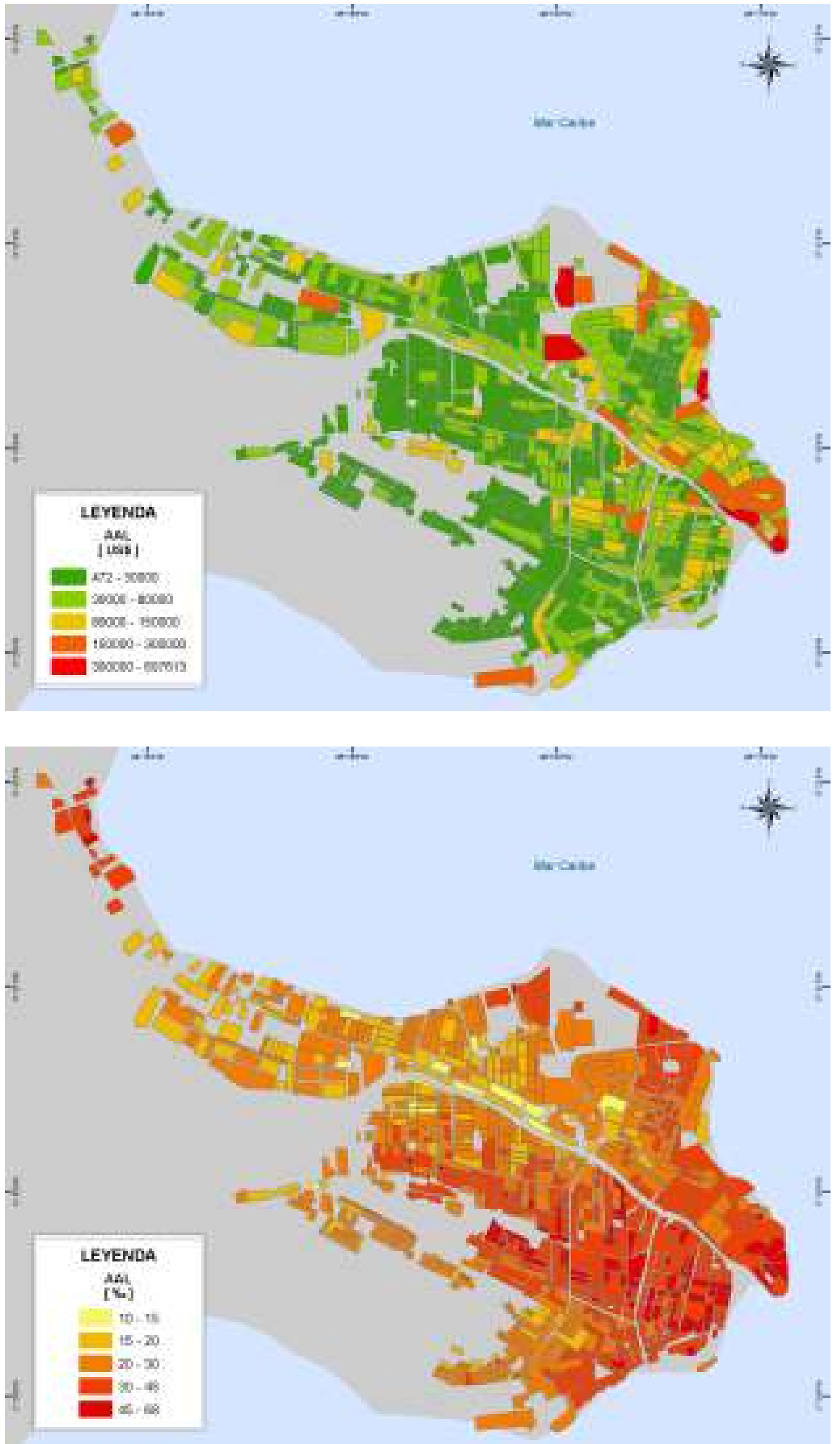

Figure 6-13
Average annual loss by blocks for hurricane (wind and storm-surge)
(Top: value, US$; Bottom: Thousand of exposed value)

7 Conclusions and recommendations

The analysis of seismic and hurricane risk analysis (hurricane winds and storm-surges) presented for Belize City should be seen as an initial platform which will allow the risk to the city to be quantified and qualified at any time (according to the best information available), and this should serve as a basis so that, with the gradual complementation of information, it can soon become an integral evaluation of risk for decision-taking purposes.

The hazard that controls the risk of the city is the hurricane. For this hazard, the maximum probable loss for a return period of 500 years is equal to US$ 461 million, or 19.7% of Belize´s GDP and 36% of total exposed value in the city. The values reported allow quantification of risk in the city, which is the basis for the definition of clear strategies for risk management, and which involve, amongst other things, a strategy for financial protection to cover future losses.

The pure premium for the overall risk calculated for the city is high (29 per mill), due mainly to contribution of probable losses due to hurricane (premium of 28 per mill), this is due to the conditions of hazard, given a geographical location which is sensitive to the passage of hurricanes generated in the Caribbean basin.

With regard to seismic hazard, and in terms of annual loss, it can be concluded that the associated risk is comparatively lower compared to the hurricane risk. However, it is important to include these risks in policies to reduce or transfer risk, so that the problem can be approached in a comprehensive manner.

We now give explicit limitations to the information used in the analysis. They should be used as a basis for future work and studies of Belize city, in order to improve the quality and reliability of these preliminary results.

(a) Information on seismic hazard: This can be improved by considering local faults, and effects at given places, which are not included in this analysis due to lack of information. It is also very important to keep the catalogue of past events up to date with the greatest possible amount of information related to effects, damage and impact.

(b) The information about hurricane winds and flooding by storm-surges: these can be considered to be of good quality and complete for the purposes of this analysis. The cost and time required to improve this type of information is very high, and requires in particular the availability of more and better information. It is of greatest importance to maintain the catalogue of events up to date, and with better information, in order to be able to calibrate and adjust the models.

(c) Exposure information: The cadastral database should be used. The model used in this analysis is only for illustrative purposes, and indicative of global values to be expected. For the purposes of results and decision-making, there should be a property register base with official indicators of occupation and cost. Alternatively, there should be tasks to make a survey and obtain information on the basis of intensive field visits.

(d) The functions of vulnerability should be reviewed and evaluated in a medium-term plan, by engaging universities and research centers. This would be based on analytical modeling and experiment in terms of the types of construction in the city and observations on the typical comportment of types of construction in the face of specific events.

(e) The results of the risk analysis and interpretation for decision-making should be produced jointly with entities and specialists responsible for each of the applications to be derived from these results.

The results presented above depend directly on the quality and type of information supplied for the model. The more detailed and reliable the information, the smaller the uncertainty associated with results, and therefore the process of decision-making would be able to take place with greater confidence.

In particular, we specially emphasize the following information:

- Inventory of buildings exposed, including principal characteristics
- Valuation of assets, contents and possible consequential loss
- Identification of dominant structural types and distribution in the city
- Categorization of types of content, classification and variation
- Classification of structural and human vulnerability to different sources of hazard
- Inventory, valuation and classification of all complementary infrastructure exposed including roads, bridges, infrastructure and public services, major industrial installations, power plants, airports, and in general all relevant infrastructure exposed.

A more detailed information especially for exposed infrastructure, can be obtained from the CAPRA system, to undertake the following complementary evaluations:

(a) Identification of critical infrastructure for the city in terms of hazard, exposed value, human occupation and other criteria. The purpose of this would be to give priority to public investment in recovering or modernizing key elements for development.

(b) Risk assessment by sectors, including residential, industrial, commercial, health, education, public and other.

(c) Requirements to reinforce public assets, especially essential buildings and buildings which provide services to the public.

(d) Estimates of the risk to private assets in low, medium and high strata, for the purposes of financial protection, and public awareness of the risk.

(e) Analysis of vulnerability and requirement for reinforcements to mitigate impact on public services which may be affected by the phenomena analyzed.

(f) Special requirements for land-use plans, definition of high-risk zones, restrictions which are to areas which flood or are prone to landslides, relocation of housing or essential buildings, and others.

Finally, a more detailed analysis of the information presented in this document can be used as a basis for a series of complementary analyses for the purposes of plans and preparations for an emergency in the city, including the following:

(a) Health sector: requirements for medical attention for the injured, emergency attention centres, location, requirements for public services, medical personnel, ambulances, organization of treatment of fatalities.
(b) Security. Security requirements at the moments and days after the event, with regard to the organization of the police and the army. Possibility of social problems due to lack of food or services.
(c) Attention to emergencies. The planning of various actions subsequent to the disaster, such as reconnaissance, identification and closure of buildings affected, demolitions, notices to the public, rescue teams, management of donations, food supplies, temporary housing, management of waste, the availability of machinery, etc.
(d) Requirements of temporary housing, camps, food, supplies, those requiring emergency medical attention, problems of social interest housing.
(e) Problems of unemployment or lack of places of work, by zones; immediate requirements, effects on production, long-term effects, measures for mitigation of impact.
(f) Contingency plans for the various sectors for public services and social services, including water supplies, power, gas, public transport, power electricity generation, telecommunications, etc.
(g) Expected economic loss, effects in the medium and long term on public finances, need for a risk-transfer mechanism, insurance plans and future projections.

The risk analysis with the tools indicated therefore becomes a fundamental element in integral risk management, and a key factor in economic and social development. The process requires the active participation of public agencies, universities, the private sector, and the community in general in relation to these matters.

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