



designing a world of hope



2019 **EMI Conference**

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Pre-disaster Risk Assessment



Course Description

Process presented to evaluate facilities located in high natural hazard, low income regions to determine their natural hazard exposure. Measures to mitigate observed vulnerabilities with local labor and resources will also be presented. EMI's clients provided with the results of such an assessment can then take positive steps to reduce injuries and loss of lives as well as damage to their facilities, when a major natural hazard occurs.

Learning Objectives

1. Learn how to find resources to determine the probability and magnitude of earthquakes and high winds
2. Learn how the physical and geological elements of the region can affect the severity of damaging natural hazard events
3. Learn how to safely, methodically, and efficiently assess existing structures for vulnerabilities to a variety of natural hazards.
4. Learn methods to mitigate common vulnerabilities using local labor and resources.

Introductions

Professional

M.S. in Structural Engineering University of California, Berkeley

B.S. in Civil Engineering, Colorado State University

Registered California Structural Engineer

- 10 years as sole-proprietor of structural consulting firm
- 25 years in earthquake consulting firms
- Perform EQ risk evaluations worldwide
- Post-EQ recovery assistance
- 8 years in nuclear industry

Ministries

Kairos Prison Ministries

18 years on Church mission committee

EMI

First volunteered on EMI project in 2012

Participated in 2 EMI design projects and 4 EMI disaster response teams

Family

Married 42 years to Linda with two married children and five grandchildren





DESIGNING A WORLD OF HOPE

EMI volunteers contribute to a world of hope:

- Providing economical and sustainable master plans and designs for those in need around the world
- Providing technical expertise to impacted communities struck by natural disasters
- **Performing risk assessments of facilities located in high hazard regions**



WHAT IS A PRE-HAZARD RISK ASSESSMENT?

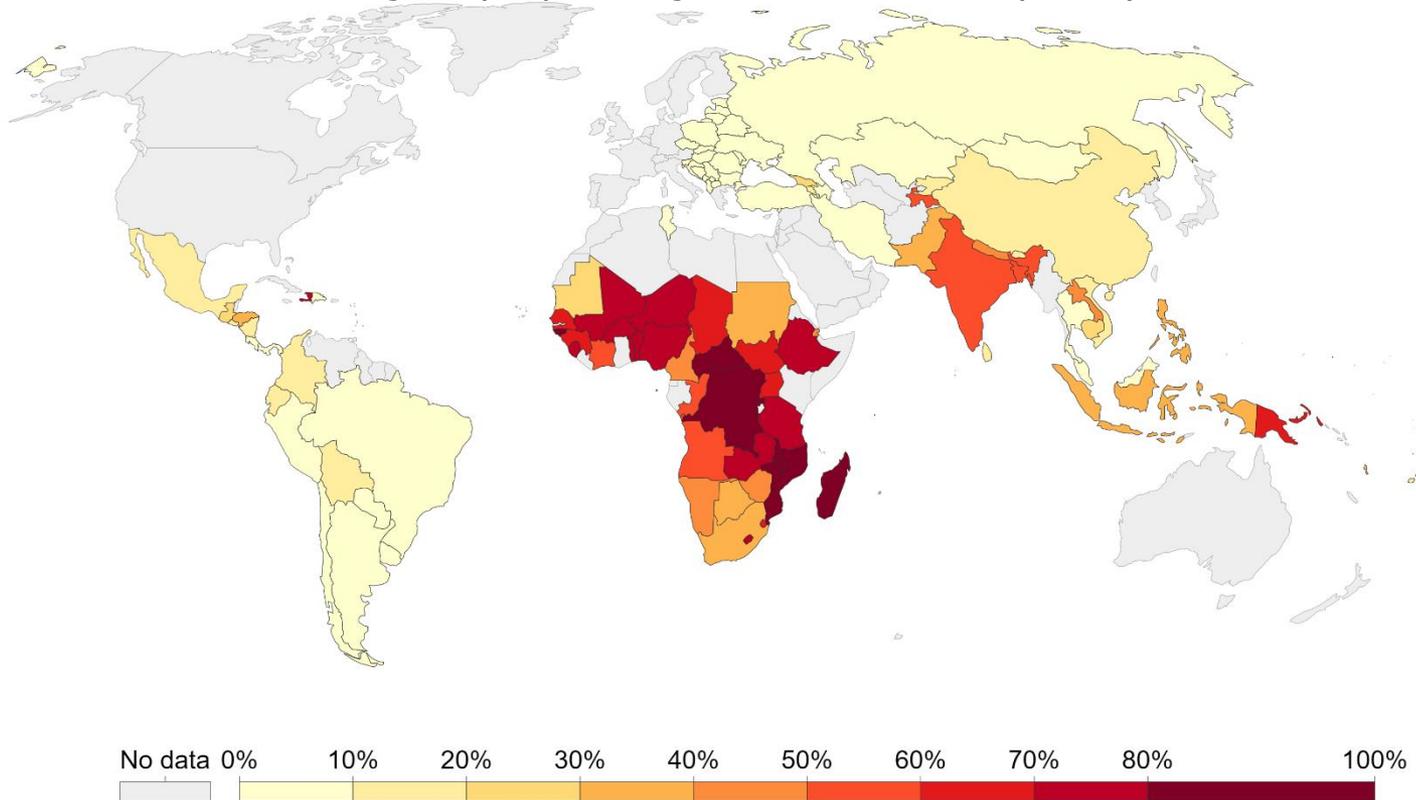
An evaluation of multiple facilities in a high natural hazard region to determine the facilities' vulnerabilities which coupled with the hazard defines the facilities risk, i.e.:

RISK = HAZARD + VULNERABILITY

EMI CLIENTS

World Poverty Map

Percentage of people living on less than \$3.10 per day



Source: World Bank – WDI

OurWorldInData.org/extreme-poverty/ • CC BY

Note: Consumption per capita is the preferred welfare indicator for the World Bank's analysis of global poverty. However, for about 25% of the countries, estimates correspond to income, rather than consumption.



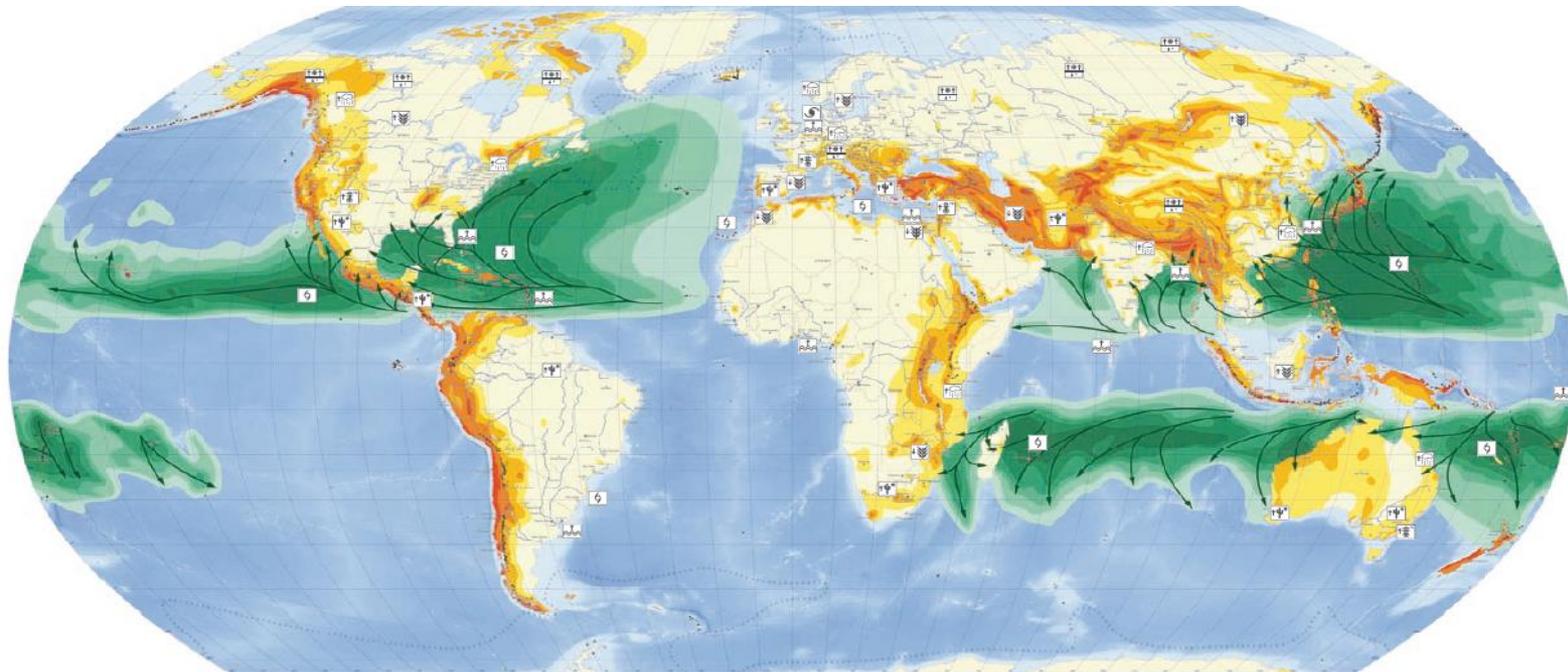
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EMI CLIENTS

World Natural Hazard Map



EARTHQUAKES

- Zone 0: MM V and below
- Zone 1: MM VI
- Zone 2: MM VII
- Zone 3: MM VIII
- Zone 4: MM IX and above

Probable maximum intensity (PMI: Modified Mercalli scale) with an exceedance probability of 10% in 50 years (equivalent to a "return period" of 475 years) for medium subsoil conditions.

Large city with "Mexico City effect"

TROPICAL CYCLONES

Peak wind speeds (in km/h)*

- Zone 0: 76-141
- Zone 1: 142-194
- Zone 2: 195-212
- Zone 3: 213-251
- Zone 4: 252-299
- Zone 5: ≥300

* Probable maximum intensity with an exceedance probability of 10% in 10 years (equivalent to a "return period" of 100 years).

Typical track directions

VOLCANOES

- ▲ Last eruption before 1800 AD
- ▲ Last eruption after 1800 AD
- ▲ Particularly hazardous volcanoes

TSUNAMIS AND STORM SURGES

- ~ Tsunami hazard (seismic sea wave)
- ~ Storm surge hazard
- ~ Tsunami and storm surge hazard

ICEBERG DRIFTS

- △△△△ Extent of observed iceberg drifts

CLIMATE IMPACTS

Main impacts of climate change already observed and/or expected to increase in the future

- ☁ Change in tropical cyclone activity
- ☁ Intensification of extratropical storms
- ☁ Increase in heavy rain
- ☁ Increase in heatwaves
- ☁ Increase in droughts
- ☁ Threat of sea level rise
- ☁ Permafrost thaw
- ☁ Improved agricultural conditions
- ☁ Unfavourable agricultural conditions

POLITICAL BORDERS

- ~ State border
- ~ State border controversial (political borders not binding)

CITIES

- Denver > 1 million inhabitants
- San Juan 100,000 to 1 million inhabitants
- Maun < 100,000 inhabitants
- ◆ Berlin Capital city

Data resources

Bathymetry: Amante, C. and B. W. Eakins, ITOPO11 1-Arc-Minute Global Relief Model; Procedures, Data Sources and Analysis, National Geophysical Data Center NESDIS, NOAA, U.S. Department of Commerce, Boulder, CO, August 2008. Extratropical storms: KNMI (Royal Netherlands Meteorological Institute), Temperature/Precipitation 1978-2007: Climatic Research Unit, University of East Anglia, Norwich.



Risk Assessment Procedure

Determine the natural hazards:

- Wind
- Earthquake
- Snow
- Flooding

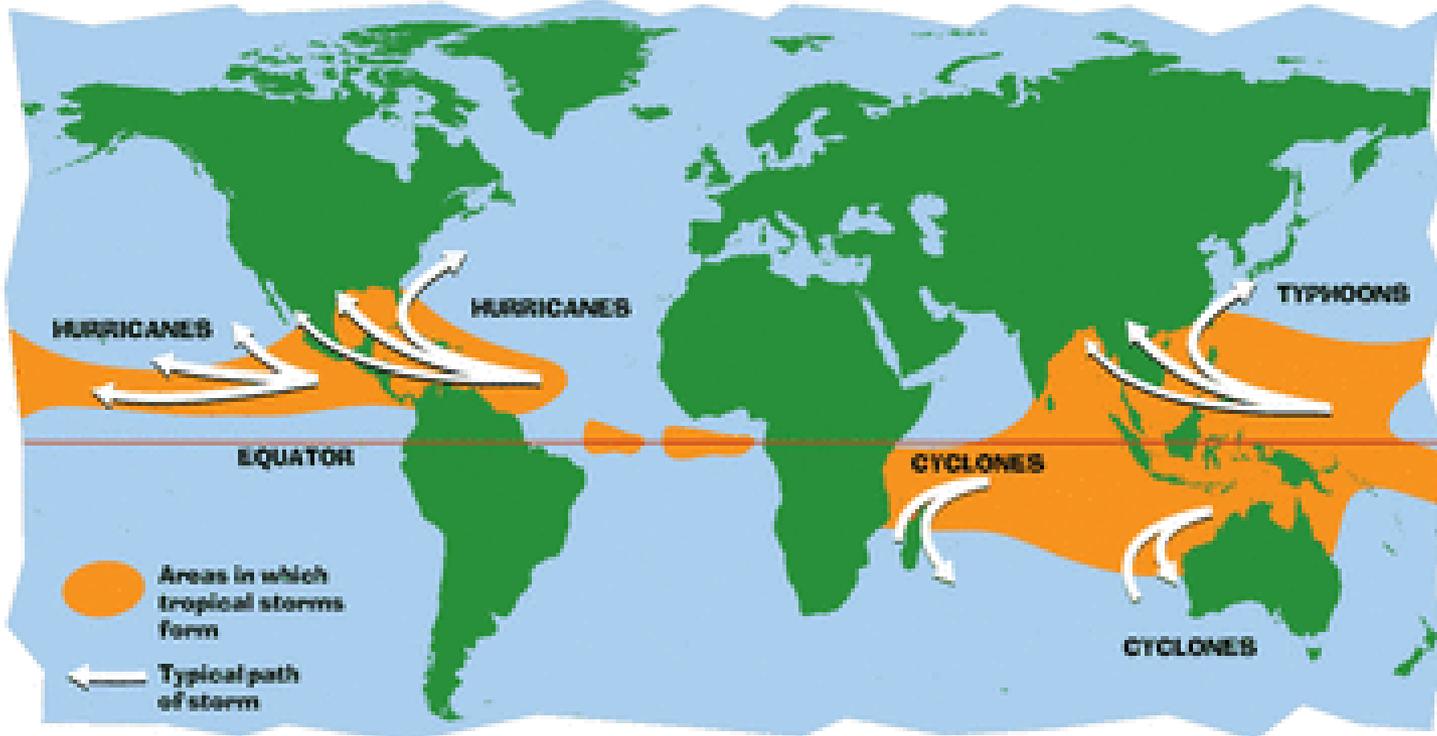
Assess the vulnerability of the facilities

- Type of construction
- Quality of construction
- Lateral force-resisting system

Tropical Hurricanes



Tropical Hurricanes



Wind Hazard Scales

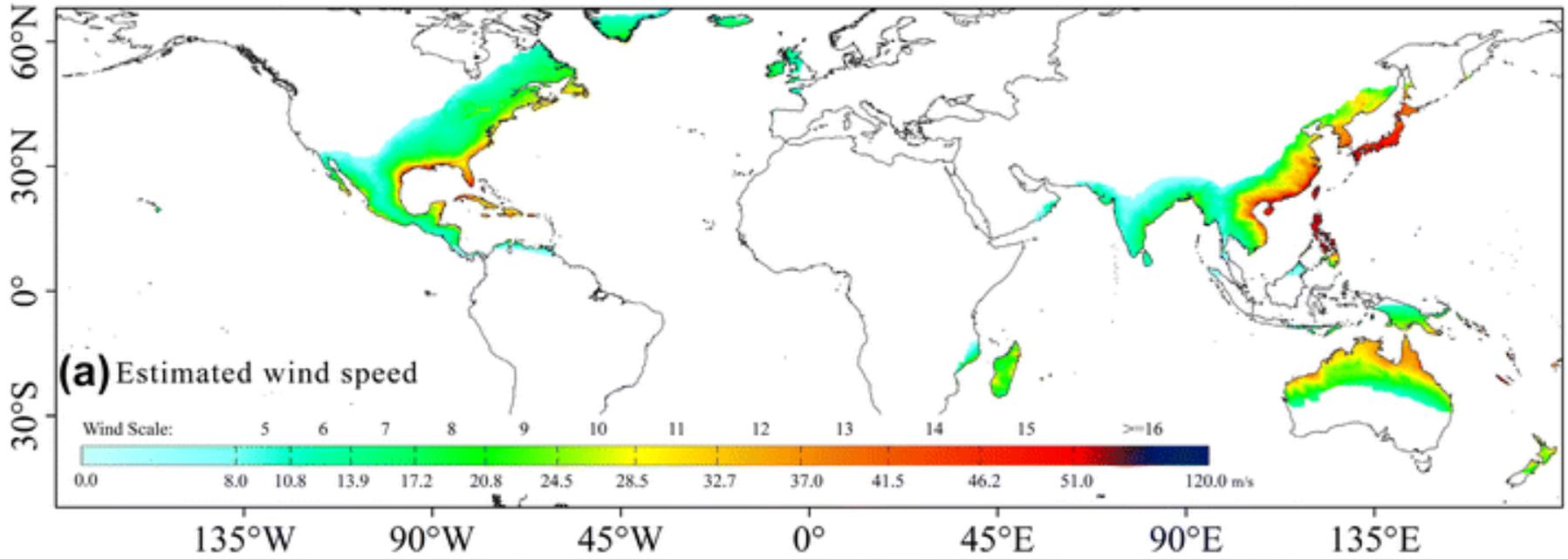
Saffir-Simpson Hurricane Wind Scale		
	Sustained Wind Speed	Effects
Category 1	74-95 mph (119-153 km/hr)	Very dangerous winds will produce some damage. Low-lying coastal roads flooded, minor pier damage
Category 2	96-110 mph (154-177 km/hr)	Extremely dangerous winds will cause extensive damage. Major damage to exposed mobile homes, evacuation of some shoreline residents
Category 3	111-130 mph (178-209 km/hr)	Devastating damage will occur. Some structural damage to small buildings; serious flooding at coast and many smaller structures near coast destroyed
Category 4	131-155 mph (210-249 km/hr)	Catastrophic damage will occur. High risk of injury or death to people, livestock, and pets due to flying and falling debris. Long-term water shortages will increase human suffering. Most of the area will be uninhabitable for weeks or months.
Category 5	> 155 mph (249 km/hr)	Catastrophic damage will occur. People, livestock, and pets are at very high risk of injury or death from flying or falling debris. A high percentage of frame homes will be destroyed. Long-term power outages and water shortages will render area uninhabitable for weeks or months.

Wind Hazard Scales

 Beaufort Scale of Wind Force				
Beaufort Force	Description	When You See or Feel This Effect	Wind (mph)	Wind (km/h)
0	Calm	Smoke goes straight up	less than 1	less than 2
1	Light air	Wind direction is shown by smoke drift but not by wind vane	1-3	2-5
2	Light breeze	Wind is felt on the face; leaves rustle; wind vanes move	4-7	6-11
3	Gentle breeze	Leaves and small twigs move steadily; wind extends small flags straight out	8-12	12-19
4	Moderate breeze	Wind raises dust and loose paper; small branches move	13-18	20-29
5	Fresh breeze	Small trees sway; waves form on lakes	19-24	30-39
6	Strong breeze	Large branches move; wires whistle; umbrellas are difficult to use	25-31	40-50
7	Moderate gale	Whole trees are in motion; walking against the wind is difficult	32-38	51-61
8	Fresh gale	Twigs break from trees; walking against the wind is very difficult	39-46	62-74
9	Strong gale	Buildings suffer minimal damage; roof shingles are removed	47-54	75-87
10	Whole gale	Trees are uprooted	55-63	88-101
11	Violent storm	Widespread damage	64-72	102-116
12	Hurricane	Widespread destruction	73+	117+

Engineer Diary (www.strleng.blogspot.com)

Probability of High Winds

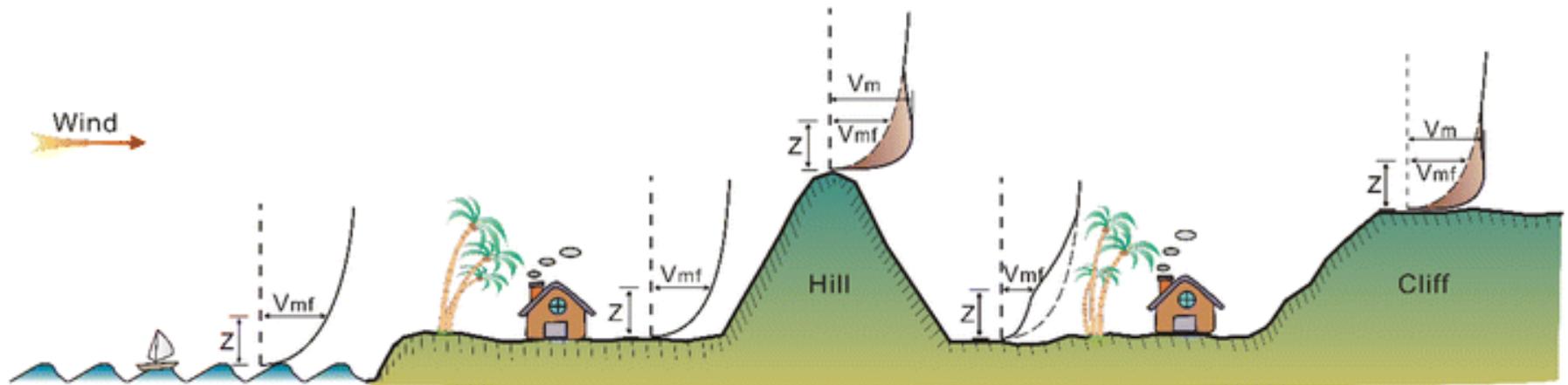


Tropical Cyclone Map of Wind Speeds (3-sec gusts) with a 100-year return period

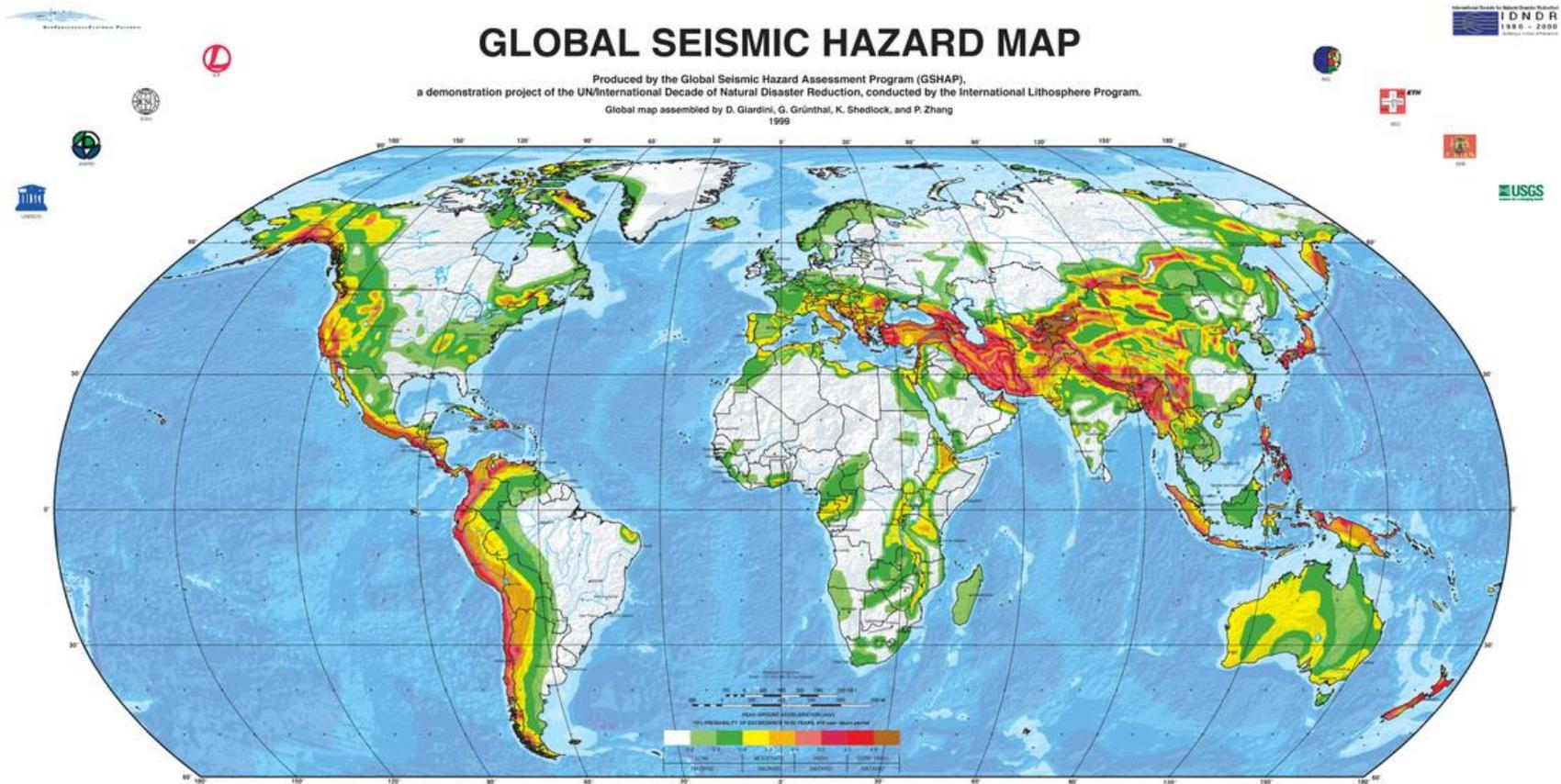
Mapping the Wind Hazard of Global Tropical Cyclones with Parametric Wind Field Models by
Considering the Effects of Local Factors by Chenyan Tan and Weihua Feng
International Journal of Disaster Risk Science
March 2018, Volume 9, Issue 1, pp 86–99



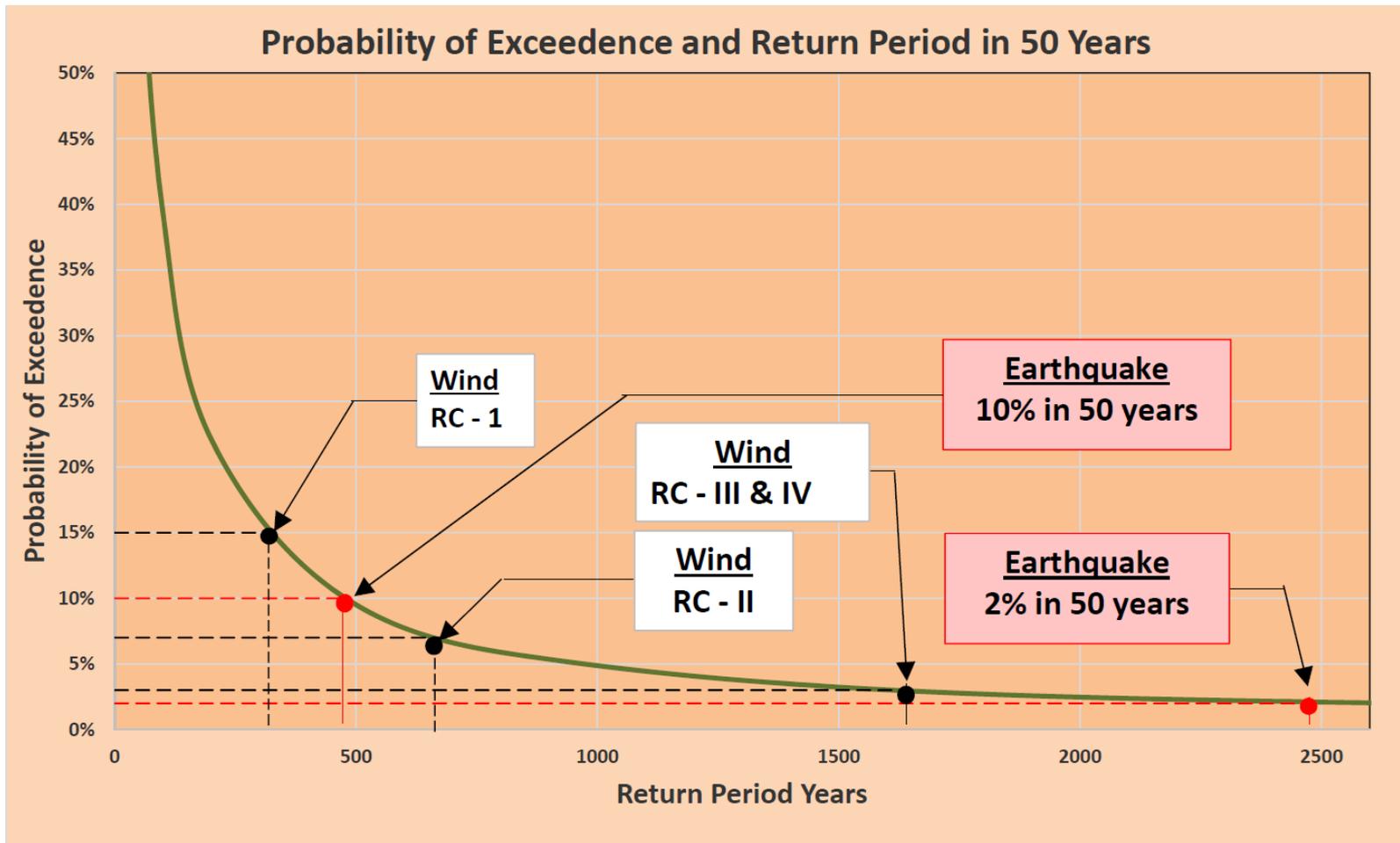
Local Topographic Effect



Earthquake Hazards



Probability of Hazard



Demand Modifiers by Risk Category

Table 1.5.2

Risk Category	Importance Factor			
	Snow	Ice		Seismic
		Thickness	Wind	
	I_s	I_i	I_w	I_e
I	0.8	0.8	1	1
III	1	1	1	1
III	1.1	1.25	1	1.25
IV	1.2	1.25	1	1.5

Table 11.6-1

Seismic Design Category based on S_{DS}

Value of S_{DS}	Risk Category	
	I, II or III	IV
$S_{DS} < 0.167$	A	A
$0.167 \leq S_{DS} < 0.33$	B	C
$0.33 \leq S_{DS} < 0.5$	C	D
$0.5 \leq S_{DS}$	D	D

Table 11.6-2

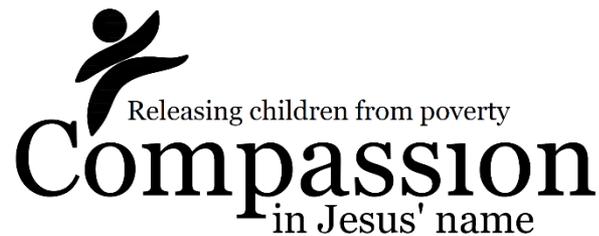
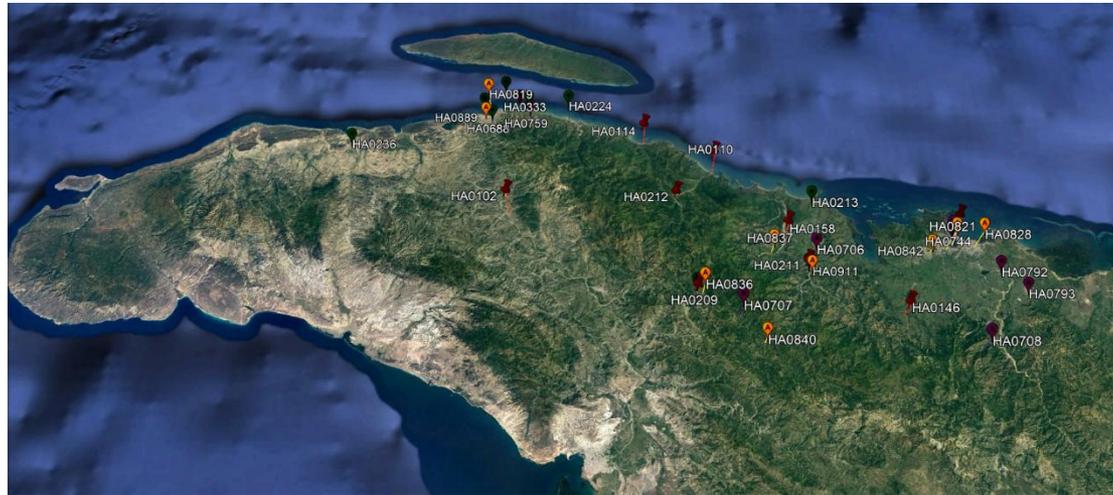
Seismic Design Category based on S_{D1}

Value of S_{D1}	Risk Category	
	I, II or III	IV
$S_{D1} < 0.067$	A	A
$0.067 < S_{D1} < 0.133$	B	C
$0.133 < S_{D1} < 0.20$	C	D
$0.20 \leq S_{D1}$	D	D

Example Earthquake Risk Assessment

Earthquake Risk Assessment of Compassion International Partner Facilities

Located in Northeast Haiti

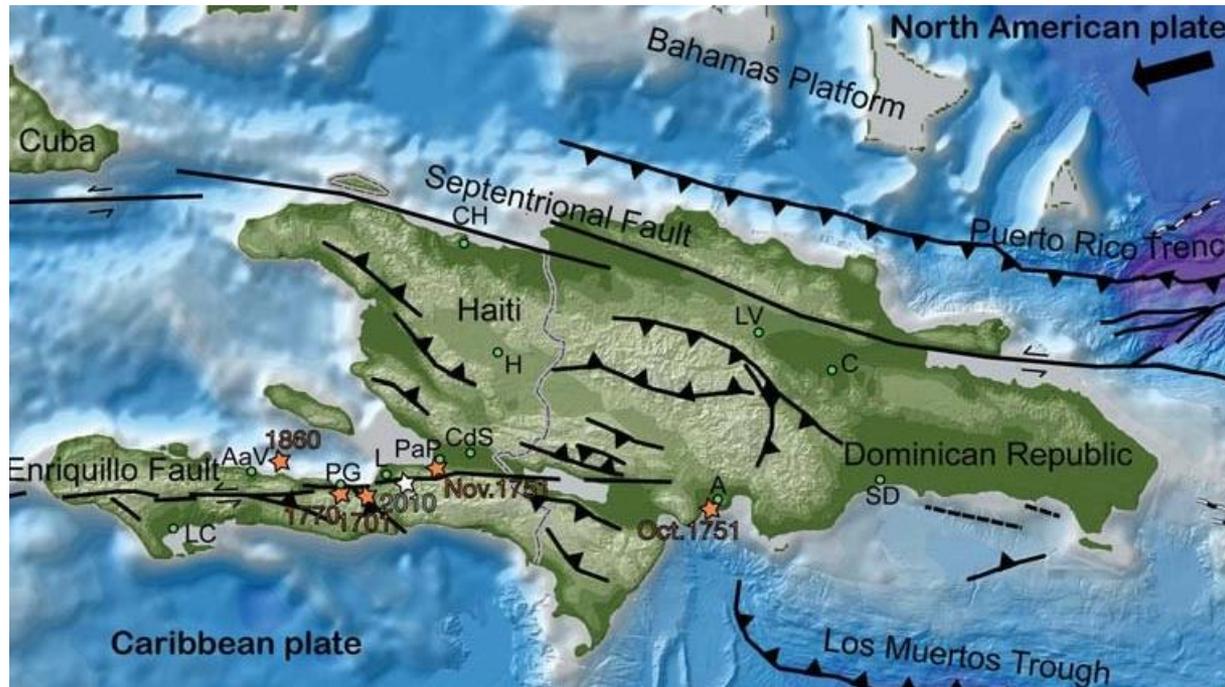


Earthquake Hazard



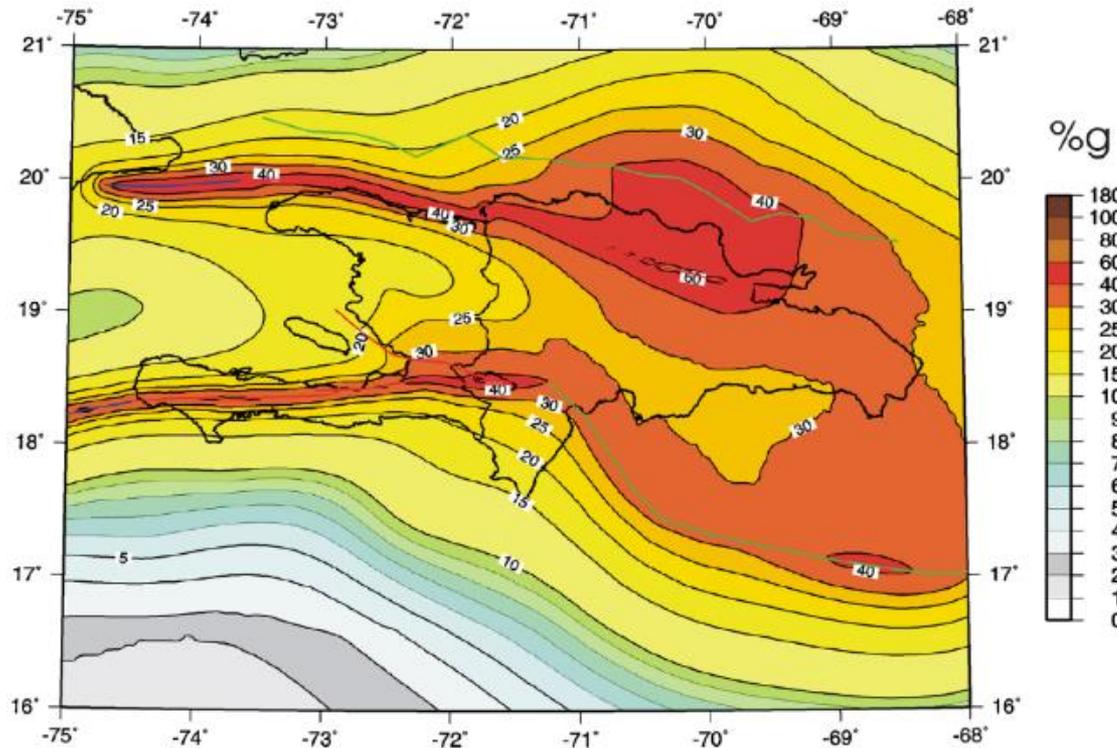
Tectonic Plates in Caribbean

Earthquake Hazard



Hispaniola Fault Map

Earthquake Hazard Probability



Peak Ground Acceleration

(10% Probability of Exceedence in 50 years)

PROJECT SITE OBJECTIVES

1. Draw a site map roughly to scale with north arrow
2. Identify project site name and client ID number
3. Assign ID numbers to each building
4. Identify function of each building (e.g. school, church, project building).
5. Identify no. of stories on map

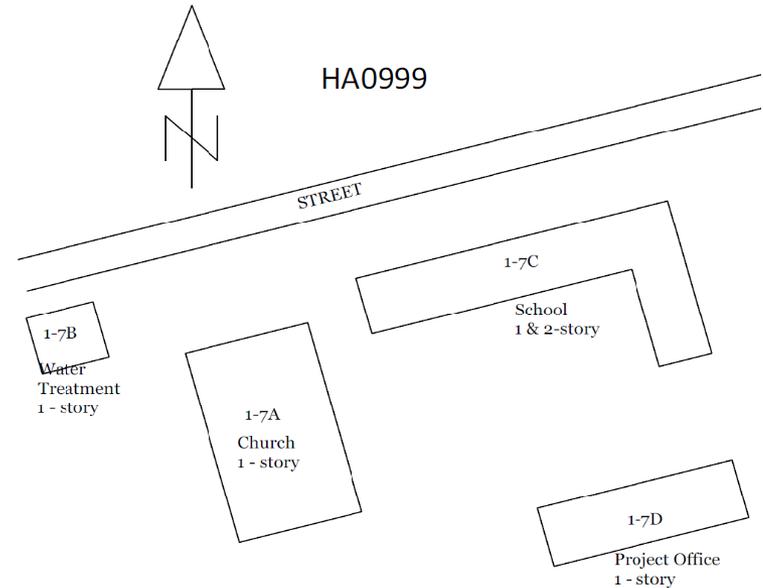


Figure 2 - Example Site

PRIOR TO LEAVING SITE

Confirm that:

1. Site objectives met
2. Individual building objectives met
3. Vulnerability and retrofit conclusions identified for each building, as applicable

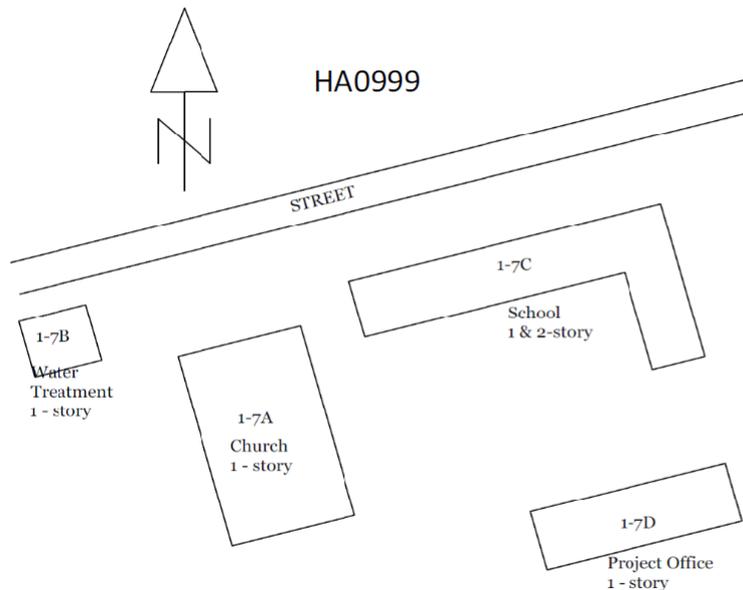


Figure 2 - Example Site

ID	Engr	Time	Concl
A	CC	9:02-9:10	OK
B	CC	9:12-9:20	R
C	WS	9:22- 9:31	OK
D	WS	9:32-9:40	R

Common Construction



Common Construction



Common Construction



Common Construction



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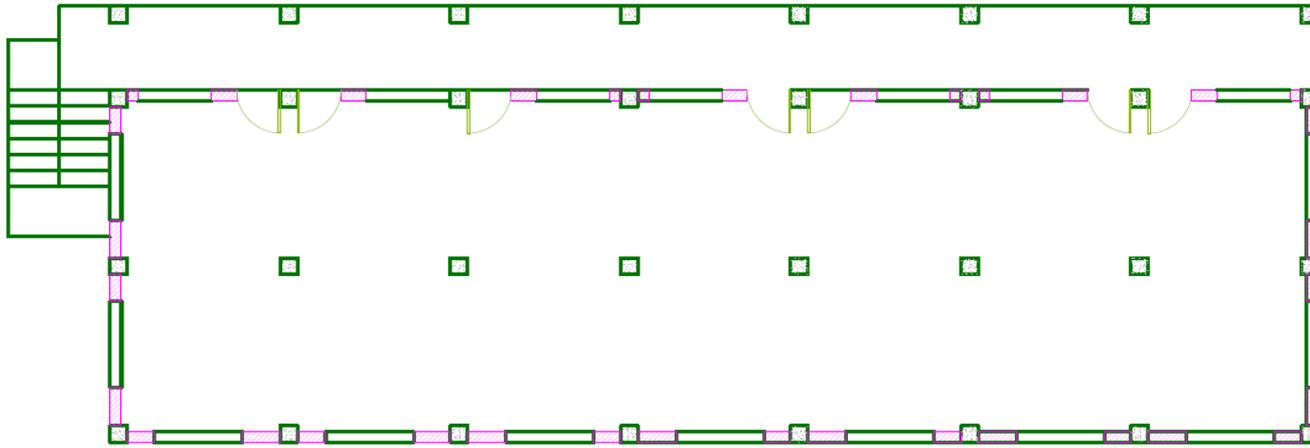
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Common Construction



Common Construction School Building



Common Construction



Common Vulnerabilities

- Too many window and door openings
- Walls not confined
- Walls not well distributed
- Heavy walls with light roofs
- No horizontal stiffness in roof (i.e. no diaphragm)
- Gable ends
- Heavy ornamentation
- Spindly columns



Confined Masonry

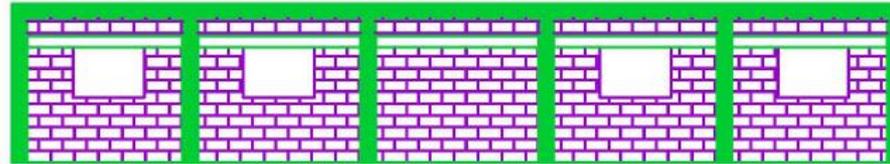


FIGURE 5 - SOUTH ELEVATION

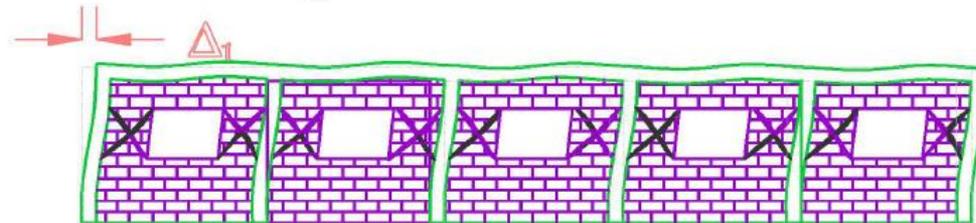
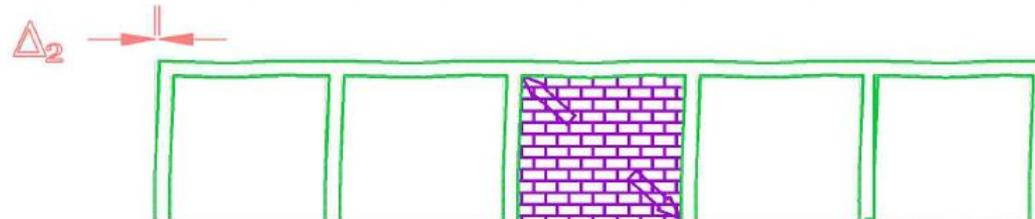


FIGURE 6 - UNCONFINED WALLS



(a) - CONFINED WALLS RESTRAIN LATERAL DISPLACEMENT

Confined Masonry

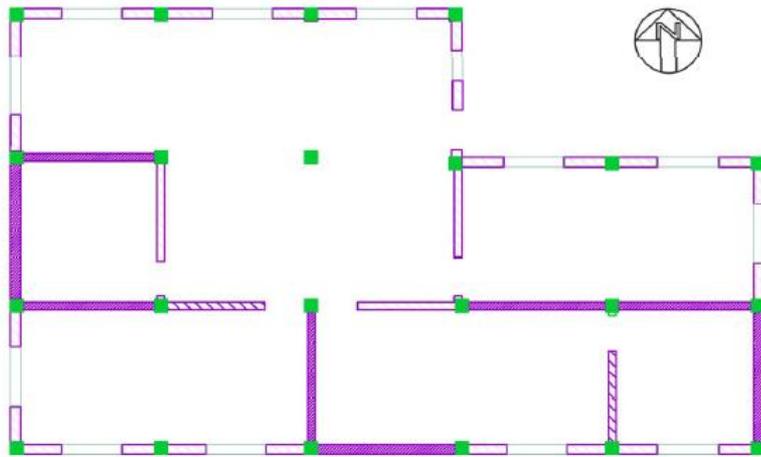


FIGURE 1 - FLOOR PLAN

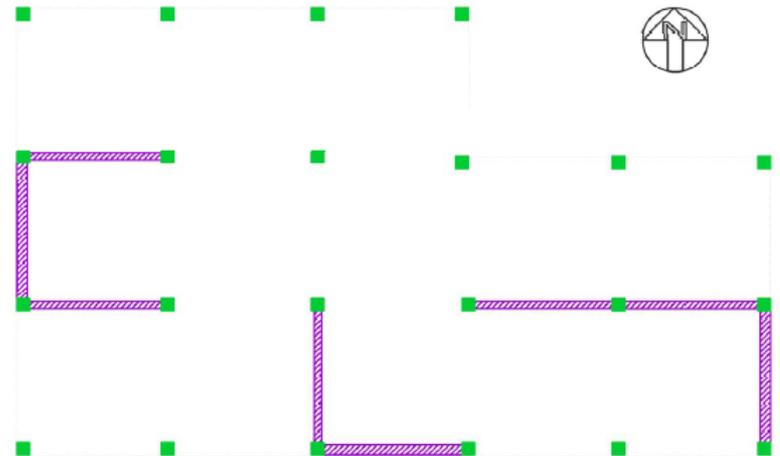
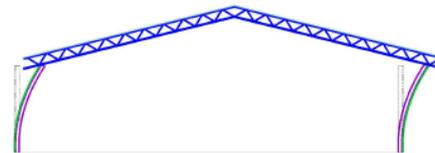
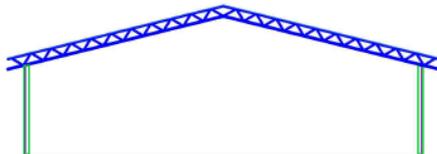
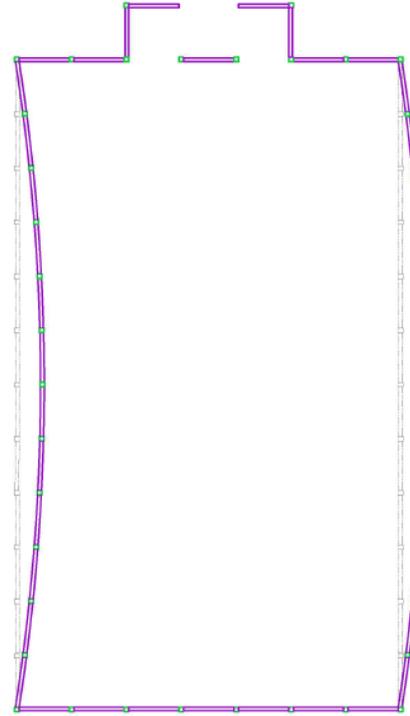
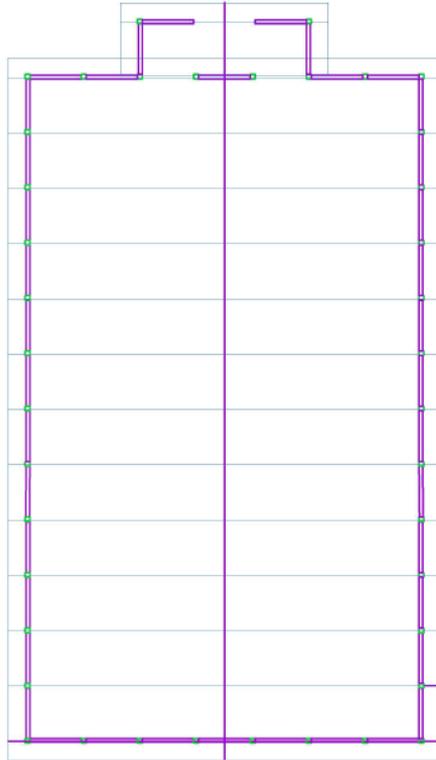


FIGURE 2 - FLOOR PLAN
CONFINED WALLS ONLY

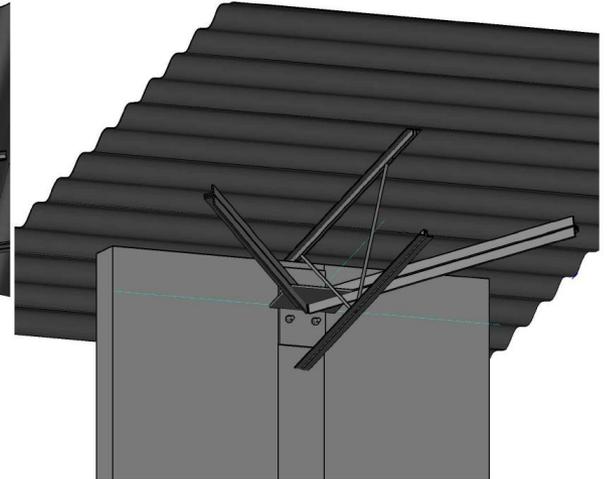
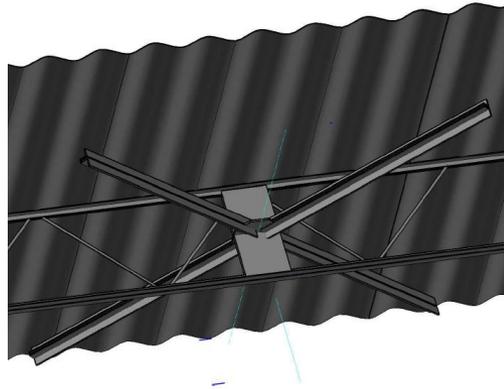
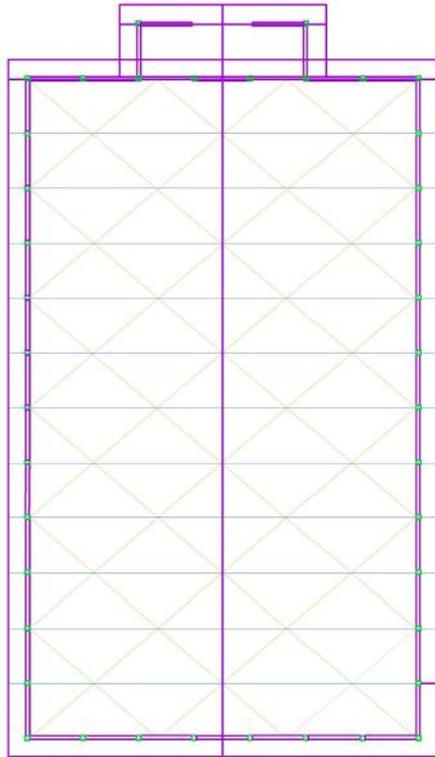
Lack of Roof Diaphragm



Gable Ends



Add diagonal Bracing



Poor Roof-to-Wall Connections



Add Cross Walls & Ties

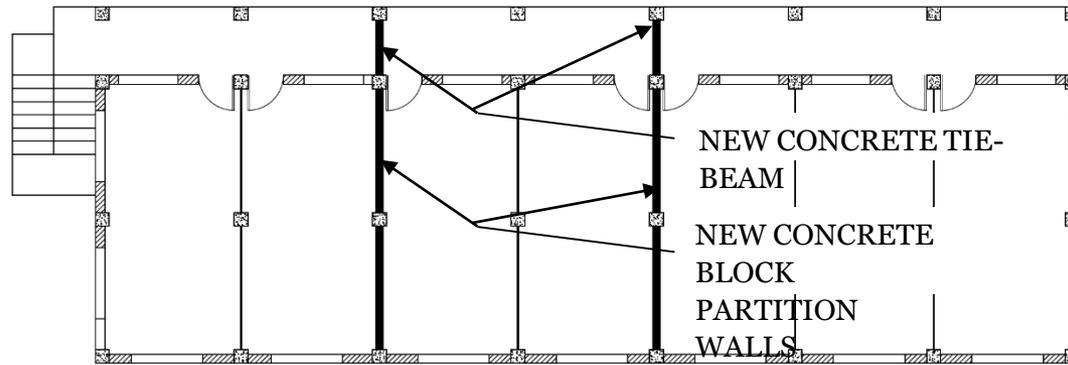


Figure C4 (a)
School Retrofit - Plan View

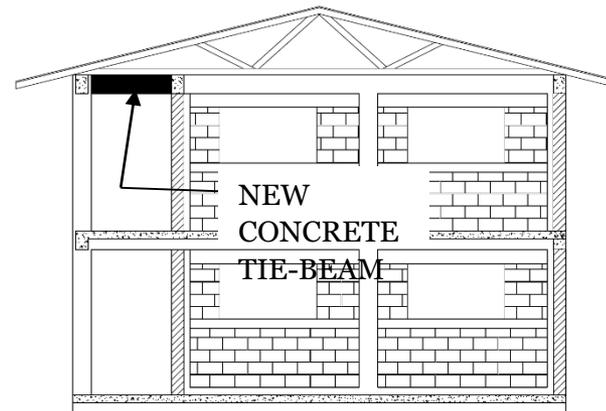


Figure C-4 (b)
School Retrofit – Section View

Report Format

Earthquake Risk Assessment IV. Observations, Findings and Recommendations



HA0744 Evangelical Church of Haiti

City: Cap-Haitien
ICP Cluster: Cap-Haitien
Latitude: 19.73945
Longitude: -72.21966 North
Seismic Hazard: 0.38 Very High Hazard

Cap-Haitien, Haiti

Building: HA0744-A

Day Evaluated: January 7, 2019
Function: Project Office/ Survivor
No. of Stories: 2
Risk Rating: Moderately Low
Damage Observations: None
Vulnerabilities: Not adequate lateral walls to resist loads.



Building HA0744-A

Recommendations: Add masonry to main floor interior 760 mm wide by full height opening.

Building: HA0744-B

Day Evaluated: January 7, 2019
Function: Project Office/ Survivor
No. of Stories: 1 and part 2
Risk Rating: Moderately High
Damage Observations: None
Vulnerabilities: None
Recommendations: None



Building HA0744-B

Building: HA0744-C

Day Evaluated: January 7, 2019
Function: Church
No. of Stories: 2
Risk Rating: Moderately High
Damage Observations: None
Vulnerabilities: No out-of-plane wall support.
Recommendations: Add diaphragm¹ in the plane of the roof. Provide shear transfer² to walls at building ends.



Building HA0744-C

¹ See Appendix B diaphragm.

² See Appendix B shear transfer.

Report Format

HA0744	Evangelical Church of Haiti
City:	Cap-Haitien
ICP Cluster:	Cap-Haitien
Latitude:	19.73945
Longitude:	-72.21966 North
Seismic Hazard:	0.38 Very High Hazard

Report Format

Building: HA0744-A

Day Evaluated:	January 7, 2019
Function:	Project Office/ Survivor
No. of Stories:	2
Risk Rating:	Moderately Low
Damage Observations:	None
Vulnerabilities:	Not adequate lateral walls to resist loads.
Recommendations:	Add masonry to main floor interior 760 mm wide by full height opening.



Building HA0744-A

Repair Cracks



(a)



(b)



(c)



(d)

Figure C6
Examples of Observed Wall Cracks

Risk = Hazard + Vulnerability

			Seismic Risk					
			Vulnerability					
			Low	Moderately Low	Moderate	Moderately High	High	Very High
			Hazard	PGA < 0.1g	Low	1	2	2
0.1g ≤ PGA < 0.17g	Moderately Low	1.5		2	2.5	3	4	4
0.17g ≤ PGA < 0.23g	Moderate	2		2.5	3	4	5	6
0.23g ≤ PGA < 0.3g	Moderately High	2.3		3	4	5	6	8
0.3g ≤ PGA < 0.37g	High	2.5		4	5	6	8	9
0.37g ≤ PGA	Very High	3		4	6	8	9	10

Seismic Risk Rating

Seismic Risk	
1 1.86	Low Risk
2.71 3.57	Moderate Low Risk
4.43 5.29	Moderate Risk
6.14 7	Moderately High Risk
7.86 8.5	High Risk
9.36 10.2	Very Hig Risk

Report Results

**Table V-1
Seismic Risk of Partner Facilities**

EMI	CI ID	Partner	Church	School	Proj. Off.	Other
7-1	HA0744	Evangelical Church of Haiti	HR		HR	MLR
7-2	HA0781	Wesleyan Church of Cité Chauvel	HR	MR		MLR
7-3	0	Rodrigue				MLR
8-1	HA0708	Evangelical Church of Grand-Gilles	MR	MR LR	MLR	
8-2	HA0793	Baptist Church of Limonade	MR		MLR	
8-3	HA0792	Bethlehem Baptist Church of Quartier	MLR	MR	MR	

Report Results

Table V-1
Seismic Risk of Partner Facilities

EMI	CI ID	Partner	Church	School	Proj. Off.	Other
7-1	HA0744	Evangelical Church of Haiti	HR		HR	MLR
7-2	HA0781	Wesleyan Church of Cite Chauvel	HR	MR		MLR
7-3	0	Boulevard				MLR
8-1	HA0708	Evangelical Church of Grand-Gilles	MR	MH LR	MLR	
8-2	HA0793	Baptist Church of Louverture	MR		MLR	
8-3	HA0792	Bethlehem Baptist Church of Quartier	MLR	MR	MR	
8-4	HA0828	First Baptist Church of Petite- Anse	HR		VHR	
9-1	HA0706	Evangelical Church of Limbe	MR	LR	MR	
9-2	HA0911	First Baptist church of Limbe	MLR	MH R	MH R	
9-3	HA0746	Nazarene Church of Quessasse		VHR	HR	
10-1	HA0816	Bethanie Baptist Church of Petit-bourg	MH MH R	VHR	HR	
10-2	HA0212	Wesleyan Bethel Church				MLR
10-3	HA0110	Baptist Church of Borgne	MH R	MR MR	MR	MLR
11-1	HA0213	Bethlehem Church of Boy	MLR	MH MR	MH R	MLR
11-2	HA0158	Wesleyan Church of Port Margot	MR	MH LR LR	MH LR	MLR ML R
11-3	HA0837	Baptist Church of Petit- Bourg	MR	MH R	MH R	
11-4	0	Faouel		LR LR	LR LR	MLR LR
12-1	HA0822	Haut -Limbe Baptiste Church	MR M R	MR MR MR	MR	MLR
14-1	HA0637	Evangelical Church of Pilate	LR	MH R	MH R	
14-2	HA0209	Antioche Wesleyan Church of Pilate	MR	LR LR MH R	MR	
14-3	0	Saint-Cyr Mother's Residence	LR			
14-4	HA0836	First Baptist church of Pilate	MLR	MLR MLR	MR	MH R LR
14-5	HA0707	Evangelic Church of Gaubert	MR	MLR MR MLR	MR	
14-6	HA0211	Samarit Wesleyan Church of Plaisance	HR	MLR HR MLR	MR HR	HR
14-7	HA0840	Plaisance Baptist Church	MR			LR
15-1	HA0794	Nazarene Church of Boy Roi/ Versailles	MR	MR MR MLR	MR LR	LR LR
15-2	HA0730	Edise Evangelique Baptiste Bethel	MR	MLR	MR LR	
16-1	HA0399	Bethel Baptist G\Church of Gros Morne	HR	MH R	MH R	MR MR
16-2	HA0915	First Baptist Church of Labadie	MLR	MR	LR	LR
16-3	HA0684	Nazarene Church of Dubedou	MLR	MLR MLR	LR	
16-4	HA0677	Nazarene Church of Chemin Neuf	MR		LR LR LR	
17-1	HA0845	First Baptist Church of Plaine du Nord	MLR	MLR MLR MLR	MR	
17-2	HA0146	Evangelical Church of Tovar	MLR	MLR MR MLR MR	LR	
17-3	HA0842	Evangelical Church of Manou	MLR	MH R	HR	LR MR
17-4	HA0159	Wesleyan Church of Cap- Haïtien	MLR	MH R	MH R	



Conclusion

A report has been provided to the client listing:

- All their facilities
- The Hazard at each facility
- Observed vulnerabilities at each building
- A risk rating for each building

Also provided are retrofit techniques to address common vulnerabilities