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Organization of
American States

STATUS OF HAZARD MAPS VULNERABILITY ASSESSMENTS AND DIGITAL MAPS

MARTINIQUE REPORT

**THE CARIBBEAN DISASTER EMERGENCY
RESPONSE AGENCY (CDERA)**

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Table of Contents

	Page
Preface	1
1.0 Introduction	2
1.1 Physical and socio-economic background	2
1.2 Major disaster issues confronting the country	3
2.0 Hazard mapping initiatives	4
2.1 Methods of preparation and distribution	6
2.1.1 Landslide hazard map	6
2.1.2 Flood hazard map	7
2.1.3 Storm hazard map	7
2.1.4 Seismic hazard map	8
2.1.5 Volcanic hazard map	8
2.2 Users and uses	9
2.3 Current condition and limitations	9
2.4 Critical success factors	9
2.4 Respondents	9
3.0 Vulnerability Assessment Studies	9
3.1 Methods of preparation and distribution	10
3.2 Users and uses	11
3.3 Current condition and limitations	11
3.4 Critical success factors	11
3.5 Respondents	11
4.0 Digital Maps	11
5.0 Conclusion and Remarks	12
Appendix 1	13

Preface

From 2002 – 2005, the Caribbean Disaster Emergency Response Agency (CDERA) is implementing two major regional initiatives which are designed to reduce vulnerability to natural and technological hazards. These are the Japanese International Cooperation Agency (JICA) supported Caribbean Disaster Management (CADM) Project and the Canadian International Development Agency (CIDA) supported; Organization of American States executed Caribbean Hazard Mitigation Capacity Building Programme (CHAMP). The hazard mitigation planning component of the latter is being implemented in close collaboration with the Caribbean Development Bank's Disaster Mitigation Facility for the Caribbean. Hazard maps, vulnerability assessment studies, and digital maps are critical inputs to both initiatives.

This survey reviewed the status of these thematic activities in sixteen (16) CDERA Participating States, Haiti, Martinique, Suriname and Puerto Rico over the period August – October 2003. The objectives of the Survey were as follows:

1. To determine the status of hazard maps and vulnerability assessment studies and their use in the socio-economic planning and management of the Caribbean.
2. To determine critical success factors, gaps and best practices in the preparation and use of hazard maps and vulnerability assessment studies in the Caribbean.
3. To compile a database of hazard maps, vulnerability assessment reports, and digital maps available in the Caribbean.

Hazards considered under the survey included natural hazards such as floods, hurricanes, landslides, coastal disasters (surge, wave, and erosion), earthquakes, and volcanic eruptions as well as technological hazards. The types of vulnerability assessment considered were structural, economic, and human assessments.

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Survey of Hazard Maps, Vulnerability Assessments and Digital Maps in the Caribbean: MARTINIQUE

1.0 Introduction

1.1 Physical and socio-economic background

Martinique, an overseas department of the republic of France in the Eastern Caribbean, and a member of the European Union, is situated at approximately 14° 40 N, 61° 00 W between Dominica, to the north and Saint Lucia, to the south. It has an area of 424.7 square miles (1,100 km²), and is dominated by a northern and central highland area that descends gradually to the sea. The highest peak, Mount Pelée 4586 ft (1,397 m) is in the northern part of the island. In the central part of the island is the Lamentin Plain, made up of small rounded hills and enclosed valleys, that slopes down to the southern part of the island.

The island has a tropical marine type of climate, being affected by the prevailing Northeast Trade winds throughout the year. Annual temperatures range from 18°C to 33°C. The dry season is from January to May and the wet season from June to December. During the wet season the weather is affected by the passage of the Inter Tropical Convergence Zone, tropical storms and hurricanes.

The central part of the island is covered by tropical rainforest vegetation, montane forest and secondary rain forest that provide habitats for a wide range of flora and fauna.

The population of Martinique is about 425,966 (July 2003 est.) with 28.8% of its people under 15 years old and 66.9% making up the economically active population.

The country's economy is based mainly on agriculture from bananas and sugar cane, light manufacturing industry, tourism and services. Martinique's export of bananas, mainly to France, is smaller than its import of meat, vegetables, and grain, which results in a trade deficit. Tourism earns more foreign exchange than agriculture. To keep the island's economy alive, the French government supports Martinique through annual transfers of aid. Martinique's per capita GDP is an estimated US\$10,700 (2001 est.) with the sectors of agriculture, industry and services contributing 6%, 11% and 83% respectively to the GDP (CIA World Factbook 2003).

1.2 Major disaster issues confronting the country

The information for this section of the report is taken from the *Plan de Prevention des Risques* (PPR) document available in .pdf format on the CD, entitled, *Plan de Prevention des Risques Naturels Previsibles*.

Martinique is part of a volcanically active ridge formed along the subduction zone in the Eastern Caribbean. The active volcano in Martinique is Mount Pelée, having had four major eruptions in 1792, 1851-1852, 1902-1905, and 1929-1932. The eruption of Mt. Pelée on 08 May 1902 was one of the most violent and destructive that the Caribbean has seen. Pyroclastic flows and noxious gases completely destroyed the city of Saint Pierre, killing 30,000 inhabitants. The 1902 eruption became the type-example of Pelean eruptions and gave rise to modern volcanological studies of the behaviour of pyroclastic flows.

Martinique's central location on the Lesser Antillean island arc system gives rise to strong seismic activity. Several earthquakes of magnitude greater than or equal to 6 have been recorded in the vicinity of Guadeloupe and Martinique. Earthquakes that have caused great damage occurred in 1839, 1843, 1851, 1897, and 1946. The most destructive of these, with an intensity of VIII to IX, occurred in 1839, when most of Fort-de France, the capital city, was razed to the ground, killing some 300 people.

There are two types of seismic events that affect the built environment in Martinique. These are shallow events, occurring at depths less than 15 km in the earth's crust, and intermediate to deep events, associated with plate subduction. The shallow events have a magnitude less than 6, are of high frequency and short duration, and affect one-storey buildings. The intermediate to deep events have a magnitude of about 8, are of lower frequency and longer duration, and affect multi-storey buildings. On the average, Martinique experiences one to two felt tremors each year. The majority of the felt earthquakes are associated with intermediate to deep events.

The following factors make the built environment highly vulnerable to earthquakes:

- A high population density in certain parts of the island, particularly in major towns.
- Occupation of areas prone to the effects of earthquakes, such as, steep and unstable slopes, and areas prone to liquefaction.
- Building practices by the individual that go against construction for seismic events.
- Old buildings that have been weathered by the passage of time.

Martinique has a history of being affected by tropical storms and hurricanes. As early as 1780, a devastating hurricane claimed the lives of about 9000 people. Over the last 40 years, Martinique experienced 17 major hurricanes, five of which were Class V hurricanes in the Saffir-Simpson scale. Overall, the island experiences one tropical storm every 3 to 6 years, and one hurricane every 12.5 years.

Storm surges, floods and landslides often accompany these events. Coastal erosion is a continuous threat to property and communication networks, along with anticipated sea level rise that make the coastal zone particularly vulnerable to beach erosion, loss of habitat for marine life, loss of fresh water aquifers, and damage to coastal infrastructure.

Volcanoes, earthquakes, hurricanes, storm surges, floods, landslides, mudslides, rock falls and coastal erosion are potential disaster issues facing the country.

2.0 Hazard Mapping Initiatives

As a result of a law of 1982, the Préfecture de la Région Martinique, in an effort to regulate the use of land subjected to natural hazards, undertook the development of a study entitled *Plans d'Exposition aux Risques naturels prévisibles* (PER), whose aim was to prevent and curtail damage due to natural hazards by delimiting vulnerable areas and by prescribing measures of prevention. The law of 1995 replaced PER by the study, the *Plan de Prévention des Risques naturels* (PPR), in an attempt to clarify and simplify the method of risk prevention while making it more effective.

The PPR was prepared for each of the 34 communes that make up the territory of Martinique. A committee, formed in June 2001, comprised mainly the Prefecture of Martinique, the Regional Council, the General Council and the Mayors' Association of Martinique. Members of working groups included professionals from the construction industry, building societies, specialist associations such as the *Association Pour La Prévention des Risques Majeurs à la Martinique* (APRM), and officials from various state agencies such the *Direction Départementale de l'équipement* (DDE). The committee agreed that the main concerns of the study should:

- Take into account the constraints specific to Martinique (its insularity, department status, population density, multiple hazards)
- Make recommendations rather than prohibitions.
- Identify clearly the zones at stake in order to refine the rules and regulations to be formulated.

In the development of the PPR, consultation was held in each of the 34 communes that make up Martinique, with members of the community, representatives of the municipal council, the DDE and research units to reach agreement on the Plan. The consultation proceeded in a series of stages:

- Defining the stakes in areas of varying levels of hazard vulnerability
- Presenting the hazard study results
- Presenting the regulatory map showing the hazard areas and the stake zones to the municipal council at an official consultation.

The PPR was aimed at assuring people's safety and reducing the vulnerability of inhabitants, their property and activities in hazard-prone areas. In this regard, the PPR indicated the nature of the analysis of hazards in a given area to arrive at a demarcation of hazard zones. Depending in the hazard zones defined, the PPR granted permission to develop in those areas not prone to hazards or gave advice on urban issues such as construction and management in those vulnerable areas. Risk preparedness plans of the PPR are state-approved and enforced. The public is expected to adhere to the approved PPR by going through the local urban plans that must respect the recommendations of the PPR. Non-compliance with the caveats and prescriptions of the PPR makes one liable to penalties as stated in article L.480 of the *Code de l'Urbanisme*. The PPR does not define the nature of construction in a given area. It merely indicates the vulnerable zones and the related hazards and the constraints affecting these zones if they were to be built upon. The cost of preparing the PPR was €1 million.

Table 1 shows the hazard maps prepared for Martinique.

Table 1: Hazard maps prepared for Martinique

Type	Purpose	Cover age	Scale	Date produced	Primary sources	Author
Landslides	To map areas of landslide occurrence	Entire island	Unknown	Unknown	Bureau de Recherche Géologique et Minières (BRGM) http://www.brgm.fr/risques/antilles/	BRGM
Floods	To map areas prone to flooding					
Volcanic eruption	To map areas likely to be affected by volcanic hazards					

Storm surges and coastal erosion	To map areas affected by storm surges and coastal erosion					
Earthquakes	To map areas of landslide occurrence					
Landslides, Mudslides, Rock falls	To show areas prone to mass movements	Entire island	1:10 000	Sept 2002	Préfecture de la Région Martinique; Direction Départementale de l'équipement (DDE)	Bureau Central d'Etudes Outre Mer (BCEOM)
Floods	To show areas prone to flooding					
Earthquakes	To show areas prone to earthquakes					
Volcanic eruption	To show areas prone to volcanic eruption					
Coastal storm surges and erosion	To show areas prone to storm surges, erosion					

2.1 Methods of preparation and distribution

2.1.1 Landslide hazard map

The methodology used for preparation of landslide, mudslides and rock fall hazard maps for the PPR were based on the following studies:

- *Guide méthodologique des Plans des Préventions des Risques*
- *Guide technique pour de la caractérisation et la cartographie de l'aléa dû aux mouvements de terrain*
- *PPR, Risques Sismiques Guide méthodologique*
- *Cahier des Clauses Techniques Particulières du marché d'étude établi par la DDE 972.*

Two approaches were used, namely, a static approach and a pseudo-static approach that used an application program called **TALREN 97**. Four hazard levels were defined for landslides and rock falls. They are:

1. Weak hazard
2. Moderate hazard
3. Strong hazard
4. Major hazard

Please see Section 5.3.1 on page 110 of the '*notes de presentation.pdf*' folder for the methodology used in the creation of landslide hazard maps.

The maps are distributed in *.pdf* format and hard copies.

2.1.2 Flood hazard map

There were two methods to the study of floods, one that used a more precise method of mathematical modelling in areas near to the centres of towns, and the other a hydro-geomorphological approach for other areas. Four flood hazard levels were identified:

1. Major hazard (coloured violet on the hazard map)
2. High hazard (coloured red on the hazard map)
3. Moderate hazard (coloured yellow on the hazard map)
4. Low hazard (coloured white on the hazard map)

The mathematical model used in the flood analysis was the multidirectional cell-based flood hazard model, STREAM, used to study flood risk, and the effects of flood protection works and the impact of new developments in flood plains. It was developed by Bureau Central d'Etudes Outre Mer (BCEOM), a French Engineering Consultancy specializing in Official Development Assistance.

Please see section 5.1.5 on page 81 of the '*notes de presentation.pdf*' file for the methodology used in the creation of flood hazard maps.

The maps are distributed in *.pdf* format and hard copies.

2.1.3 Storm surge hazard map

Coastal flooding and erosion were modeled by METEO FRANCE, in relation to tropical storms using Geographical Information Systems (GIS) to arrive at three levels of coastal hazards:

1. Major hazard
2. High hazard
3. Moderate hazard

Please see section 5.2.2 on page 93 of the '*notes de presentation.pdf*' file for the methodology used in the creation of storm surge hazard maps.

The maps are distributed in *.pdf* format and hard copies.

2.1.4 Seismic hazard map

The seismic hazards dealt with are liquefaction and faulting. The Seismic Hazard map shows hazards at four levels:

1. Major hazard
2. Strong hazard
3. Moderate hazard
4. Low or no hazard.

Please see section 5.4 on page 130 of the '*notes de presentation.pdf*' file for the methodology used in the creation of seismic hazard maps at the local level (1:10000).

The maps are distributed in *.pdf* format and hard copies.

2.1.5 Volcanic hazard map

The volcanic hazard maps, prepared for either a phreatic or magmatic eruption of Mt. Pelée, were based on the probable occurrence of seven phenomena associated with volcanic eruptions. These are tephra (ballistic projectiles), lava flows, pyroclastic flows, lahars, earth movements (debris avalanches), volcanic gas emissions, and tsunamis. The hazard zones defined for each phenomenon were based on field reconnaissance, analysis of the geology and topography, reconstruction of past eruptions, and modelling.

A hierarchy of the different volcanic hazards was arrived at based on two criteria:

- Intensity of the hazard in relation to its capacity to do damage.
- Probability of occurrence of a given intensity of the hazard based on geological and geochronological indicators; and their frequency arrived at using a statistical approach, modelling of an eruption and the capacity of buildings to withstand resulting damage.

Five intensity scales ranging from "Very weak to nil", "Weak", "Moderate", "High" and "Very high", and five probability of occurrences ranging from "Very low to nil", "Low", "Moderate", "High" and "Continuous and nearly continuous" were arrived at. These two scales were combined to give a hierarchy of the different classes of volcanic hazards:

Tephra –	4 classes:	Major, High, Moderate, Low
Pyroclastic flows –	3 classes:	High, Moderate, Low

Lava intrusion –	1 class:	Major
Gas emissions –	2 classes:	Major, Moderate
Lahars –	3 classes:	Major, High, Moderate
Earth movements –	2 classes:	Major, Moderate
Tsunami -	3 classes:	Major, High, Moderate

Overlaying these seven hazards with their corresponding hazard levels produced an integrated volcanic hazard map at a scale of 1:50,000.

The maps from the PPR are distributed in hard copy form and in *.pdf* format.

Please see section 5.5.1 on page 1351 of the '*notes de presentation.pdf*' file for the methodology used in the creation of hazard maps for each volcanic phenomenon.

2.2 Users and uses

The hazard maps are used by government agencies and local communities for hazard prevention and information, and by members of the general public for education and information.

2.3 Current condition and limitations

The PPR document is yet to be made law. In the event of this occurrence, it is envisaged that citizens of all communes would use the maps along with the recommendations for erecting or modifying construction to suit the type and level of hazards in each zone.

2.4 Critical success factors

Success factors were that the PPR was developed through public consultation, was funded by the French state, along with regional and territorial funds, and involved professionals from France and within Martinique for undertaking the hazard studies.

2.5 Respondent

Mr. Julio Nacitas	Physical Planner, PPR (Plan de Prévision des Risques) DDE (Direction Départementale de l'équipement)	Tel: (596) 596 595 733 Email: Julio.Nacitas@equipement.gouv.fr
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Please see Appendix 1 for a list of persons interviewed.

3.0 Vulnerability Assessment Studies

Maps of ‘stakes’, i.e. those elements of the built and human environment that would be affected by the occurrence of particular levels of hazards were drawn for each commune in the PPR. Three zones of different degrees of stakes were defined through public consultation:

- Very high stakes – these are zones making up the historic centre, commercial areas
- High stakes – zones of actual and potential urban activity
- Moderate stakes – agricultural areas, rural areas and natural areas.

Maps of these zones of stakes were overlaid with those of the hazard zones to produce maps of regulation zones for each commune. Five regulatory zones were defined with each zone coloured-coded for easy identification and correlation among maps:

- White zone
- Yellow zone
- Orange zone
- Red zone
- Violet zone

Table 2 gives the particulars of vulnerability assessments done for Martinique

Table 2: Vulnerability assessments

<i>Type</i>	<i>Purpose</i>	<i>Coverage</i>	<i>Date produced</i>	<i>Primary source</i>	<i>Authors</i>
Structural and human vulnerability	To map the different degrees of vulnerability	Island wide	Sept 2003	Préfecture de la Région Martinique	Préfecture de la Région Martinique
Earthquake	To evaluate consequences of an earthquake on public facilities and dwelling houses	Fort de France		BRGM	BRGM

3.1 Methods of preparation and distribution

For the PPR, details of the derivation and meanings of these zones are given in the document “Presentation du Règlement ”.

The maps are distributed in hard copy form and in *.pdf* format.

The Prefecture of Martinique commissioned the earthquake vulnerability study for Fort de France. No date was given for the start and completion of this study. No information was given on the categories of the vulnerability assessment.

3.2 Users and uses

State agencies, community groups and members of the public use these maps for development planning and management.

Various government departments and communities for general information are using the earthquake vulnerability for Fort de France study. There are plans to prepare other vulnerability assessments of the island.

3.3 Current condition and limitations

The PPR, before being made a law, is awaiting comments from the public for final approval.

3.4 Critical success factors

Success factors were that the PPR was developed through public consultation at the level of the community, was funded by the French government, along with regional and territorial funds, and involved professionals from France and within Martinique for undertaking the hazard studies.

3.5 Respondent

Mr. Julio Nacitas	Physical Planner, PPR (Plan de Prévision des Risques) DDE (Direction Départemental de l'équipement)	Tel: (596) 596 595 733 Email: Julio.Nacitas@equipement.gouv.fr
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4.0 Digital Maps

Table 3 shows details of digital data themes available in Martinique.

Table 3 – Digital Maps Available in Martinique

<i>Data Theme</i>	<i>Input scale</i>	<i>Year produced</i>	<i>Coverage</i>	<i>Format</i>	<i>Primary source</i>
Landslides	1:10,000	2003	Community	.shp	BCEOM; Direction Départementale de l'équipement (DDE)
Coastal erosion					
Storm surges					
Floods					
Earthquakes					
Liquefaction zones					
Volcanic eruption	1:50,000				
Contours	1:10,000	2003	Community	.shp	BCEOM; Direction Départementale de l'équipement (DDE)
Roads					
Rivers					
Buildings					
Settlement					
Social facilities					
Economic facilities					
Coastline					

5.0 Conclusions and Remarks

Martinique faces many hazards that impact on the lives and economy of the island. In an attempt to reduce the devastating effects of these hazards, the Prefecture of Martinique devised the *Plan de Prévention des Risques naturels* (PPR), a very comprehensive document that includes hazard maps, 'stakes' maps, regulatory maps and accompanying detailed explanatory documents for use by all administrative agencies, communities and members of the public. The PPR, recently completed in June 2003, aims to be advisory rather than prohibitive. The PPR will become law when the authorities and the public agree to the final version of the document by a process of public consultation, and will be executed through the Mayors' office for each commune. Failure to abide by the regulations stated will result in penalties.

The PPR contains hazard maps for hazards related to mass movements such as landslides, mudslides, rock falls; earthquakes and liquefaction; coastal hazards, such as floods, storm surges associated with tropical storms and hurricanes,

erosion and tsunamis; and volcanic eruptions related to the island's active volcano, Mt Pelée. The maps were produced at a scale of 1:10 000 at a cost of € 1 million. It is hoped that implementation of the PPR will reduce the socio-economic costs incurred due to frequently occurring hazards in Martinique.

Appendix 1

Table 1: Persons interviewed on 02 September 2003, Martinique

Contact	Position	Agency	Tel. No./Fax. No	Email
Julio Nacitas		PPR (Plan de Prévision des Risques) DDE (Direction Départemental de l'équipement)	Tel: (596) 596 595 733	Julio.Nacitas@equipement.gouv.fr
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