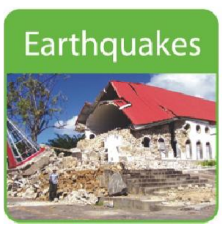
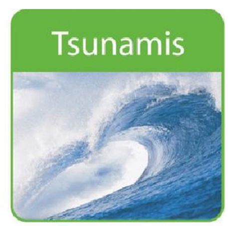
THE UNIVERSITY OF THE WEST INDIES
SEISMIC RESEARCH CENTRE

Final Report

Development of Ergo Modules for Building Vulnerability and Population Exposure to Earthquake





Prepared for
Enhancing Knowledge and Application of Comprehensive Disaster Management Initiative,
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Table of Contents

Executive Summary 3

Introduction 3

Building Vulnerability Estimation Ergo Module 5

Data Warehouse 5

CaribEViz 6

Healthcare and Shelter Facility Capacity Ergo Module 7

Seismic Risk: Building Damage, Casualties and Population Dislocation 7

Limitations 13

Conclusion 13

Appendix I: PROJECT TEAM 14

Appendix II: DETERMINING BUILDING VULNERABILITY IN THE CARIBBEAN 15

- Introduction 16
  - Seismic Vulnerability 16
  - Overview of methodology 18
- Data Requirements and Collection 19
- Analysis 22
- Determining Structure Type, Occupancy Type and Rate 26
- Limitations 40
- References 42

Appendix III: HEALTHCARE AND SHELTER FACILITY CAPACITY METHODOLOGY 44

Appendix IV: BUILDING VULNERABILITY ESTIMATION MODULE DOCUMENTATION 46

- Requisite Datasets 47
  - Building Footprints 47
  - CSO Population and Enumeration Districts 49
  - OpenStreetMap Road Network 49
  - Building Classification Parameters 49

Running the Analysis 50
Editing Building Vulnerability Data 53
Appendix V: DATA WAREHOUSE WEB-APP USER MANUAL 58
Web Application Configuration Files 59
Admin User 60
Manual Installation 60
Data Warehouse Web Application 61

Executive Summary

This report details the completed work on the development of software and dataset products for the Enhancing Knowledge & Application of Comprehensive Disaster Management (EKACDM) Initiative. The University of the West Indies, through the Disaster Risk Reduction Centre (UWI-DRRC), with partial funding by the Department of Foreign Affairs Trade and Development (DFATD) Canada is currently implementing the EKACDM Initiative. The products of this project are aligned with the EKACDM Initiative's output for 'Improved gender-sensitive methodologies for Comprehensive Disaster Management (CDM)'. The primary outputs include a building vulnerability estimating Ergo module; a post- earthquake healthcare and shelter facility capacity Ergo module; and a building vulnerability data warehouse application. The project's analyses were carried out on three regions of interest: the Kingston Metropolitan Area, Jamaica; Portmore, Jamaica; and Barbados. For these three regions, populations will be disaggregated with respect to sex and age and their vulnerability to seismic hazard presented.

Introduction

The UWI Seismic Research Centre (**SRC**) is the agency mandated with monitoring and providing advice on the earthquake and volcanic phenomena of the English speaking Eastern Caribbean. The SRC along with its sister agency, The University of the West Indies, Earthquake Unit of Jamaica, and under the auspices of The UWI Disaster Risk Reduction Centre executed the Caribbean Risk Atlas (**CARISKA**) framework. The SRC completed the project in 2012 to define the seismic hazard and risk exposure of the population of the Kingston Metropolitan Area (**KMA**)[1]. Seismic risk is a convolution of seismic hazard and the vulnerability it impacts[2]. For the seismic risk component of CARISKA, the seismic hazard, in the form of a Probabilistic Seismic Hazard Assessment along with site amplification effects, was quantified in great detail. The seismic vulnerability is derived by determining, for each building, the occupancy, occupancy type and known structure class with associated fragility curves. These fragility curves describe the building's response to lateral acceleration. Regrettably, it was realised that classifying the KMA building stock with regards to structural type and occupancy was prohibitively expensive.

[1] Salazar, W., Higgins M., Yueng, C., Juman, A., St. Bernard, J., *Final Report: Development of Caribbean Risk Atlas for Earthquake Hazards*, Seismic Research Centre, The University of the West Indies, 2012.

[2] Crowley, Helen, and Julian J. Bommer. "Modelling seismic hazard in earthquake loss models with spatially distributed exposure." *Bulletin of Earthquake Engineering* 4, no. 3 (2006): 249-273.

To accomplish the project's objectives, surveys of building typologies were first carried out in the KMA Enumeration Districts for which good quality socio-economic data was readily available. A statistical method was then used to extrapolate the data gathered to the rest of the KMA. The method yielded a preliminary classification of the KMA vulnerability but the dataset has been noted as incomplete and demanding further work.

One of the project's goals is to address the shortcomings of the CARISKA study. The multi-hazard software platform, Ergo[3] (formerly the Earthquake Loss Estimation Software, MAEViz) has been modified to accept the requisite datasets, implement a building vulnerability estimation methodology, and to collect building vulnerability information from potential users. This modification will allow users to input readily available socioeconomic data and produce a dataset with classified buildings.

Another deficiency of the CARISKA study was a failure to develop a methodology that determines how a region can cope with its injured or dislocated population after an earthquake. To rectify this, two analyses were added to the Ergo platform. These analyses determine the capacity and utilization of healthcare and shelter facilities after an earthquake.

The products, including intermediate products, developed under this project are as follows:

I. Building Vulnerability Estimation and Data Capturing Ergo Module.
II. Data Warehouse - data management system for data imported\exported by users.
III. Healthcare, Emergency Shelter facilities analysis Ergo Module.
IV. Building Stock Vulnerability for KMA, Portmore and Barbados.
V. Building stock occupancy rate with respect to age and sex.
VI. Population seismic hazard exposure with respect to age and sex for KMA, Portmore and Barbados.
VII. Methodology for determining and building and population vulnerability using existing socioeconomic data.
VIII. Documentation of Ergo Modules.

[3] Ergo, formerly the Mid Atlantic Earthquake Visualizer (MAEviz): http://mharp.ncsa.illinois.edu

Building Vulnerability Estimation Ergo Module

This project uses the HAZUS MR3[4] taxonomy when describing building vulnerability. HAZUS is multi-hazard software developed by the United States, Federal Emergency Management Agency. This project utilizes the HAZUS MR3 taxonomy on the advice of professional structural engineers who have expert knowledge of the historical building practices of the regions of interest. This was an outcome of the CARISKA[5] project.

Using data from the CARISKA project and newly acquired data from this project, an analysis was carried out on 2968 buildings and their associated socioeconomic information. From this analysis the relationships between building characteristics and socioeconomic data was derived. These relationships were then used as a testing function for a Monte Carlo (**MC**) simulation. When applied to the building stock of a region, these relationships, buttressed with MC, ultimately produce a frequency distribution of the structure types for each building. Once the structure type with the highest probability is assigned as the building's structure type, using socioeconomic data it was possible to determine the occupancy type and rates.

This analysis has now been implemented in Ergo where the user has the option to change parameters for the Building Vulnerability Estimation. The only requisite input Graphical Information System (**GIS**) datasets are

- Building Footprints
- OpenStreetMap Road Network
- CSO population data at the Enumeration District level.
- Unimproved Land Values

Details of the methodology employed in the software are further expounded in Appendix II.

Data Warehouse

The Data Warehouse is a Web Application that serves as the focal point for users adding building vulnerability information or retrieving data sets required for earthquake related analyses on Ergo. The Data Warehouse also offers the ability to bulk-add building datasets, perform quality control of user submissions and view statistics of the building datasets. Using

[4] *HAZUS MH MR3 Earthquake Model Technical Manual* , FEMA, 2003, https://www.fema.gov/media-library/assets/documents/12110

the user submissions as seeds for Building Vulnerability Estimation analysis, the Data Warehouse will create a new building dataset on a weekly basis.

CaribEViz

Further modification to Ergo was carried out to provide a facility whereby a user can commit data to an Internet accessible Data Warehouse. The Ergo platform was not designed to be GIS editing software. For this reason, modifications were made to Ergo to allow users to edit building vulnerability datasets. With the inclusion of satellite imagery to help in identifying buildings, it is hoped that this facility promotes the ethos of user contributed data in creating a comprehensive dataset for the region. The aggregated data at the Data Warehouse is made available through the Ergo software or any Web Browser.

To engender a regional community of users who provide data and perform earthquake loss calculations, the Ergo software has been rebranded to CaribEViz - Caribbean Earthquake Loss Visualizer.

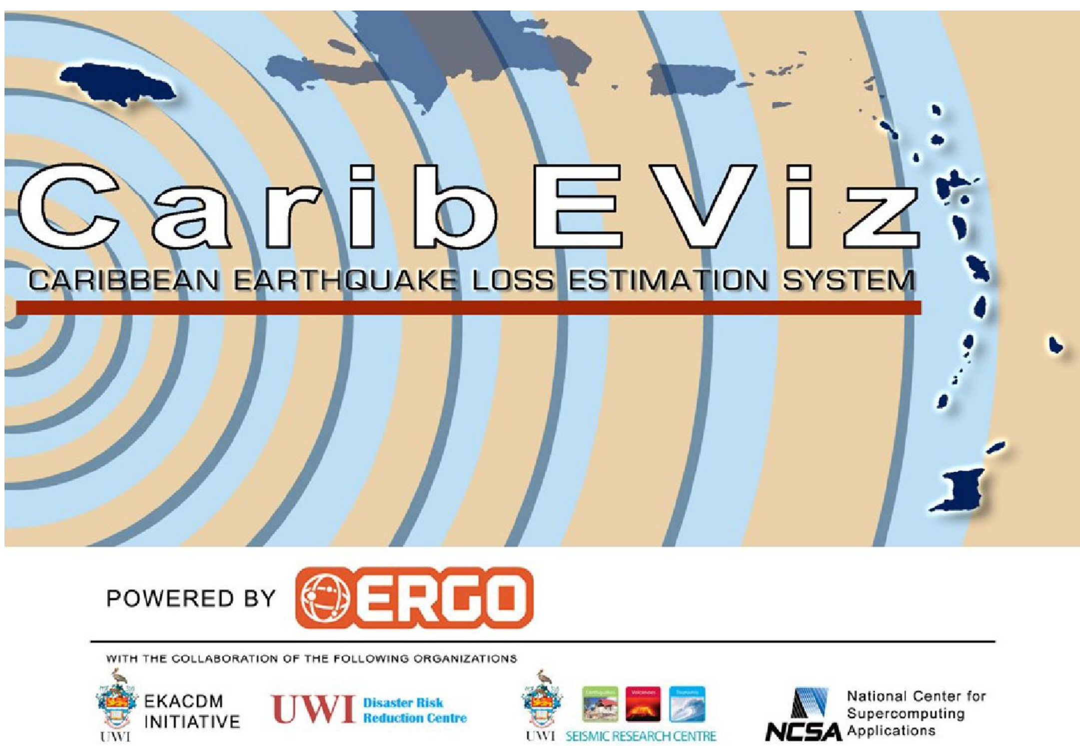

Figure 1: Rebranded splash screen and logo for CaribEViz.

Healthcare and Shelter Facility Capacity Ergo Module

The healthcare and shelter facility capacity analyses are realized as a module in CaribEViz. It is intended that these analyses will help disaster managers in planning to accommodate the population that is injured or dislocated after an earthquake. After an earthquake, the analysis will calculate utilization and overcapacity of healthcare and shelter facilities. The inputs for these analyses are the outputs of the existing analyses *Household and Population Dislocation Analysis* and *Casualty*. The methodology implemented in these analyses is further detailed in Appendix III.

Seismic Risk: Building Damage, Casualties and Population Dislocation

Using the Building Vulnerability Estimation module, the building vulnerability and occupancy types and rates were estimated for the KMA and Portmore. A seismic hazard is then applied to the building stock to calculate building structure damage, casualties, population dislocation, shelter capacity and healthcare facilities capacity. The following results used the Probabilistic Seismic Hazard Assessment (**PHSA**) of 2475 year return period which is similar to the Kingston 1907 earthquake. This PHSA contains peak ground acceleration (**PGA**) values in the 1 second spectral period. These PGA values have a 10% probability of exceedance every 2475 years.

Structural Damage incurred by this PHSA yielded a mean damage of 55% for the KMA and direct economic loss (structural) of US$19.9 billion with standard deviation of US$7 billion. For the Portmore region, the mean structural damage was 52% with a direct economic loss of US$ 4.5 billion with a standard deviation of US$2.2 billion.

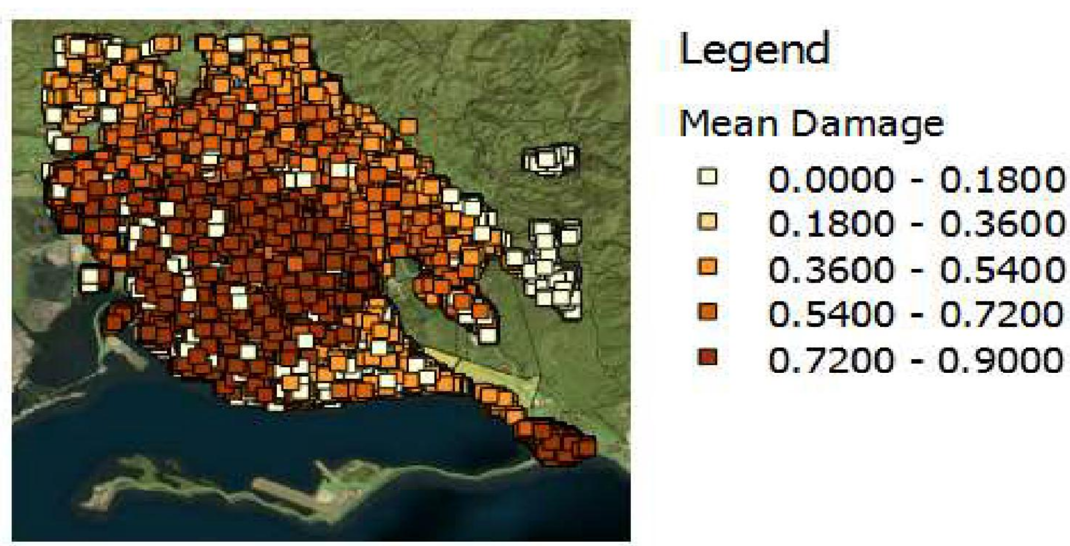

Figure 2. KMA Structural Damage using PHSA 2475 yr.

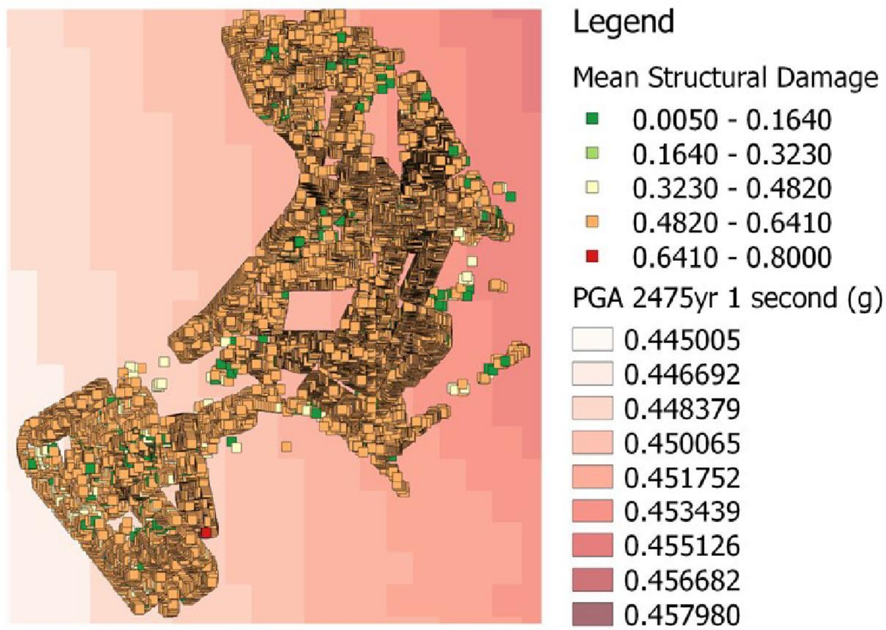

Figure 3. Portmore Structural Damage using PHSA 2475 yr.

The casualties calculated from this PHSA totalled 173,591 for the KMA region and 21,594 for Portmore. Ergo calculates casualties using the HASUZ methodology and description. Casualties are broken down into four severity level detailed in Table 1. Tables 2 and 3 detail the casualties in both the KMA and Portmore respectively.

Table 1. HAZUS Casualty Severity Levels

Injury Severity Level	Injury Description
Severity 1	Injuries requiring basic medical aid that could be administered by paraprofessionals. These types of injuries would require bandages or observation. Some examples are: a sprain, a severe cut requiring stitches, a minor burn (first degree or second degree on a small part of the body), or a bump on the head without loss of consciousness.
Severity 2	Injuries requiring a greater degree of medical care and use of medical technology such as x-rays or surgery, but not expected to progress to a life threatening status. Some examples are third degree burns or second degree burns over large parts of the body, a bump on the head that causes loss of consciousness, fractured bone, dehydration or exposure.
Severity 3	Injuries that pose an immediate life threatening condition if not treated adequately and expeditiously. Some examples are: uncontrolled bleeding, punctured organ, other internal injuries, spinal column injuries, or crush syndrome.
Severity 4	Instantaneously killed or mortally injured.

Table 2. Casualty Severity Levels for the KMA by sex and age

Female Severity 1	**Female Severity 2**	**Female Severity 3**	**Female Severity 4**
49270	16690	3071	6097
Male Severity 1	**Male Severity 2**	**Male Severity 3**	**Male Severity 4**
49681	16723	3055	6064
Child Severity 1	**Child Severity 2**	**Child Severity 3**	**Child Severity 4**
14963	5128	955	1896

Table 3. Casualty Severity Levels for Portmore by sex and age

Female Severity 1	Female Severity 2	Female Severity 3	Female Severity 4
3227	956	171	339
Male Severity 1	**Male Severity 2**	**Male Severity 3**	**Male Severity 4**
2667	769	137	271
Child Severity 1	**Child Severity 2**	**Child Severity 3**	**Child Severity 4**
1506	473	87	172

From the casualty outputs, the utilization of healthcare facilities was analysed.

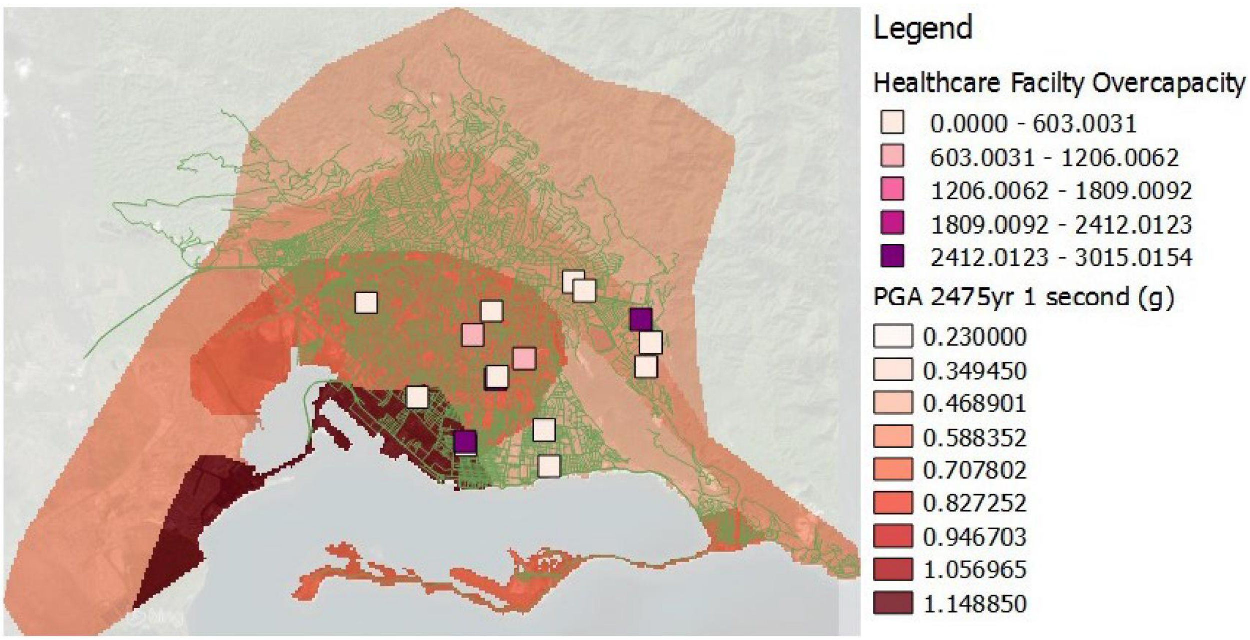

Figure 4. Healthcare Facility Overcapacity for PHSA 2475 year for the KMA.

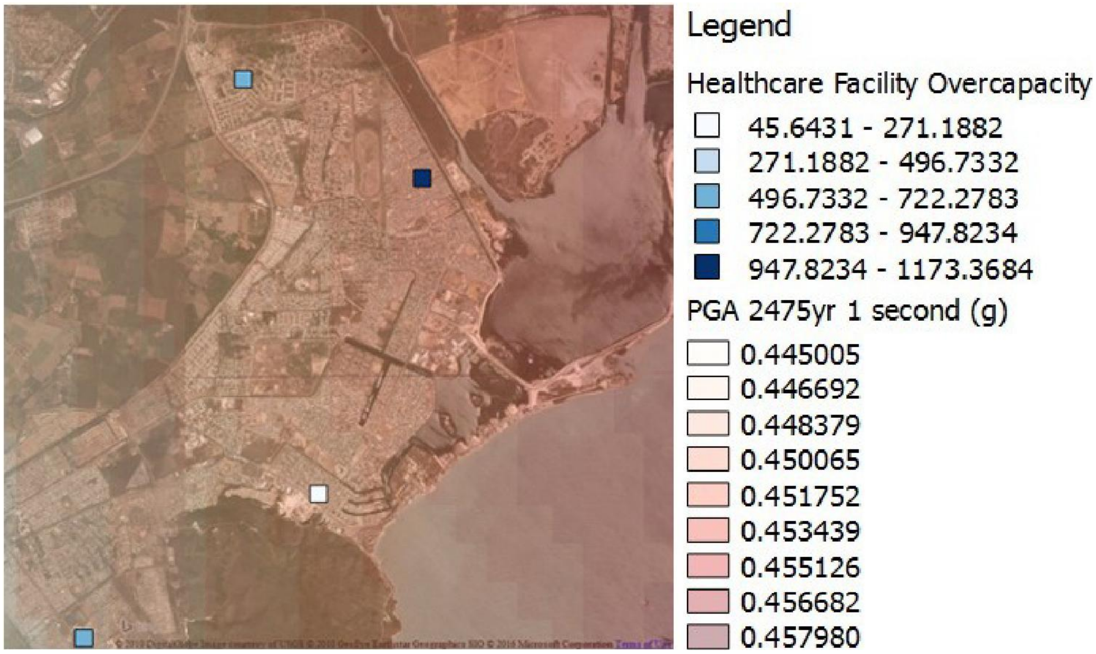

Figure 5. Healthcare Facility Overcapacity for PHSA 2475 year for Portmore.

It can be seen that the healthcare facilities in both regions are very ill equipped to handle the casualties from the largest earthquakes that are possible.

The 2475 year return period PHSA yielded a dislocated population of 67,850 for the KMA region and 33,714 for Portmore. Tables 4 and 5 details the dislocated population disaggregated by sex and age for the KMA and Portmore respectively.

Table 4. Dislocated population for the KMA

Female	Male	Child
67849	57899	57950

Table 5. Dislocated population for Portmore

Female	Male	Child
12914	10710	10090

Using the dislocated population an analysis of utilization of shelters was performed.

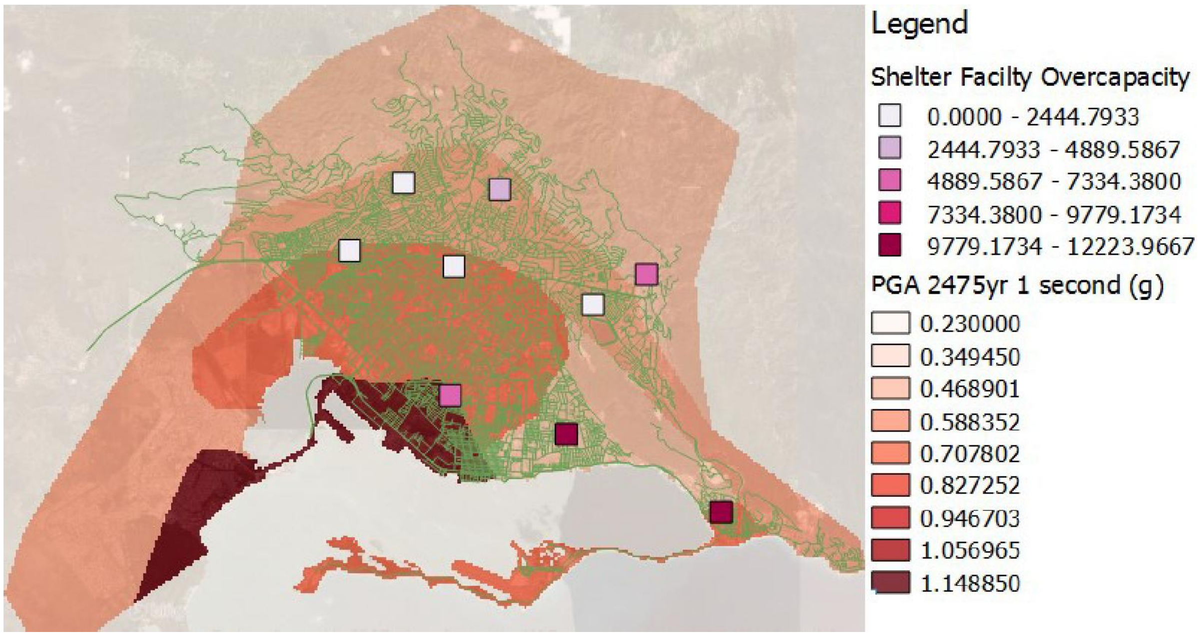

Figure 6. Shelter Overcapacity for PHSA 2475 year for the KMA.

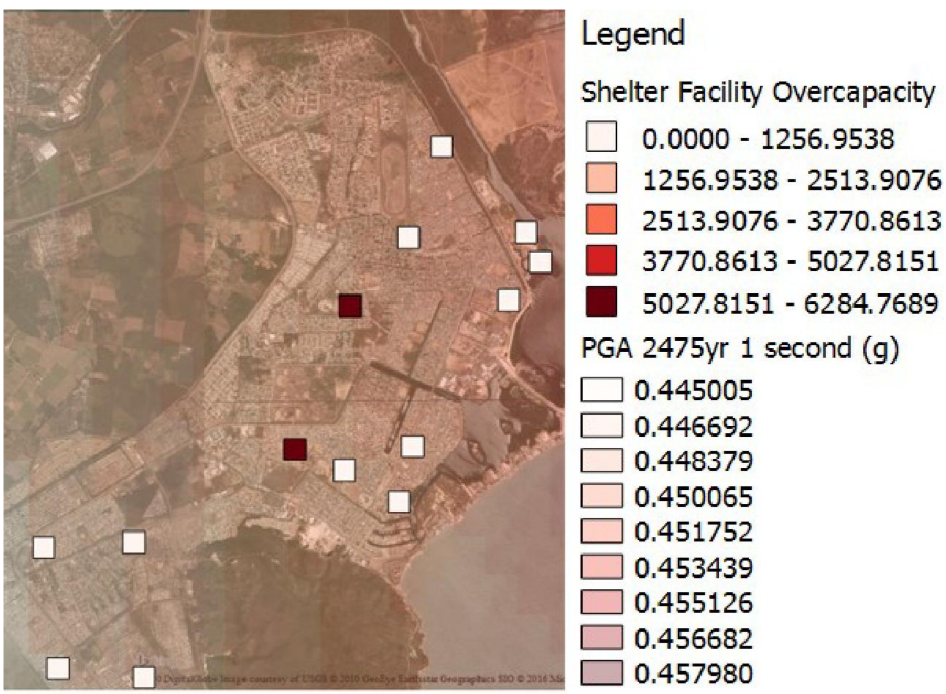

Figure 7. Shelter Overcapacity for PHSA 2475 year for Portmore.

The results from the shelter utilization after a seismic hazard similar to the PHSA 2475 year show that both regions cannot accommodate the dislocated population. Temporary shelters will have to be deployed after a major seismic event.

Limitations

There are limitations that were discovered during the execution of this project. This work has been both exploratory and product driven. As such, there are gaps in methodology that could not be covered within the scope and resources of this project.

It is expected that the building vulnerability estimation module will have errors in its output. The module can only perform as well at the data that is inputted into it. Furthermore, any computational solution will not accurately model natural or social systems. It is hoped that the data capture facility of this module, over time, will reduce the error of outputs. The limitations of the methodology employed in this module are further detailed in Appendix II.

Both healthcare and shelter capacity analyses do not cater for the structural damage that will affect the usability of the facility. Further work will have to be carried out to determine these facilities usability given the structural damage. Also, the shelter capacity analysis does not take into account dislocated population that may seek shelter with relatives or friends after an earthquake.

Dataset products with respect to Barbados, as of time of writing, were not produced. This is due to the requisite data not being made being available to the UWI-SRC team. However, it is expected that once the data becomes available all software products will be able to produce vulnerability and risk datasets for Barbados.

Conclusion

This work has been guided by the intention to provide stakeholders with tools to create a comprehensive understanding of seismic risk in the region. The building vulnerability estimation module complements the sufficiently known seismic hazard in performing seismic risk assessment. The addition of the healthcare and shelter utilization modules will potentially increase the utilization and value of the project outputs to stakeholders. The project outputs have provided a better understanding of population exposure and response following a seismic event allowing for improved planning and increased regional resilience and disaster risk reduction for regional seismic events.