WB Philippines Catastrophe Risk Assessment and Modeling Project

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Manila
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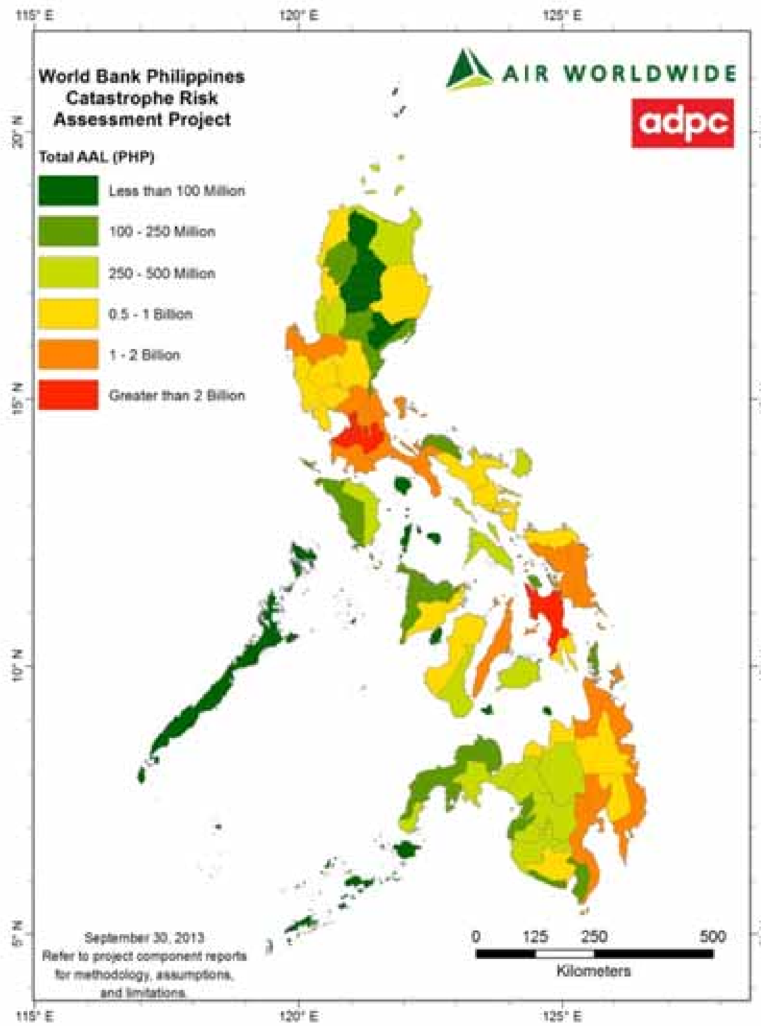
AIR WORLDWIDE®

Agenda

- Project Overview
- Risk Modeling Framework
- Catastrophe Modeling
    - Exposure Data
    - Earthquake Hazard & Vulnerability
    - Tropical Cyclone Hazard & Vulnerability
    - Non-Tropical Cyclone Hazard
- Peer Review
- Risk Modeling Results
- Loss Viewer Tool
    - Modeled Loss Structures
- Parametric Structures
    - Earthquake
    - Tropical Cyclone



Project Overview

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Philippines Catastrophe Risk Assessment Project

- Provide information assisting in the **reduction of the fiscal burden** to the Philippine Government to natural disaster impacts

- Part of Technical Assistance supported by the Global Facility for Disaster Reduction and Recovery (GFDRR) to result in **formulation of a risk finance strategy**

- Implement a **catastrophe risk assessment** for typhoon and seismic hazards for the entire country that would inform the design and implementation of a catastrophe liquidity facility addressing the **higher layers of risk**

Major Project Tasks

- The project is being developed over five distinct components

Component	Description
1	Hazard Data and Loss Data Collection and Management
2	Exposure Data Collection and Management and Vulnerability Assessment
3	Country Catastrophic Risk Profile
4	Design of Parametric Indices for Financial Transactions
5	Ongoing Support During Placement of Parametric Risk Transfer Product (conditional on DRF placement)

Overview of Project Plan

Existing AIR Catastrophe Models for the Philippines
1. Earthquake Ground Shaking and TC (Wind and Precip)
2. Province level aggregated exposure database of private assets

Expand Existing Models and Exposure Databases
1. Add non-TC Induced Precipitation Hazard
2. Add National Government Assets

Enhance Existing Models and Exposure Databases
1. Improve Country-wide Exposure Data
2. Update Representation of Seismic Hazard & TC Vulnerability in the Model

Develop Catastrophe Risk Metrics
1. Monetary physical damage loss metrics including Emergency Loss metrics
2. Development of Loss Viewer Tool and Parametric Structures

Risk Modeling Methodology and Overall Results

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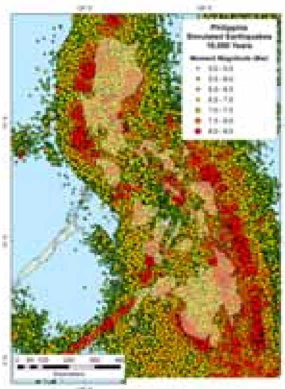
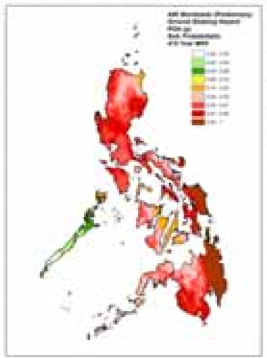
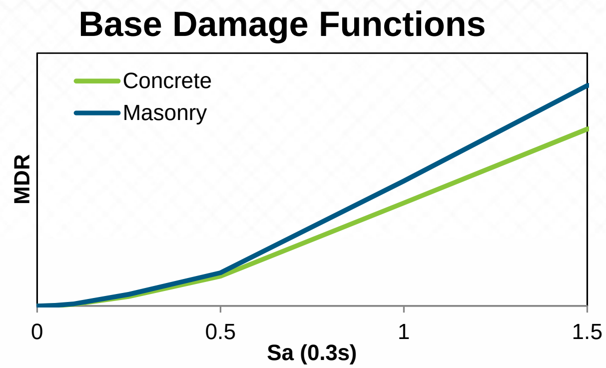
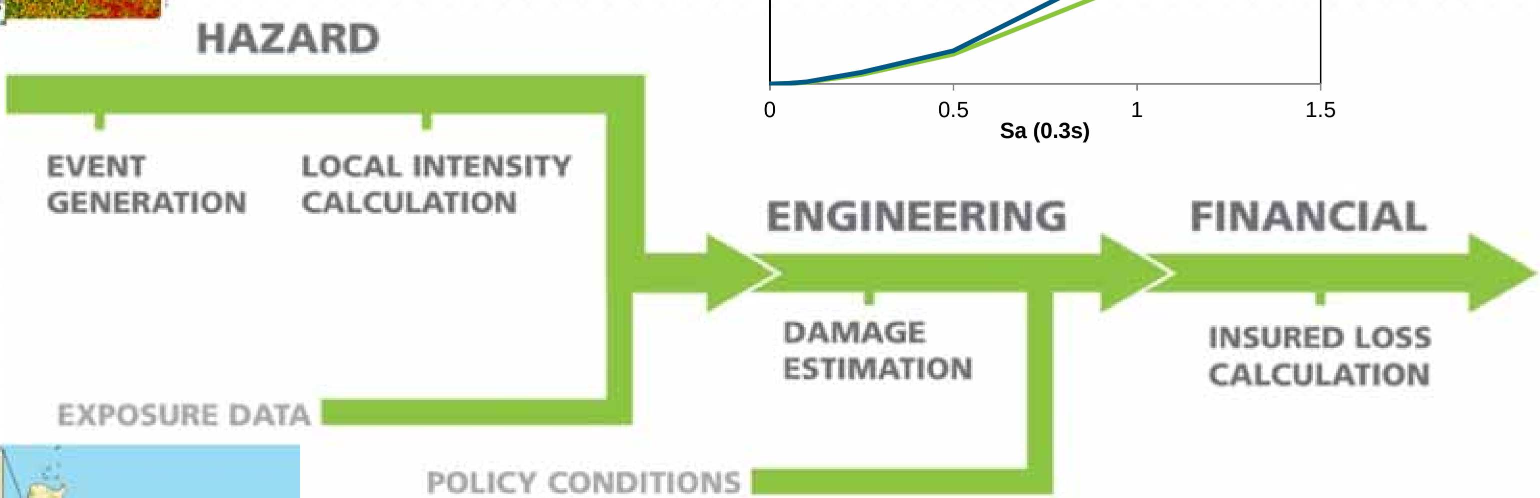
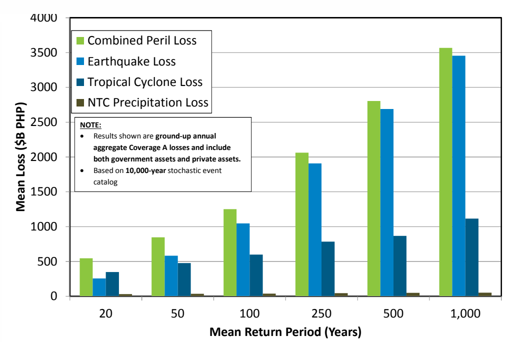
Risk Modeling Framework



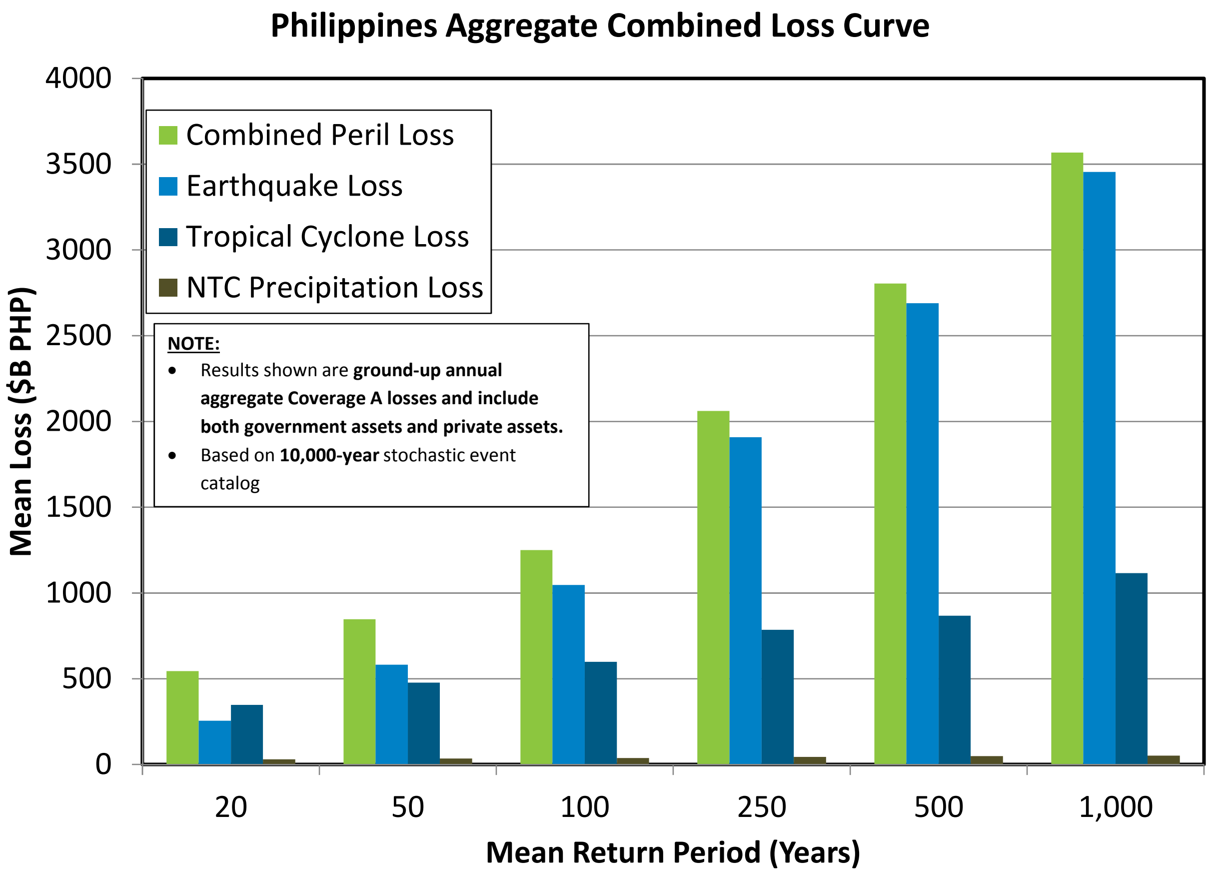








Philippines Building Loss EP Curves



AAL = 206.4 B PHP

MRP (Years)	Aggregate Loss ($B PHP)			
	EQ Loss	TC Loss	Non-TC Precip. Loss	Combined Peril Loss
20	256	347	30	545
50	582	477	35	847
100	1,047	598	38	1,250
250	1,908	786	44	2,062
500	2,689	868	49	2,804
1,000	3,456	1,117	52	3,568

Replacement Values (Coverage A):

Total = 25,000 B PHP
Private Property = 22,000 B PHP
Government Assets = 2,700 B PHP

GDP = 11,405 B PHP

Exposure

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Exposure Summary

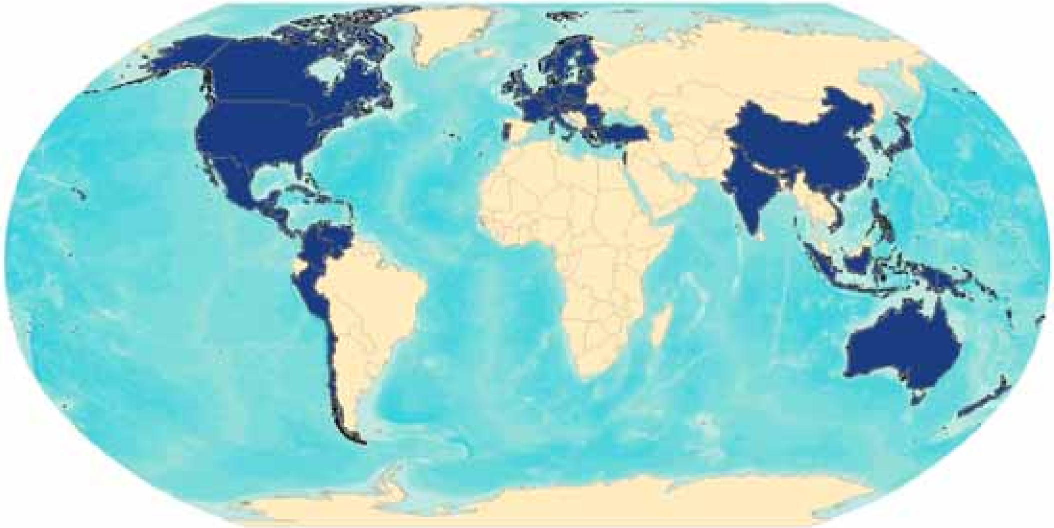
- Industry Exposure Database
  - Database of the building stock exposed to catastrophe risk has been enhanced using well established methodology and data gathered from local agencies and publicly accessible sources
  - Database includes building replacement values and other primary structural characteristics required for catastrophe risk assessment
  - Database validated using previous studies conducted in Philippines

- Government Asset Database
  - Database of national government assets has been developed using data from government agencies and supplemented by publicly accessible sources
  - Replacement values and assets characteristics required for catastrophe risk assessment are included in database
  - Database (in GIS format) has been delivered

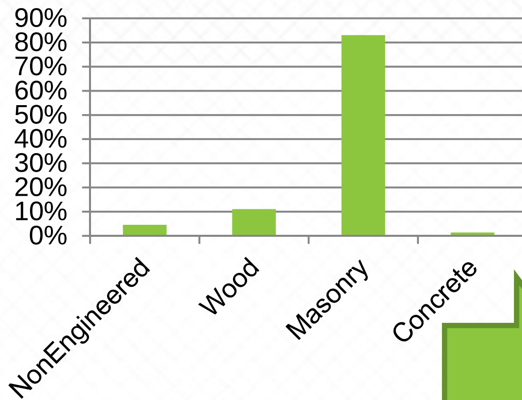
Industry Exposure Database (IED)

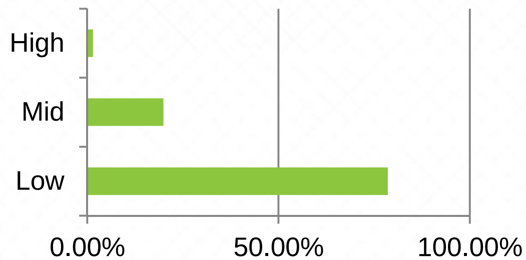
- Methodology adopted for development is similar to that adopted for about 95 countries

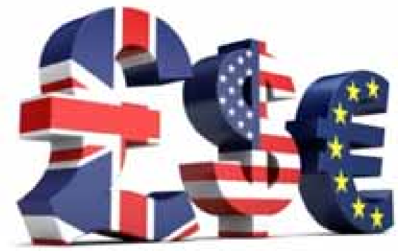
- Robust IEDs are critical for
  - Sovereign (and local) level risk assessment and risk transfer solutions
  - Developing and validating models
  - Providing confidence in loss distributions
  - Estimating losses for real-time events



Comprehensive IED for the Philippines





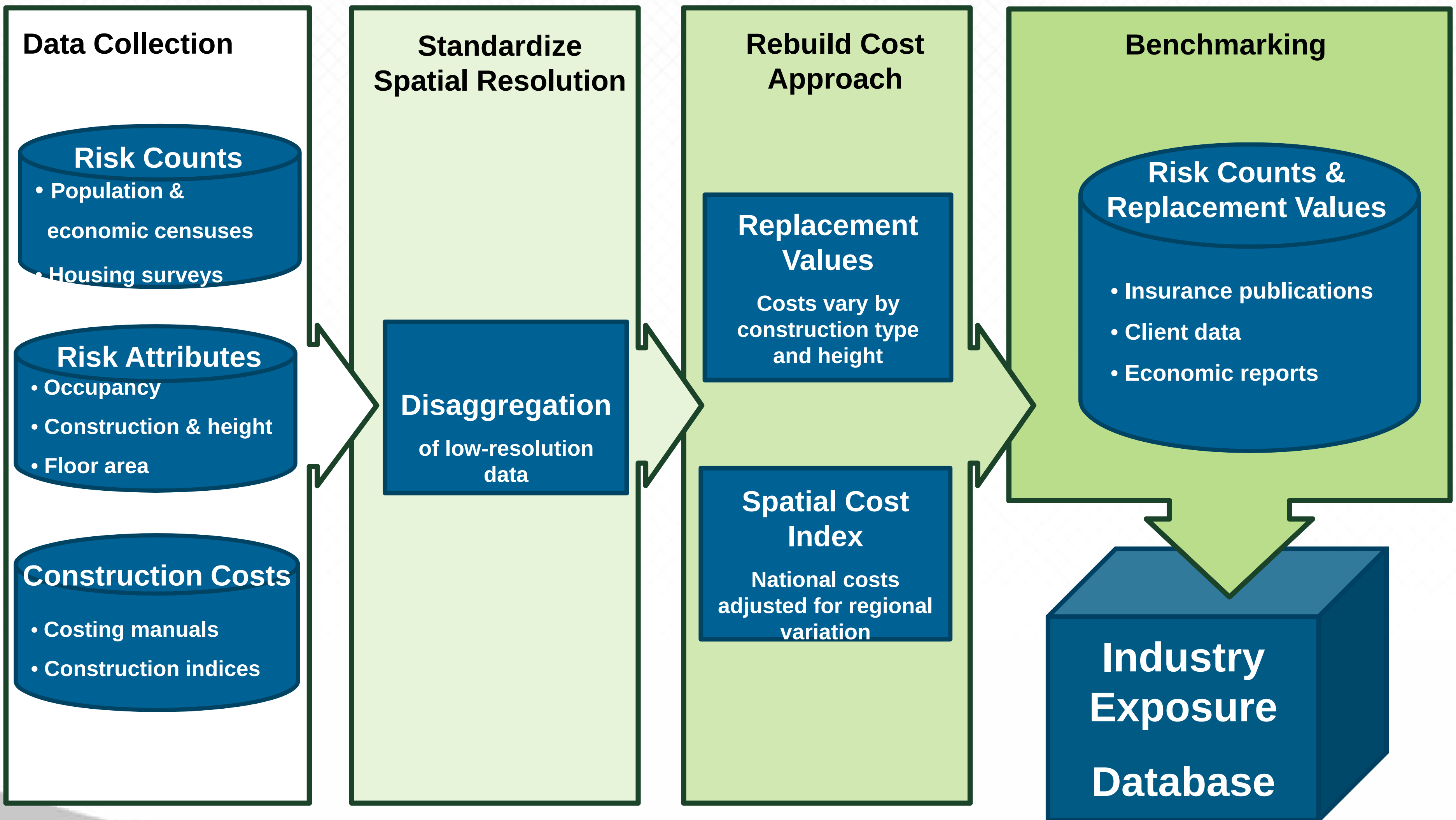


Risk counts by occupancy

Distributions of risks by construction and height

Replacement Values

Robust Approach for Building IEDs



Data Disaggregation Improves Spatial Accuracy of Exposures

Data typically available at low geographic resolution

Actual risk distributions reflect human settlement patterns

Detailed Occupancies Included in the IED

- Residential dwellings
  - Single family; duplex; and apartment
- Commercial establishments
  - Wholesale and retail trade; accommodation and food; information and communications; financial and insurance activities, real estate activities; technical activities; administrative and support services; education; human health and social work; arts, entertainment and recreation; other services
- Industrial establishments
  - Mining and quarrying; manufacturing; electricity, gas steam and air conditioning supply; water supply, sewerage, waste management and remediation activities; construction; transportation and storage
- Government (Public) assets
  - Roads, bridges, power plants, public schools, airports, public universities, ports, light rail, government hospitals, public administration buildings, government medical facilities, rails, prisons, residual institutions, etc.

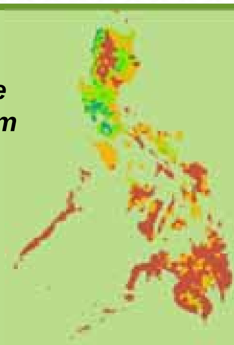
Various Types of Data Used to Develop Construction Distributions

Census and Surveys

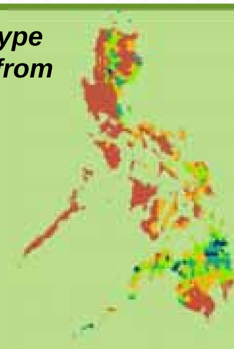
Height, Wall, Frame and Year Built Distributions

Concrete/Brick/

Stone Wall Type Distribution from Census



Wood Wall Type Distribution from Census

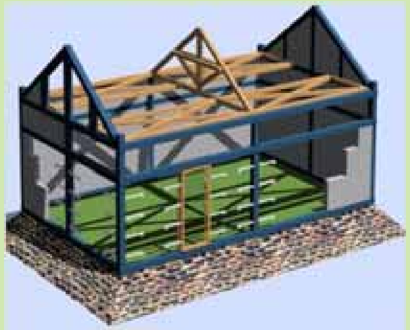


- 0-20%
- 21-40%
- 41-60%
- 61-80%
- 81-100%

Engineering and Risk Assessment Studies

Structural Types

Handbook On Good Building Design And Construction In The Philippines

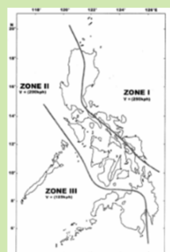


GIS Layers

Urbanicity, Hazard and Location

2001 — 2005 — 2007

Philippines Wind Zone



Philippines Seismic Zone

Philippines Hazard Map

Structural Types Included in the IED

Non-engineered & Wood

- Non-engineered
- Wood Frame

Masonry

- Unreinforced
- Reinforced

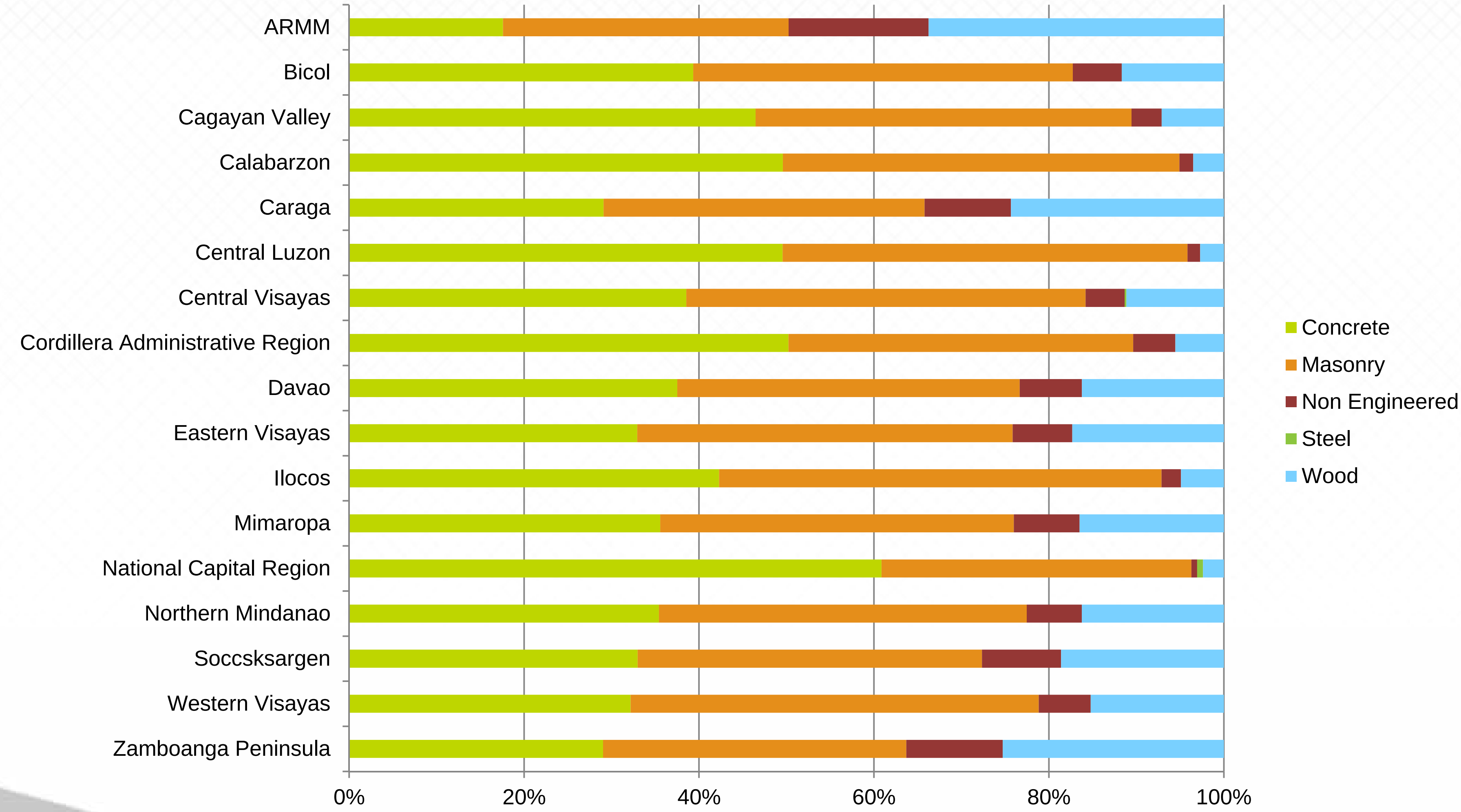
Concrete

- Reinforced Concrete Shear Wall(With MRF)
- Reinforced Concrete Shear Wall(Without MRF)
- Reinforced Concrete MRF

Steel

- Light Metal
- Steel MRF

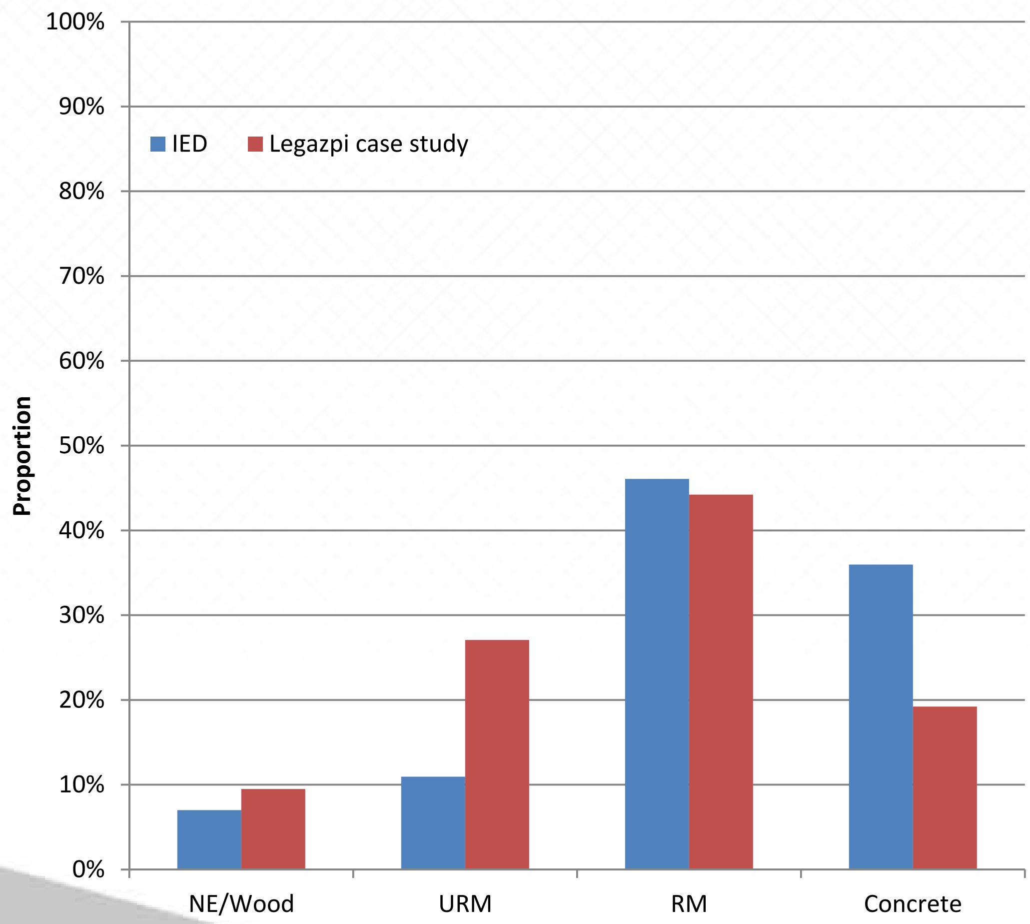
Residential Construction Distributions by Region



Commercial/Industrial Construction Distributions by Region

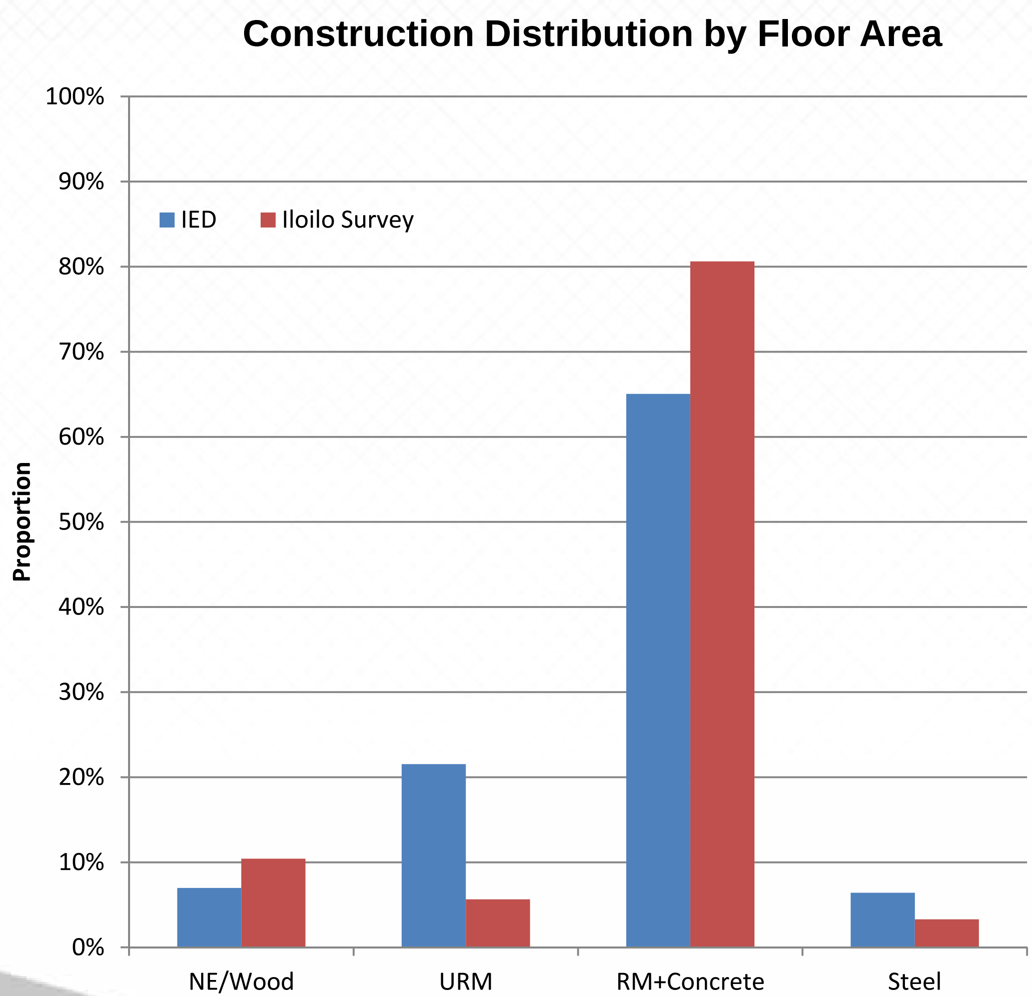
Validation: Construction Distributions in Legazpi are Consistent with Independent Surveys

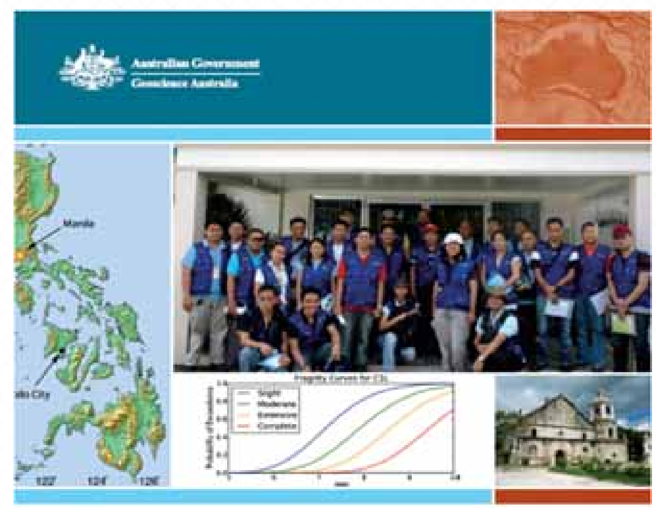
Construction Distribution by Replacement Cost



Using high resolution satellite data for the identification of urban natural disaster risk

Validation: Independent Surveys from Iloilo City Compare Favorably with AIR's Construction Distribution



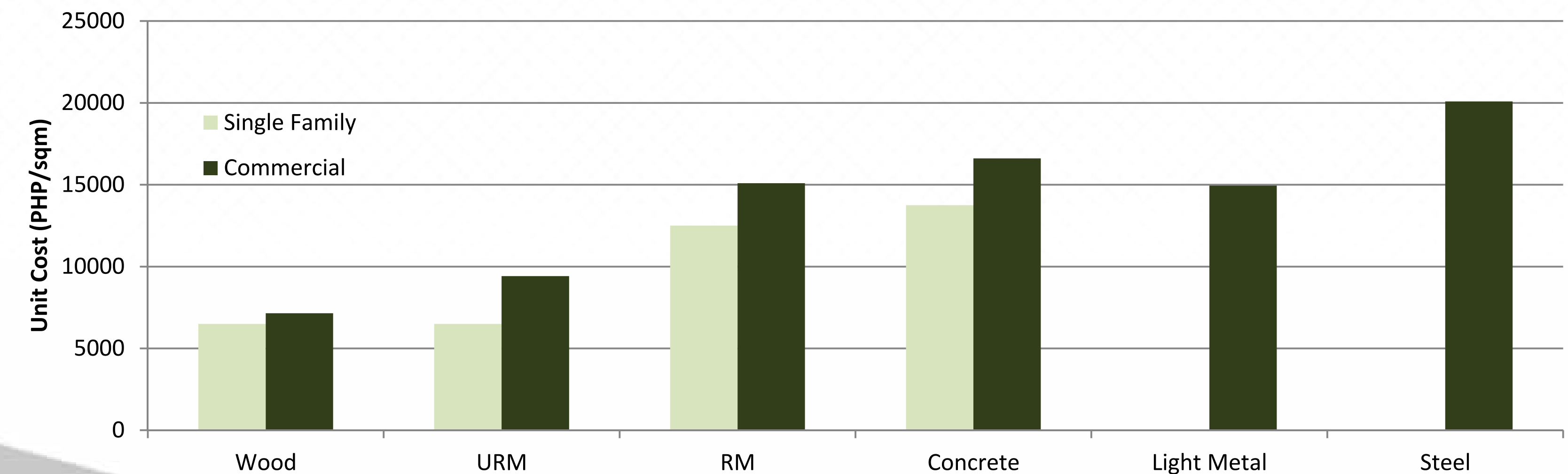

Australian Government
Geoscience Australia

Strengthening natural hazard risk assessment capacity in the Philippines:

An earthquake impact pilot study for Iloilo City, Western Visayas

Sources of Data Used to Derive Replacement Values

- Spon’s Asia-Pacific Construction Handbook (Davis Langdon & Seah International)
- Philippines Report, Rider Levett Bucknall
- International Report, Rider Levett Bucknall
- Construction Statistics from Approved Building Permits (Philippines National Statistics Office)
- Strengthening Natural Hazard Risk in the Philippines (World Bank)



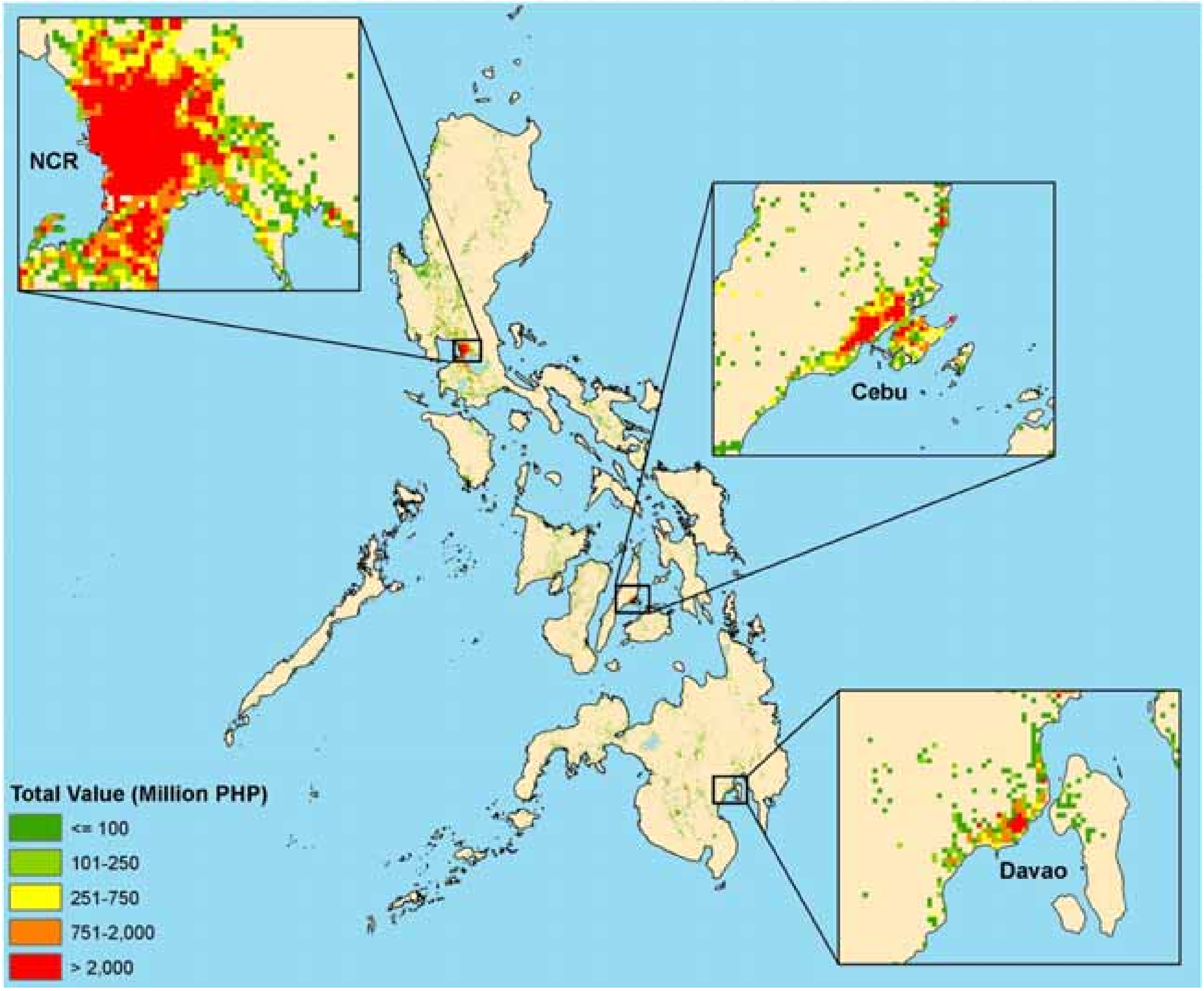
Low Rise National Rebuild Cost Estimates

Summary of Exposure Values (Building and Contents) by Region

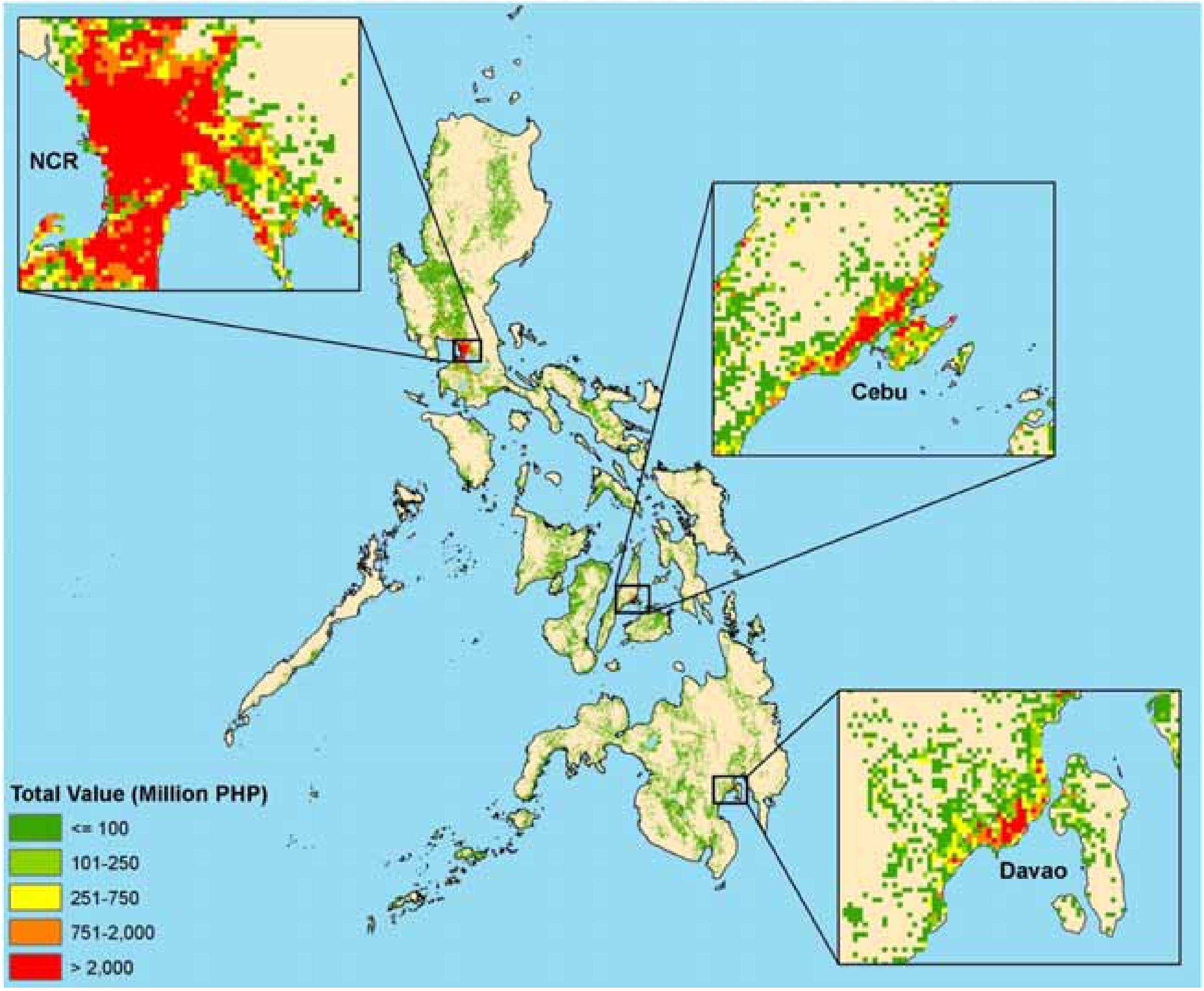
Region	Commercial*	Industrial*	Residential*	Total*
ARMM	23,187	32,671	229,350	285,207
Bicol	123,441	129,191	679,340	931,972
Cagayan Valley	97,868	63,446	538,284	699,597
Calabarzon	681,770	1,156,533	2,812,159	4,650,462
Caraga	50,956	66,211	247,129	364,296
Central Luzon	515,735	544,242	1,989,159	3,049,136
Central Visayas	496,072	444,315	1,206,439	2,146,826
Cordillera Administrative Region	95,486	63,212	269,489	428,187
Davao	177,087	144,901	609,419	931,407
Eastern Visayas	52,510	69,889	527,618	650,017
Ilocos	198,107	134,463	897,366	1,229,936
Mimaropa	64,555	105,986	326,247	496,788
National Capital Region	4,205,976	2,121,562	5,016,953	11,344,491
Northern Mindanao	197,956	312,011	623,058	1,133,025
Soccsksargen	100,668	189,349	451,754	741,771
Western Visayas	226,195	202,721	1,003,100	1,432,017
Zamboanga Peninsula	62,453	128,086	345,185	535,724
Total	7,370,024	5,908,787	17,772,049	31,050,859

***Values in million PHP**

Commercial Exposures Concentrated in Urban Areas



Residential Exposures Reflect Population Centers



Validation: Comparison with Modeled Capital Stock

- The Gross Capital Stock (GCS) represents the value of the national productive assets
  - A subset of the GCS is directly comparable to residential, commercial, and public buildings
  - Starts with an initial value from a fixed point in time, for example1970
  - New buildings are created and old ones may be removed, this is known as Gross Fixed Capital Investment (GFCI)

Occupancy	GCS Value (Million PHP)	IED Value (Million PHP)
Residential	13,903,870	14,217,639
Commercial	10,010,787	9,381,036*

*Includes public buildings

National Government Asset Database

National Government Asset Database

- Extensive data collection effort
- Objectives:
  - Develop a GIS-based exposure database of national government assets including state-owned enterprises and specific infrastructure assets
  - Liaise and collect data from local national agencies
  - Condition raw data to be used with catastrophic risk models

Balangbalang Elementary School, Agusan Del Norte

Data Collection Challenges (from a Catastrophe Modeling Perspective)

- Data was found to be incomplete and inaccurate, in general
- Same data from two sources was sometimes contradicting
- Data often was not in a format for use with catastrophe models
- Data sometimes came as a hard copy requiring significant effort to turn them into a usable electronic database
- Delays in responses from some agencies
- General difficulty in acquiring certain exposure datasets

- While it was perceived that a lot of data was available and easily accessible in the Philippines, the data in general was difficult to obtain, incomplete, and not at the level that can be directly or easily used for an exposure database

Local Agencies Contacted

Abbreviation	Agency
BOC	Bureau of Corrections
CAAP	Civil Aviation Authority of the Philippines
CHED	Commission of Higher Education
DepEd	Department of Education
DILG	Department of Interior and Local Government
DOH	Department of Health
DPWH	Department of Public Works and Highways
GSIS	Government Service Insurance System
LRTA	Light Rail Transit Authority
NPC	National Power Corporation
NSO	National Statistics Office
PNR	Philippine National Railway
PPA	Philippine Ports Authority
TransCo	National Transmission Corporation

Review of Raw Data Collected from Local Agencies

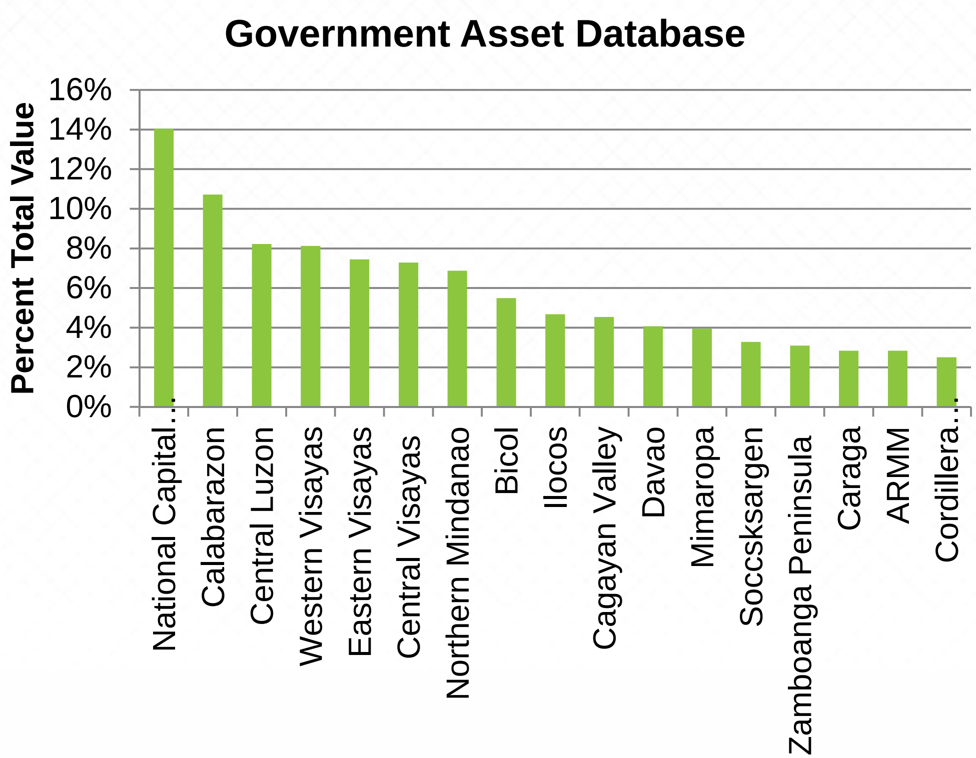
Dataset	Agency	Raw Data Quality		
		Location	**Attributes**	**Replacement Values**
Roads	DPWH	Good	Good	Good
Bridges	DPWH	Good	Good	Good
Prisons	BOC	Good	Good	Good
Light Rail	LRTA	Good	None	None
Airports	CAAP	Good	None	None
Schools	DepEd	Poor	OK	OK
Public Administration Buildings	DPWH	Poor	OK	OK
Hospitals	DOH	Poor	None	None
Seaports	GSIS	Poor	None	OK
Flood Control & Drainage	DPWH	Poor	Poor	Poor

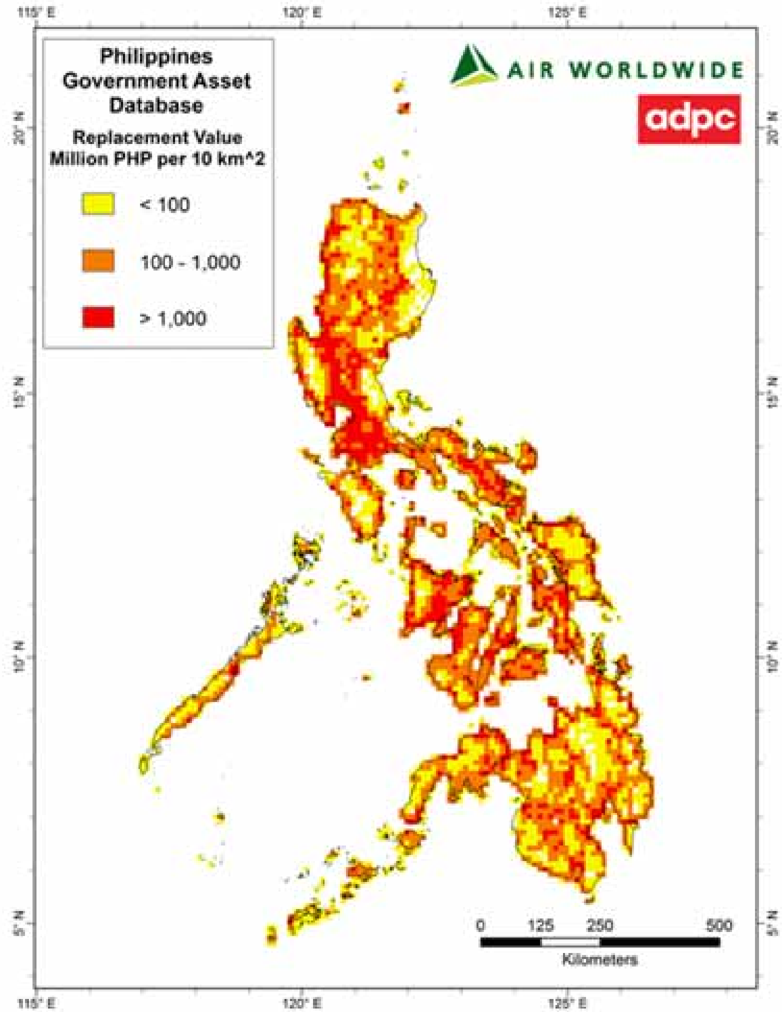
Final Government Asset Database Scope

Asset Type	Number	Estimated Replacement Value (PHP)	Percent Value
Road	30,673 km	680,566,613,326	25.1%
Residual Institutions	n/a	461,674,455,000	17.0%
Bridge	7,860	326,790,678,987	12.0%
Power Plant	24	295,667,261,120	10.9%
Public School	46,606	294,944,436,274	10.9%
Airport	85	232,017,926,000	8.6%
Public University	113	123,874,249,854	4.6%
Port	190	111,280,700,659	4.1%
Light Rail	49 km of track & 45 stations	65,470,607,012	2.4%
Government Hospital	774	49,986,422,951	1.8%
Public Administration Building	4,417	28,750,872,283	1.1%
Government Medical Facility	17,969	25,867,915,868	1.0%
Rail	479 km of track & 32 stations	14,829,614,040	0.5%
Prison	122 buildings in 7 prisons	509,850,000	0.0%
Total	**-**	**2,712,231,603,374 (25% of GDP)**	**-**

Assets in red required substantial additional work

Final Government Asset Database Statistics and Cost Map





Example of Database

ID	Name	Note	Y	X	Estimated Value (PHP)	Construction	Occupancy	Height	Type	Municipality
91667	Philippine Heart Center	DOH Hospital Level 4	14.644	121.047	1,518,595,041	131	316	4	Government Hospital	Quezon City
39243	Zamboanga International Airport	Runway	6.919	122.062	1,486,555,000	206	353	1	Airport	Zamboanga City
90765	Negros State College of Agriculture	.	9.851	122.889	1,433,671,735	131	345	1	Public University	Kabankalan City
90598	Cagayan De Oro Port	PMO: Cagayan De Oro	8.494	124.663	1,407,678,481	100	354	1	Port	Cagayan de Oro City
38534	Narciso Ramos Bridge	.	15.993	120.686	1,353,873,084	203	300	1	Bridge	Asingan

Roads – Raw Data Quality: Good

- GIS data obtained from DPWH for national primary and secondary roads
  - Raw data: 31,341 km
  - Validation data: 31,597 km (October 2012 DPWH aggregate data)

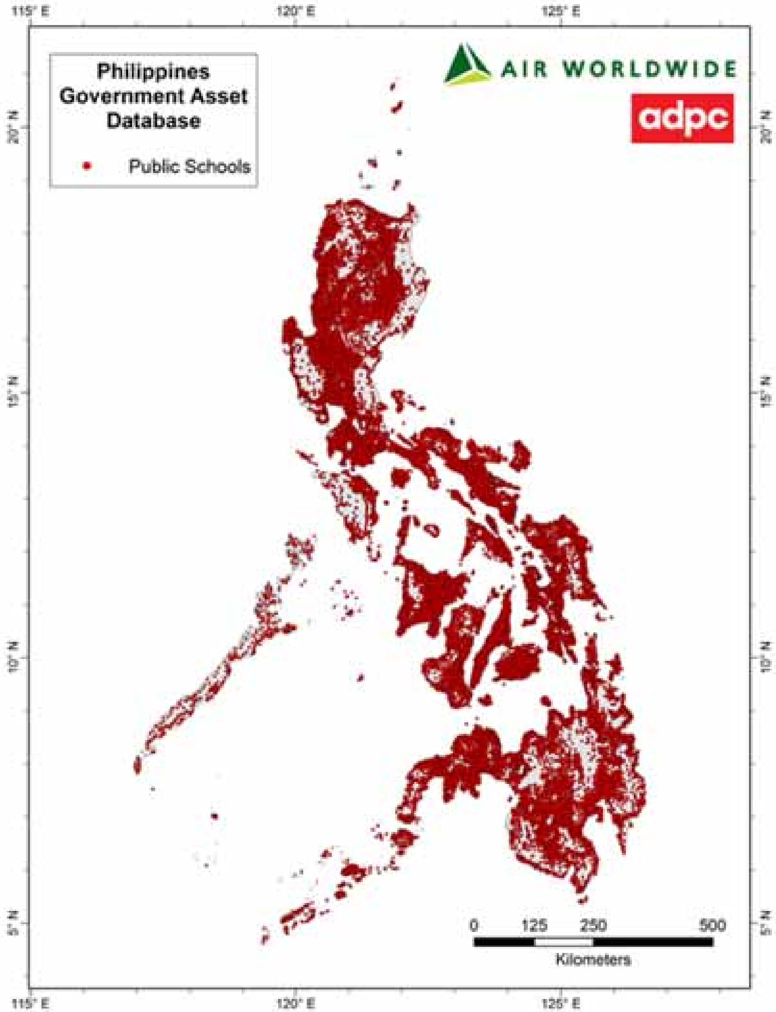
- Attributes include:
  - Road length
  - Surface type – asphalt, concrete, gravel, earth
  - Condition – good, fair, bad, poor

- Replacement costs:
  - Unit cost estimated from data obtained from DPWH
  - Function of road length, road type, and condition

- Aggregated to 1-KM grid for modeling purposes

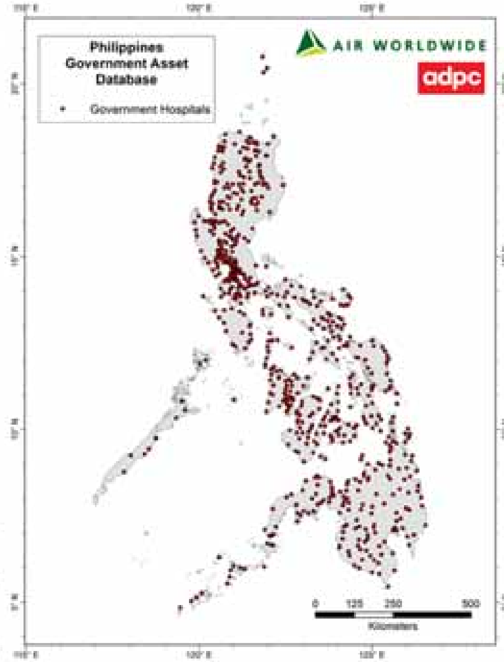
Public Schools – Moderate Data Quality

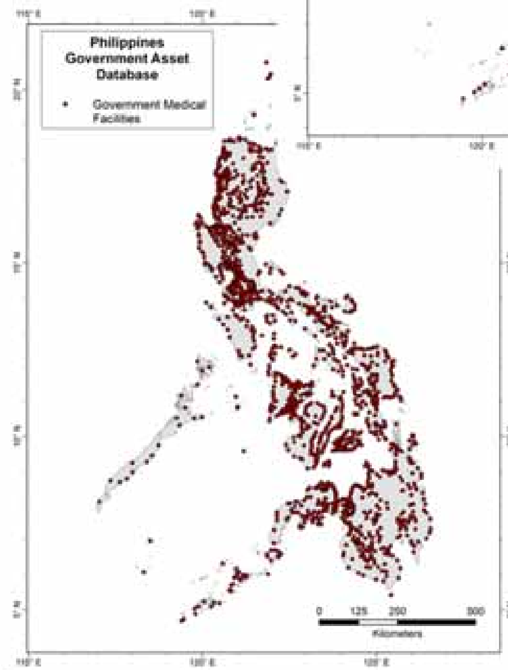
- Raw SQL data: 43,647 schools
- Validation: 45,973 schools in 2011-12 DepEd website tables
- Data attributes: School ID, Building type, Year of construction, Number of stories, Building length and width
- Replacement cost estimated as function of total floor area and region
- Quality concerns:
  - Inaccurate locations based on satellite imagery spot checks
  - Over 75% with no locations
  - Missing municipalities (e.g. no Manila schools)
  - Attribute errors (e.g. building length varied from 0m to 11km)
- Supplemental data: DepEd website and MMEIRS Study
- Unknown locations aggregated to centroids and population centroids of Municipalities, Barangays, or settlements based on given data
- **Final Database: 46,606 public elementary and secondary schools**



Hospitals – Raw Data Quality: Poor

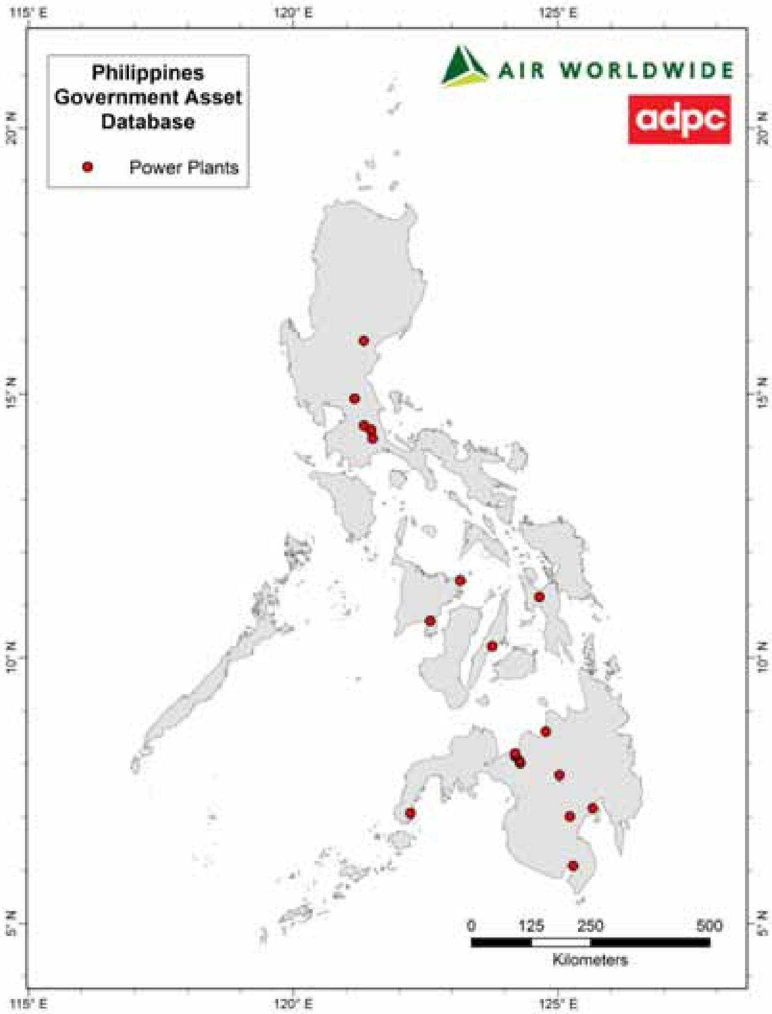
- GIS data obtained directly from DOH Agencies
  - 679 hospitals; 2,390 regional health units, 172 Barangay heath stations
  - Data attributes: only Name and (old) Unit ID
- Quality Concerns:
  - Incorrect locations
  - Not all buildings represented
  - No replacement costs
- Supplemental data: MMEIRS Study, DOH website, National Health Facility Registry, and other public sources
- Validation: all government hospital locations manually validated and corrected via satellite imagery
- Replacement costs inferred from industry reports and public sources and simulated using several metrics:
  - Building footprint area, facility type, and number of beds
- Additional government health facilities included based National Health Facility Registry data
- **Final Database Total: 774 Government Hospitals and 17,969 Government Medical Facilities**



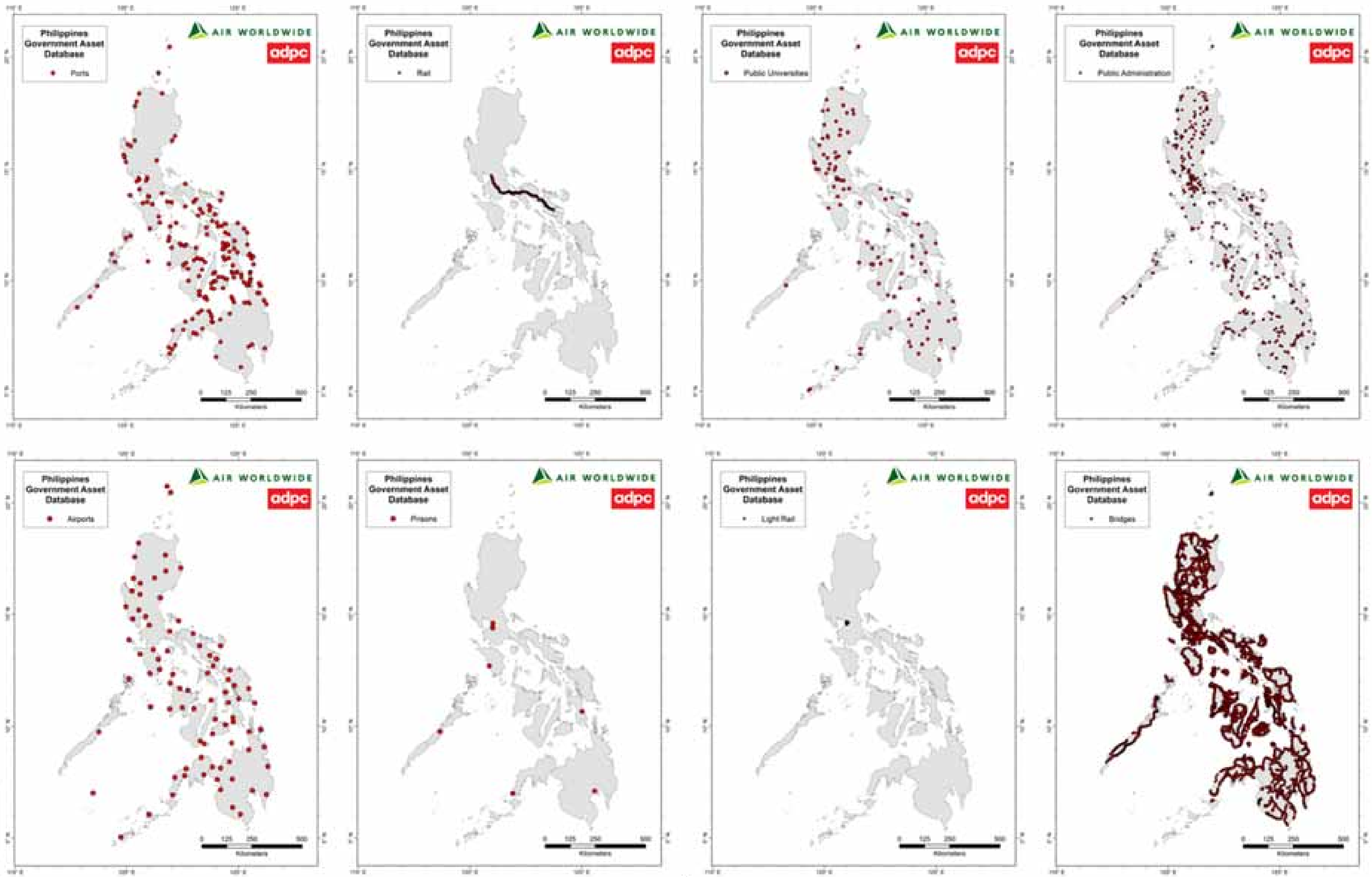


Power Plants – Raw Data Quality: None Available

- Although good data was promised, no useful data provided by local agencies
- Public data utilized instead – including DOE aggregate tables, CARMA, industry reports, and literature
- Only large NPC (National Power Corporation) and NPC/IPP (joint NPC and independent power producer) facilities considered
- Locations validated via satellite imagery
- Data attributes: Construction year, Type (coal, gas, geothermal, etc.), Power capacity, etc.
- Replacement costs estimated from industry data, construction data, publically available reports, etc.
    - For necessary, replacement costs were simulated from several metrics including plant type, size, and total power capacity
- **Final database total: 24 NPC and NPC/IPP Power Plants**



Other Assets: Ports, Rail, Public Universities, Public Administration Buildings, Airports, Prisons, Bridges, Etc.

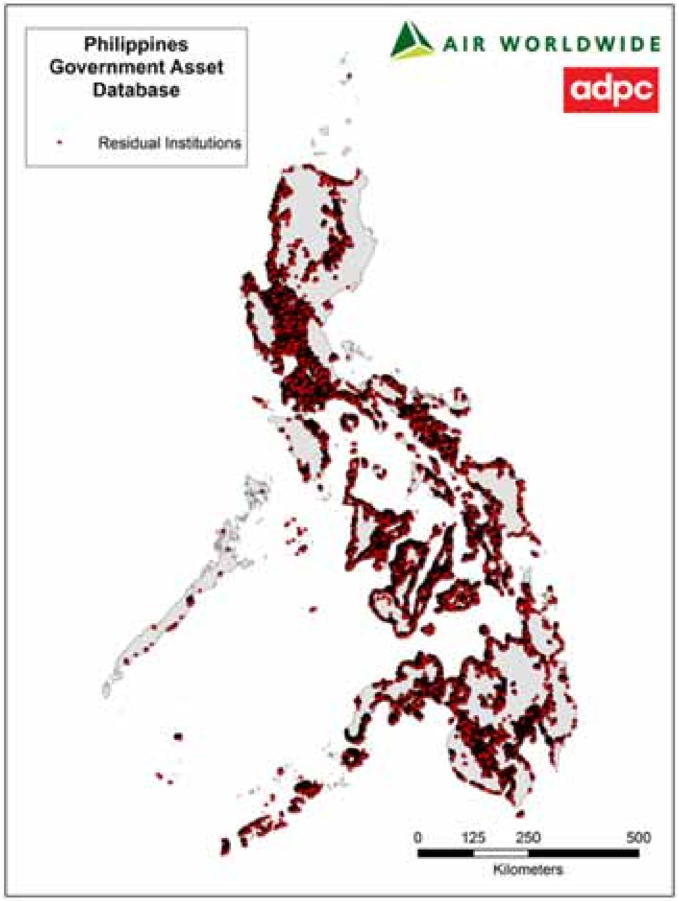


Residual Institutions

- Residual institutions represent government assets for which direct data was not obtained
    - fire stations, police stations, city halls, other public buildings, etc.

- Replacement costs determined from official construction statistics and census data, with reference to the modeled IED and government assets explicitly accounted for in the database

- Assets simulated on 1-km grid based on population data



Earthquake Hazard

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Historical Database: Earthquake

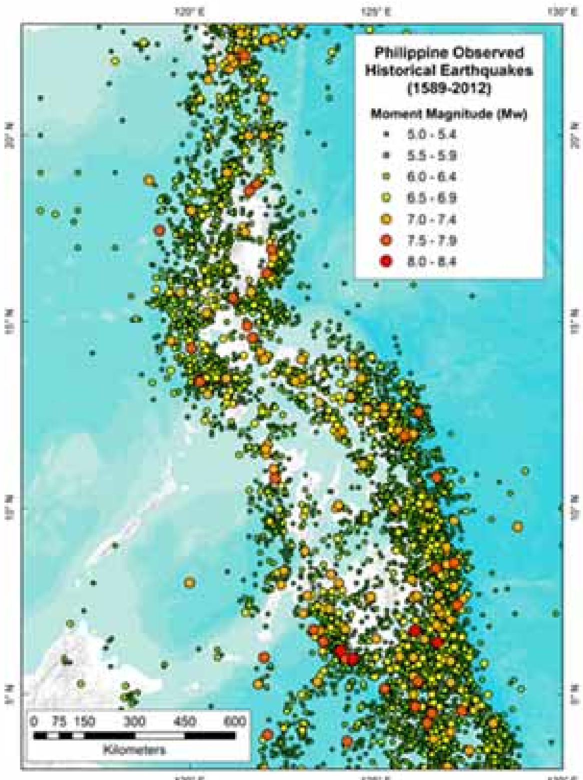
- Data Sources:
  - The ISC-GEM Global Instrumental Earthquake Catalogue
  - The USGS PAGER-CAT catalog
  - The Philippine historical earthquake catalog from Bautista & Oike (2000)
  - The International Seismological Centre (ISC) Bulletin
  - Abe's Catalog of Major Earthquakes of the World

- Harmonized (uniform M_w) earthquake catalog covering the period from 1589 to 2012 (over 21,000 earthquake events)

- Scope: magnitude M_w 4.5 or greater and epicenters within latitude 3 to 23 and longitude 115.5 to 130

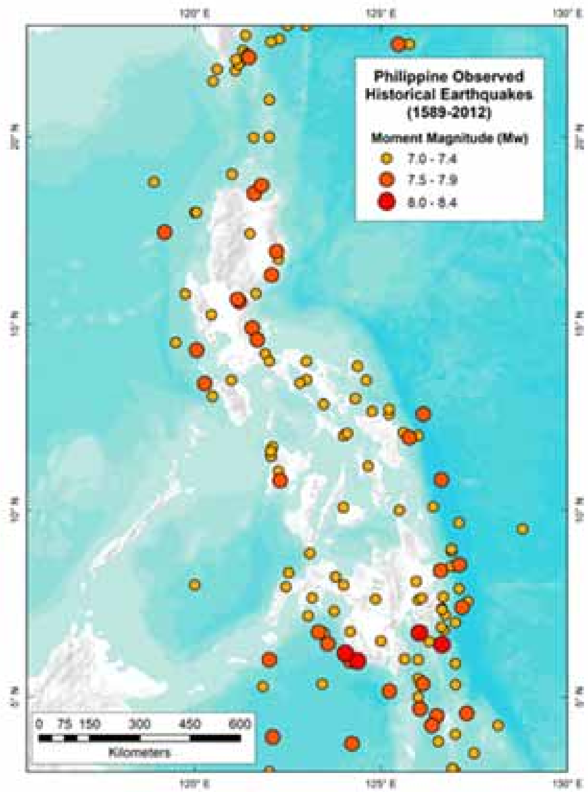
- Not de-clustered (done later for stochastic catalog validation)

Historical Database: Earthquake



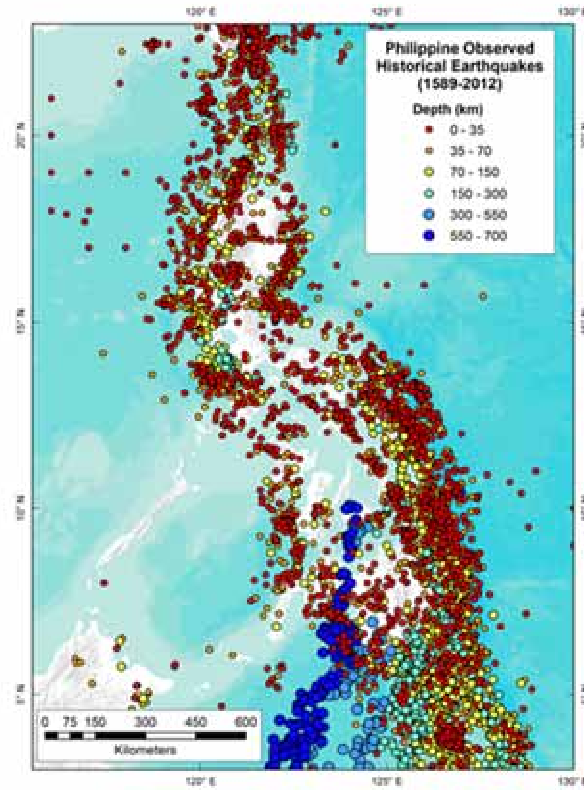
$M_W \geq 5.0$

7,980 Events



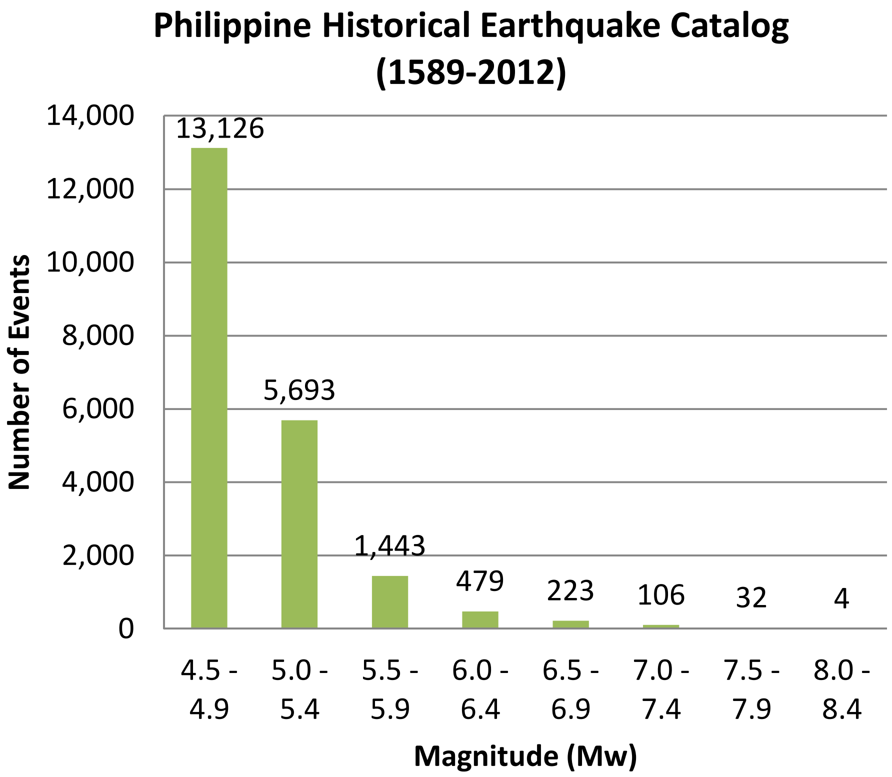
$M_W \geq 7.0$

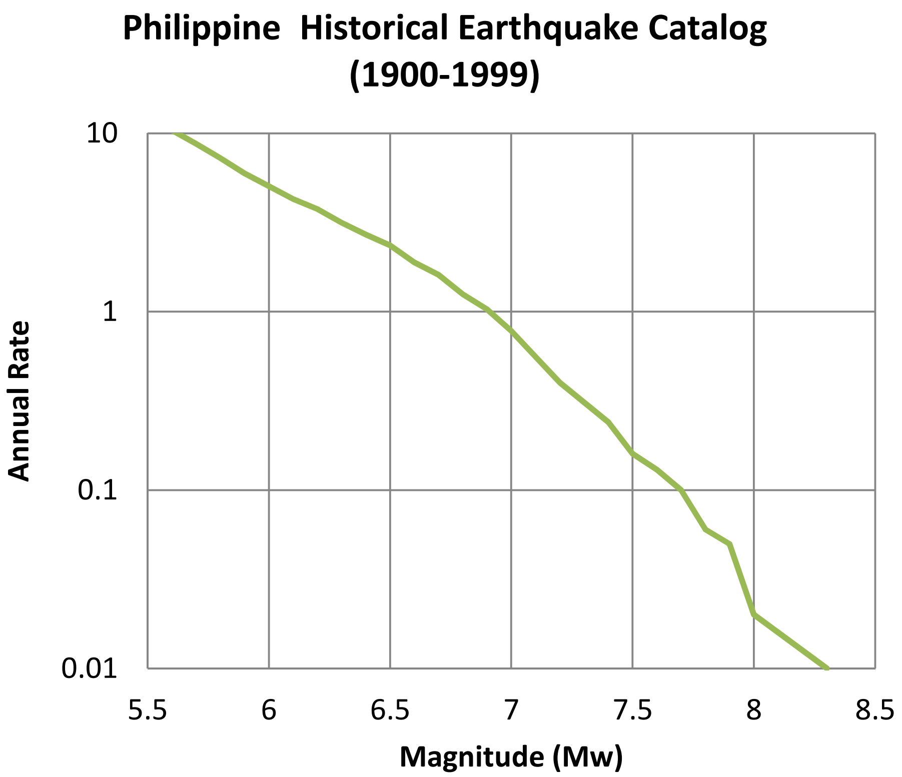
142 Events



Event Depth

Historical Database: Earthquake





Earthquake Historical Database:
1976 Moro Gulf Earthquake and Tsunami

- The historical database for earthquake events contains parametric information about the events


Images source: en.wikipedia.org/wiki/1976_Moro_Gulf_earthqua

Hist_ID	Year	Month	Day	Hour	Minute	Lat	Long	Depth_KM	Depth_Fix	Raw_Magnitude	Raw_Unit	Catalog	ISC_Mag_Author	Mw_Converted
3220	1976	8	16	16	11	6.175	124.047	20		7.96	Mw	GEM	.	8

Historical ID

Chronological information

Location

Magnitude and data source

Converted magnitude

Data sources vary (Bautista & Oike 2000; ABE Catalog, revised May 15, 2000; USGS PAGER-CAT Earthquake Catalog; GEM; ISC).

Consequence Database: Earthquake

- Data Sources: Over 20 databases and other sources, including:
  - National Geophysical Data Center / World Data Service (NGDC/WDS) Significant Earthquake Database
  - USGS PAGER-CAT earthquake catalog
  - Emergency Events Database (EMDAT), maintained by the Centre for Research on the Epidemiology of Disasters (CRED)
  - Philippine Institute of Volcanology and Seismology (PHIVOLCS)
  - Catalogue of Violent and Destructive Earthquakes in the Philippines (Maso)
  - Catalogue of Destructive Earthquakes in the Philippines (Garcia et al., 1985)

- ~300 significant earthquake events dating from 1599 to 2012

- Primary Data Fields: Tsunami Flag, Landslide Flag, Buildings Damaged, Buildings Destroyed, People Injured, Life Loss, Economic Loss

Earthquake Consequence Database: 1976 Moro Gulf Earthquake and Tsunami

- The earthquake event is uniquely identified, and the human and economic losses are enumerated.

Preferred Consq_ID	Preferred Hist_ID	Preferred Year	Preferred Month	Preferred Day	Preferred Hour	Preferred Minute	Preferred Lat	Preferred Long	Preferred Depth_KM	Preferred Depth_Fix	Preferred Raw_Magnitude	Preferred Raw_Unit	Preferred Catalog
214	3220	1976	8	16	16	11	6.175	124.047	20	.	7.96	Mw	GEM

Consequence ID and Historical ID

Chronological information

Location

Magnitude and data source

Significant fields are labeled Minimum, Maximum, or Preferred with a data source for each field. For this example, reliable sources of available data vary.

Preferred People Affected Min	Preferred People Affected Min Source	Preferred People Affected Max	Preferred People Affected Max Source	Preferred People Affected Preferred	Preferred People Affected Preferred Source
90000	NGDC_Notes	181348	EMDAT	181348	EMDAT

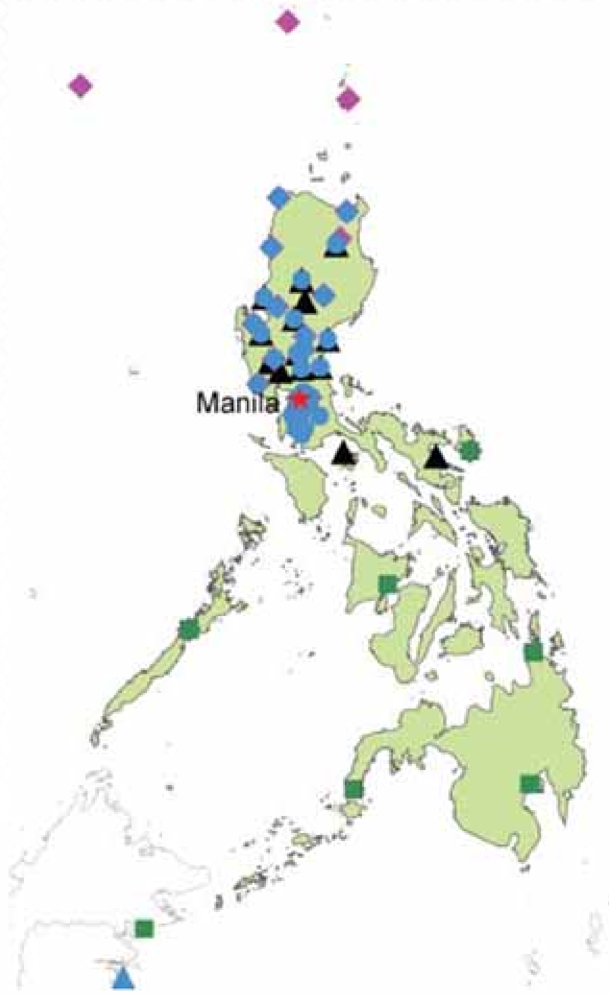
- **Buildings Damaged Preferred = 10,000 (EERI)**
- **Buildings Destroyed Preferred = (no data)**
- **People Affected Preferred = 181,348 (EMDAT)**
- **People Injured Preferred = 9,928 (PAGER)**
- **Life Loss Preferred = 7,079 (PAGER)**
- **Damage Preferred = 134 million USD (NGDC)**

Earthquake Consequence Database: Summary

Time period	Number of Events	Number of Catastrophic Events	Estimated Economic Damage (Current Million USD)	Estimated Economic Damage (Trended Million 2012 USD)	Estimated Life Loss	Estimated Life Loss (Trended 2012 Value)
16th Century	24	15	190	n/a	1,274	n/a
17th Century	15	7	105	n/a	1,124	n/a
18th Century	100	20	298	n/a	2,815	n/a
1900s	14	6	60	n/a	408	n/a
1910s	14	3	39	n/a	109	n/a
1920s	17	7	62	n/a	871	n/a
1930s	5	1	12	n/a	1	n/a
1940s	5	2	5	n/a	90	n/a
1950s	5	2	6	n/a	487	n/a
1960s	2	2	9	302	274	792
1970s	19	2	146	2,348	7,115	16,328
1980s	22	8	14	98	42	75
1990s	30	2	469	2,658	1,721	2,681
2000s	16	1	6	16	11	13
2010 – 2012	10	1	21	21	114	114

AIR Stochastic Earthquake Catalog for SE Asia

- AIR's seismicity model is based on geodetic data, geological fault data, paleoseismic data, plate tectonics, and historical earthquake catalogs
- Model domain is divided into multiple depth layers based on the depth distribution of historical events
- Modeled region is divided into different seismic source zones
- Kinematic model is based on published GPS data and fault slip rates to obtain the seismic moment rate for each seismic source zone

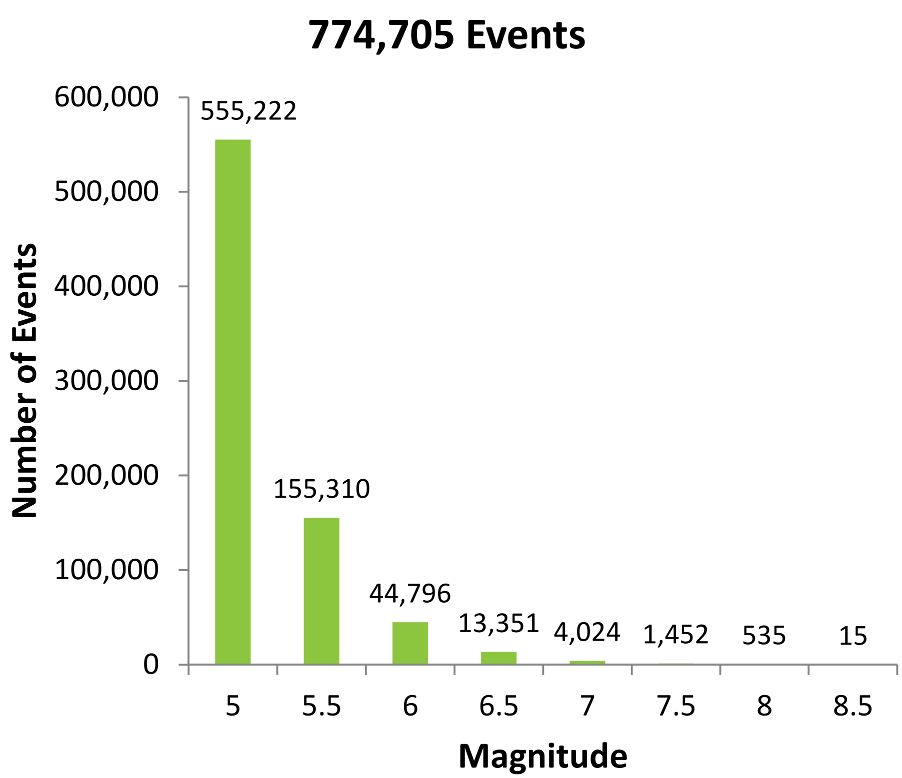


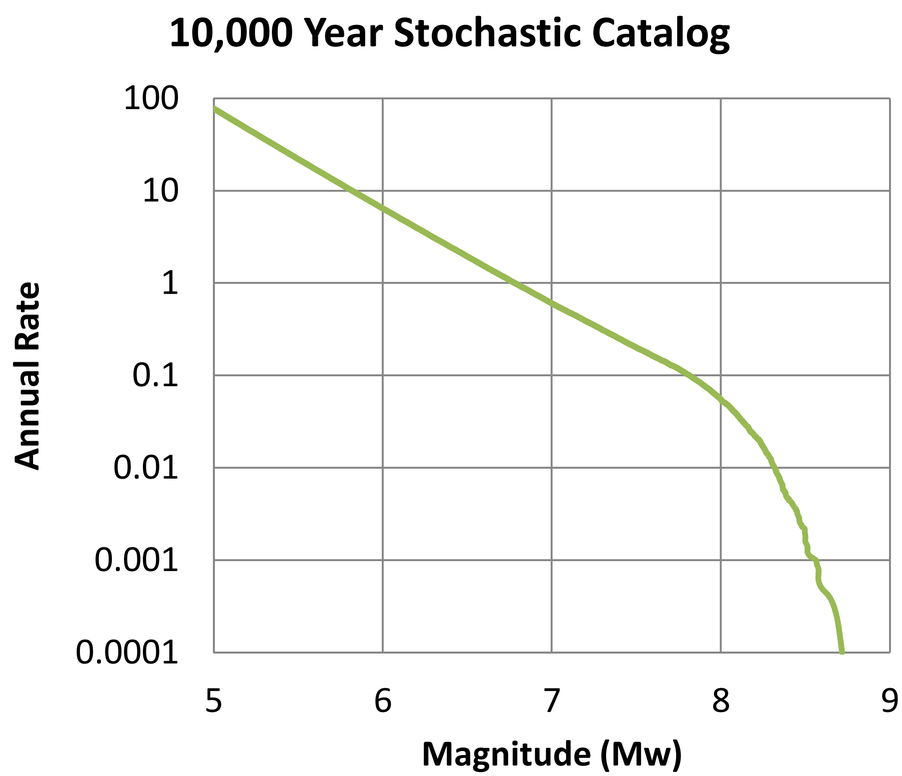
Distribution of GPS stations in the Philippines (some stations abroad are not shown)

AIR Stochastic Catalog:
Modeled Seismicity for the Philippines

AIR's SE Asia stochastic catalog:

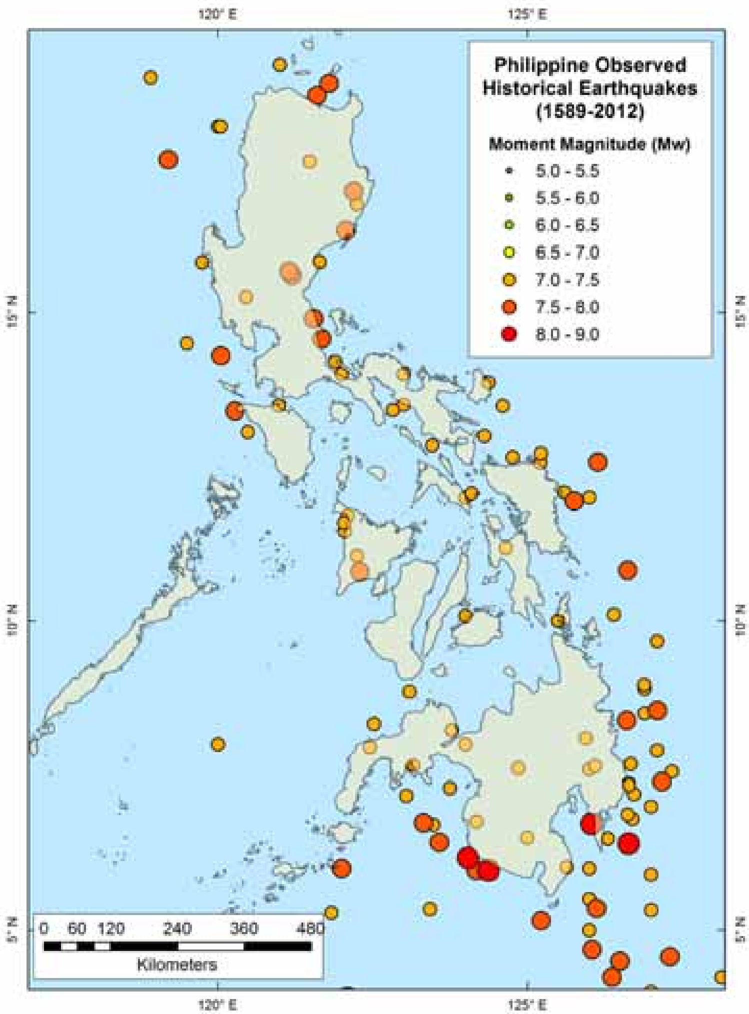
- **10,000-year stochastic catalog of 774,705 events ranging in magnitude from 5.0 to 8.7**



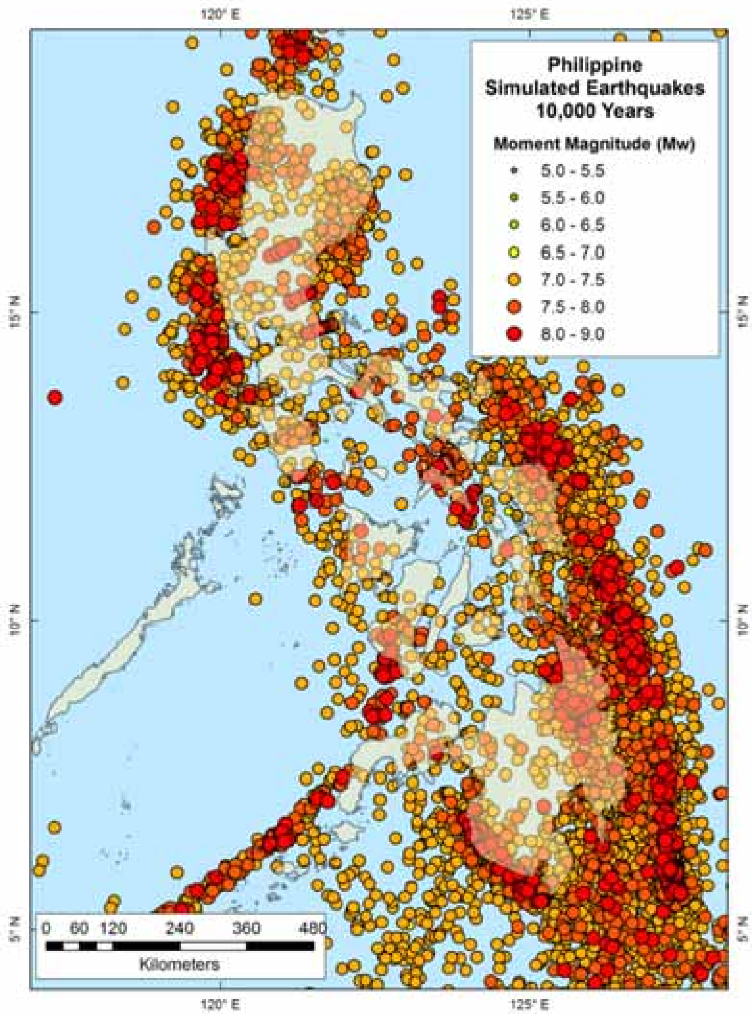


Historical Versus Simulated Earthquakes ($M_w \geq 7.0$)

Historical (423 years)



Stochastic (10,000 Years)

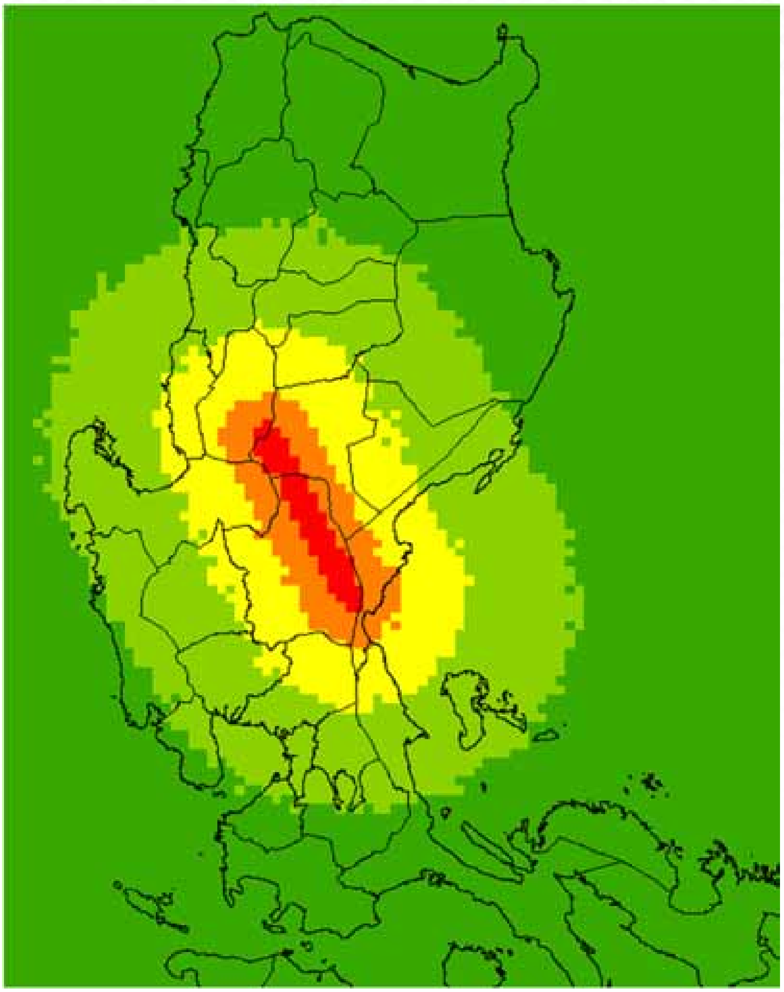


Local Intensity Computation: Ground Motion Prediction Equations

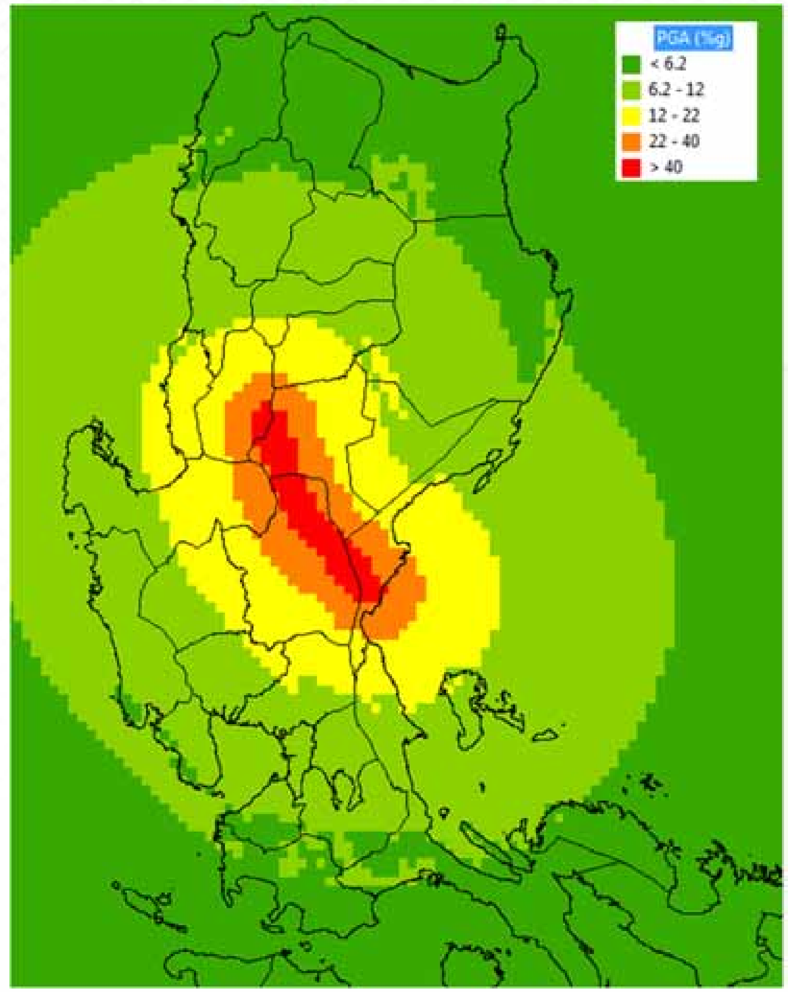
- No published standard GMPE available specifically for the Philippines

- Existing GMPEs which have been used to assess local hazard
  - Japanese GMPEs
    - Fukushima and Tanaka (1990)
    - Torregosa et al. (2001)
  - PEER NGA GMPEs
    - Abrahamson & Silva (2008)
    - Boore & Atkinson (2008)
    - Campbell & Bozorgnia (2008)
    - Chiou & Youngs (2008)
    - Additional for different source mechanisms

Validating Local Intensity: 1990 M7.7 Luzon Earthquake



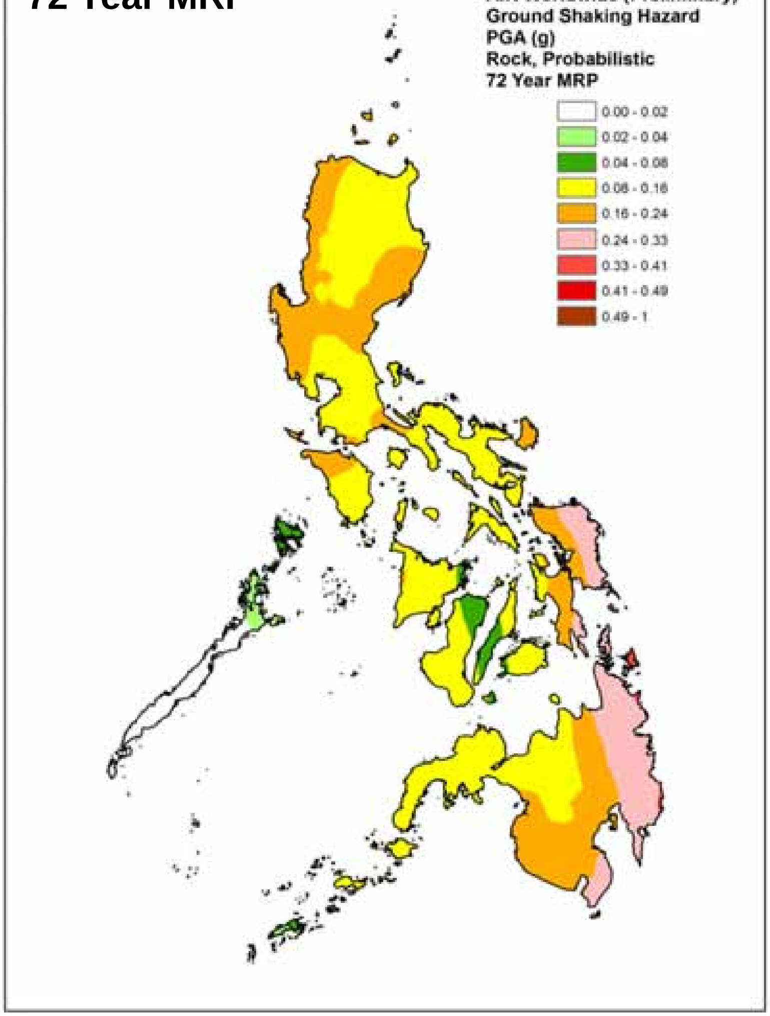
Simulated Mean



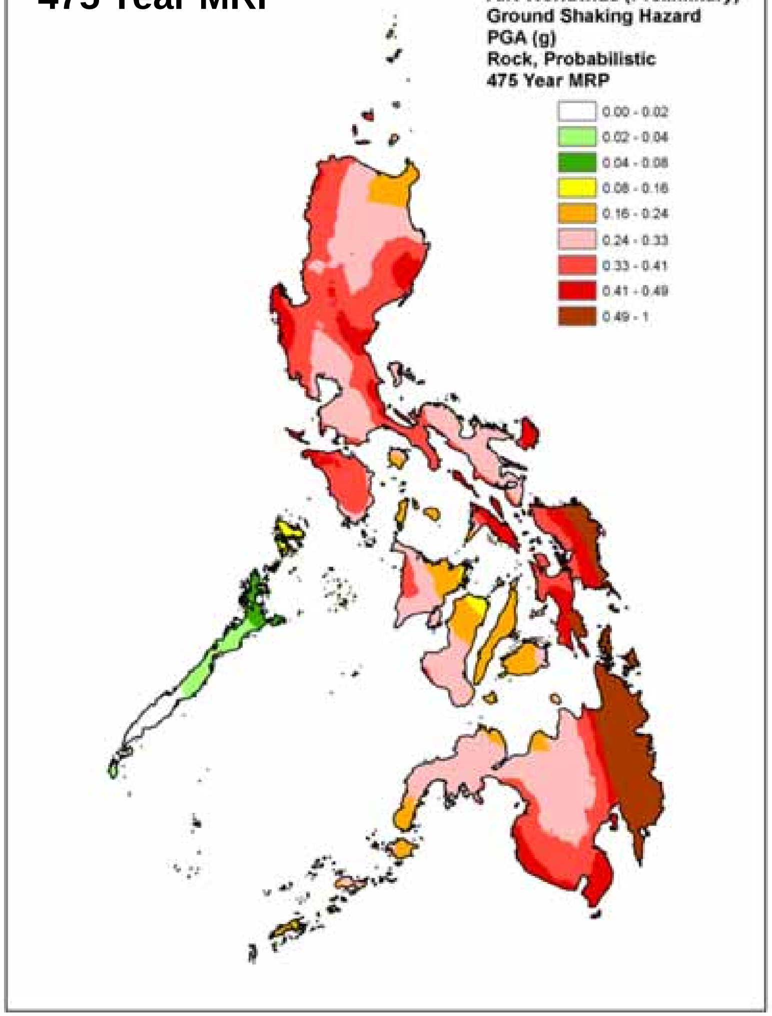
USGS Shakemap Atlas

Fully Probabilistic Ground Shaking Hazard Maps

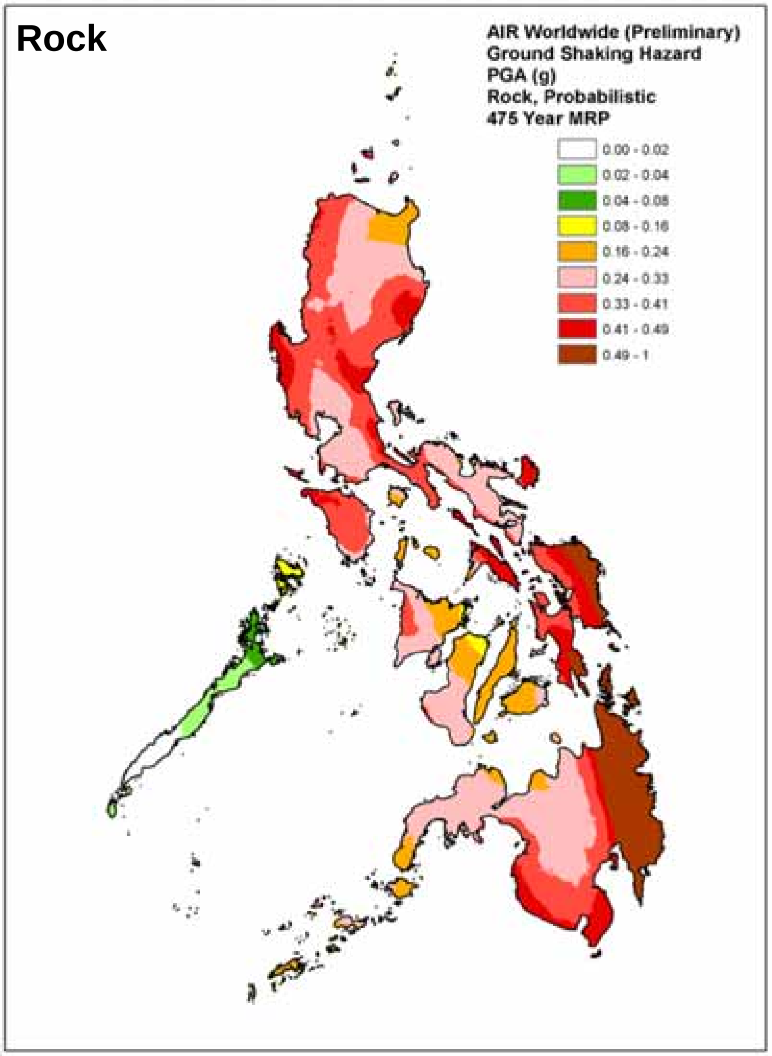
72 Year MRP

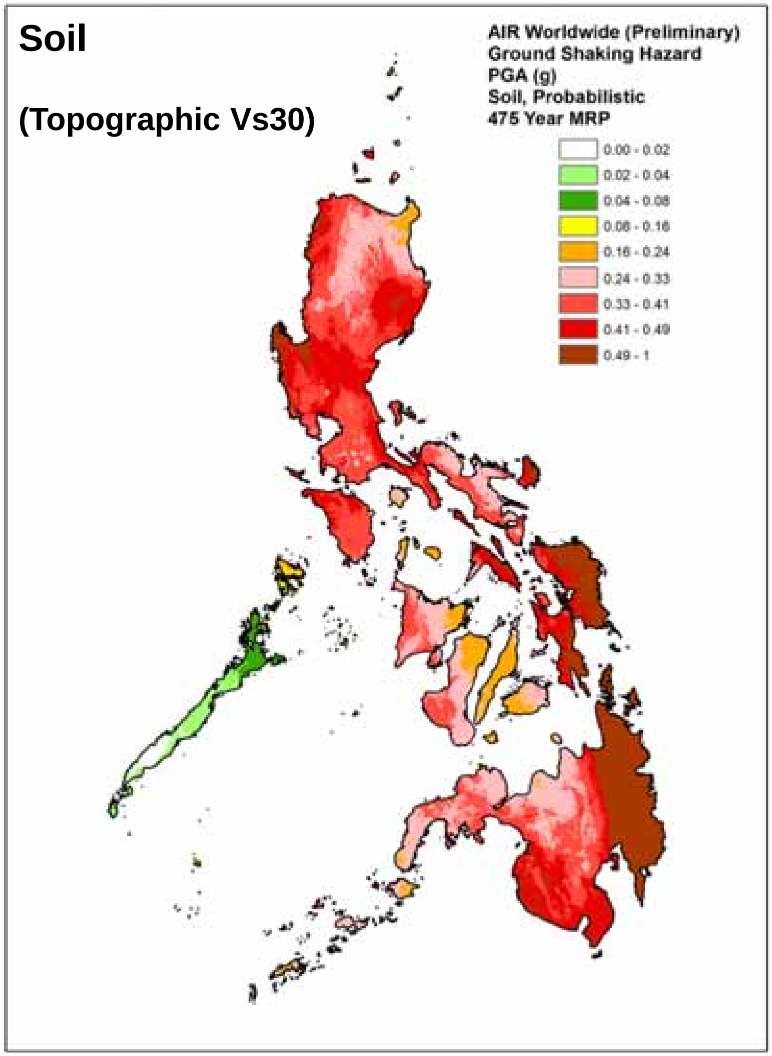


475 Year MRP

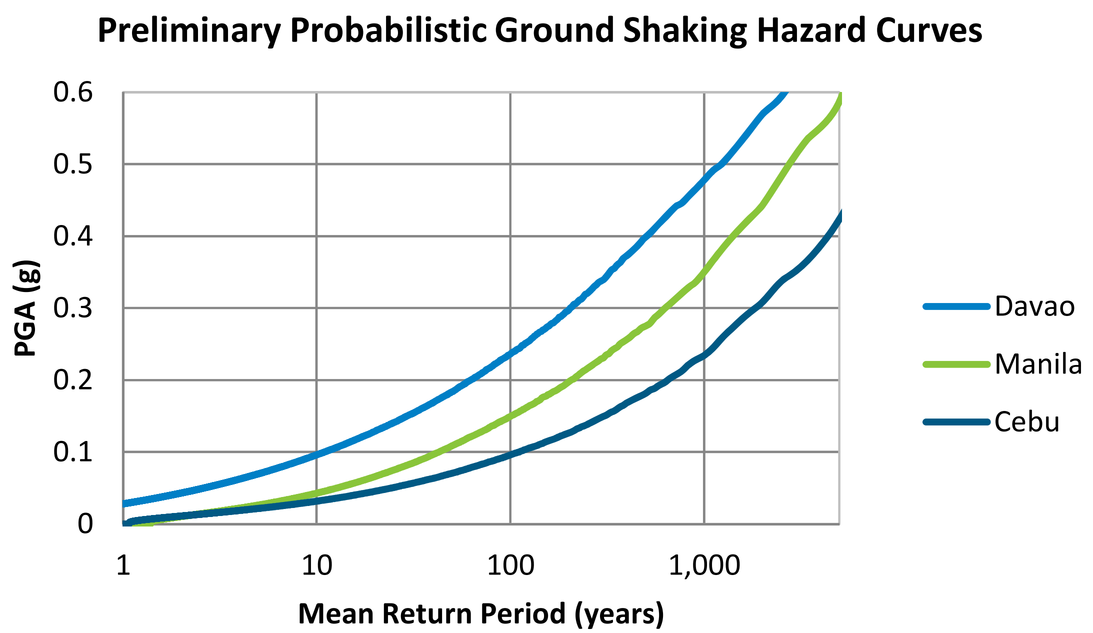


Fully Probabilistic Ground Shaking Hazard Maps





Probabilistic Hazard Result Comparisons

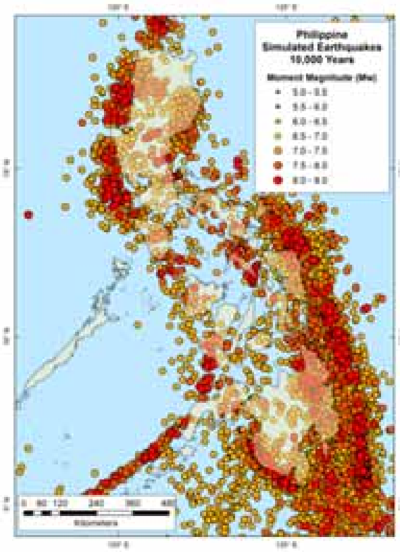


475-year, Rock-Based, Probabilistic PGA (g)		
City	GSHAP/Others[1]	AIR (preliminary)
Davao	0.38	0.38
Cebu	0.25	0.18
Cotabato	0.32	0.37
Central Manila	0.17 – 0.40	0.27

[1]**Bautista/PHIVOLCS (2001);Thenhaus et al. (1994); Torregosa et al. (2001); GSHAP (1999); Koo et al. (2009)**

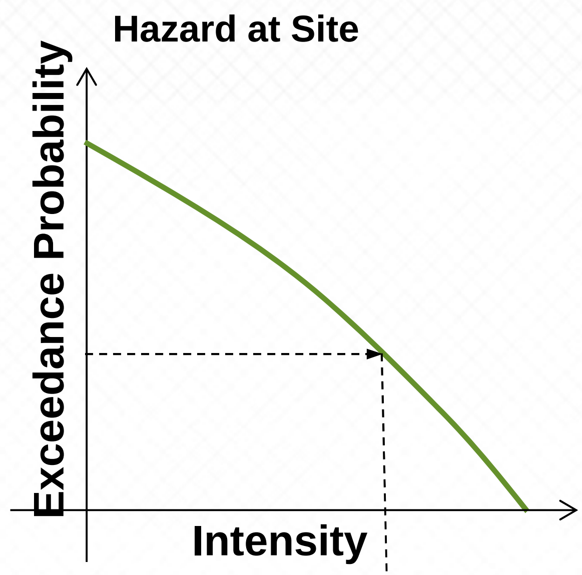
Earthquake Vulnerability

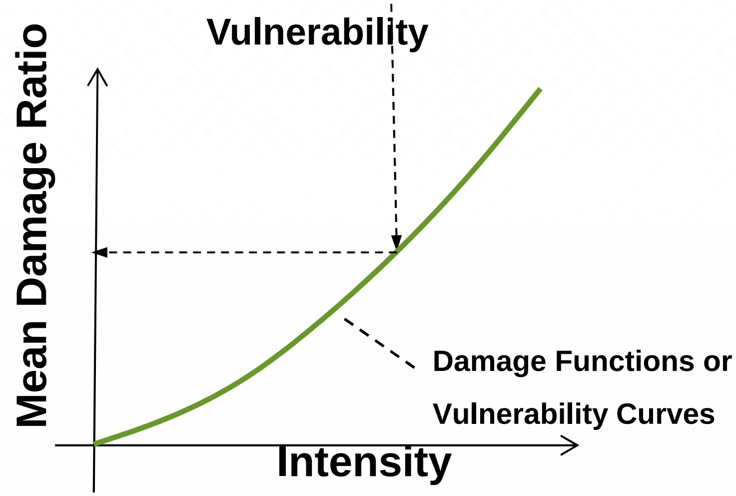
Key Components of Probabilistic Loss Estimation



Stochastic Event Generation at Source

Ground Motion Attenuation





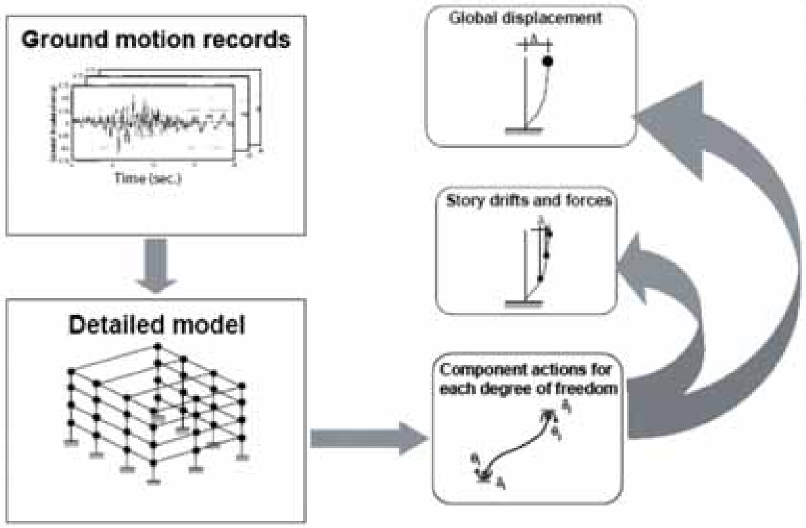
Mean Loss = Replacement Value x Mean Damage Ratio

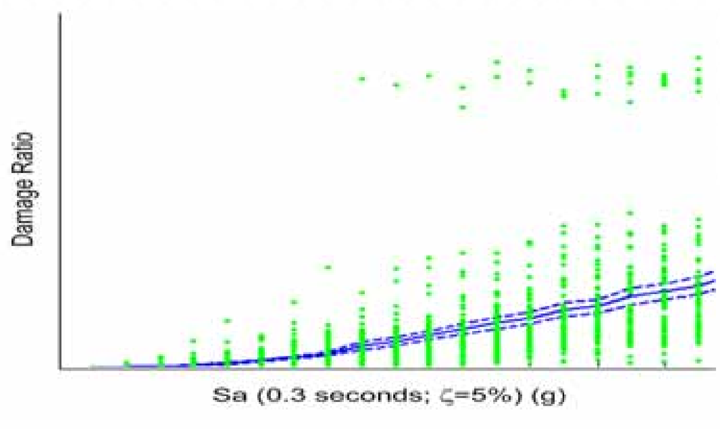
Commonly Adopted Methodologies to Develop Seismic Vulnerability Curves for Buildings

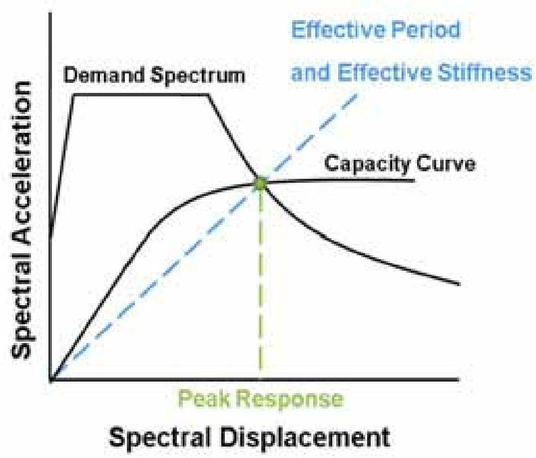
- **Analytical Methods**: Primarily based on computer modeling of buildings.

- **Empirical Methods**: Primarily based on damage data.

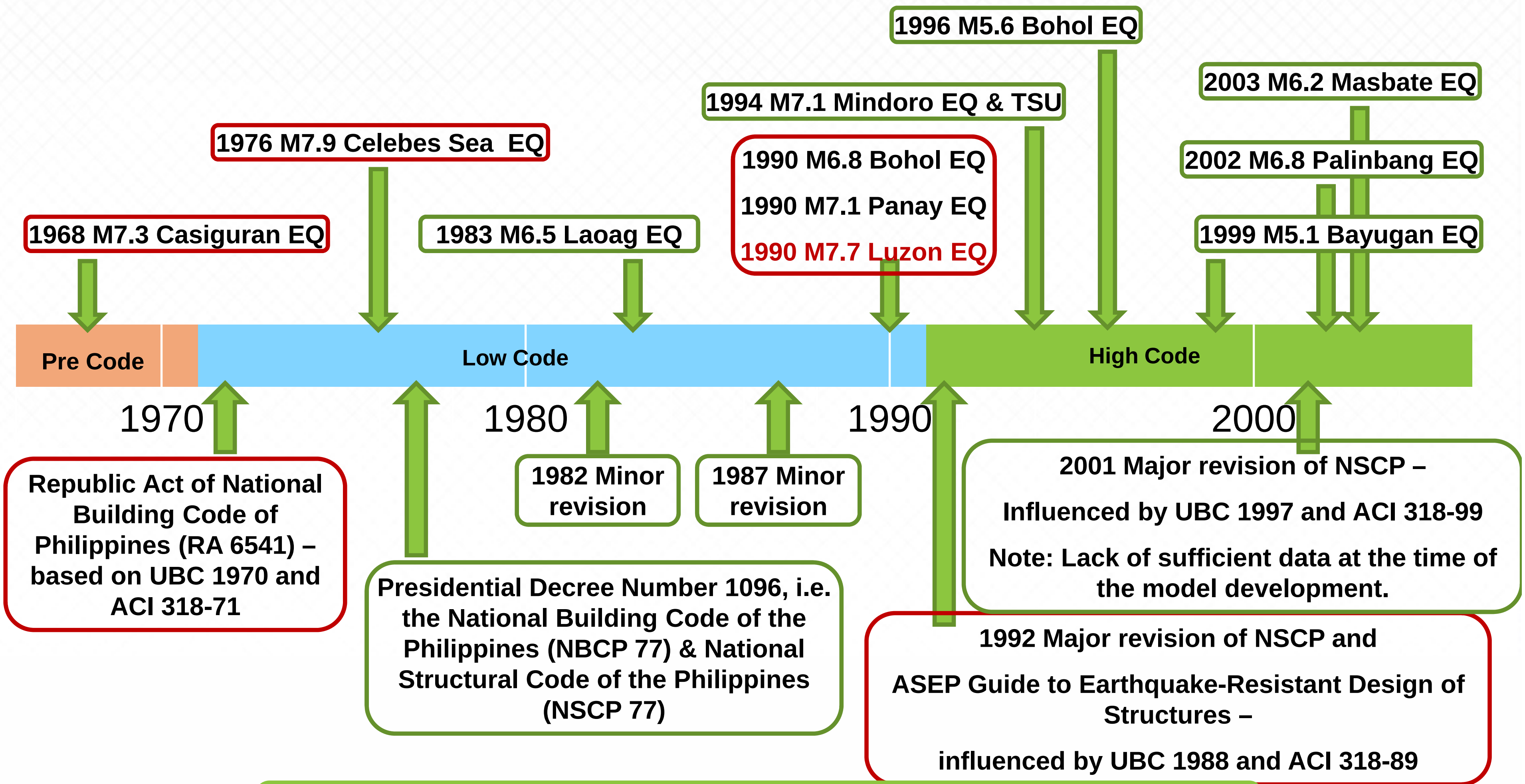
- **Hybrid Methods**: Combination of Analytical and Empirical methods.







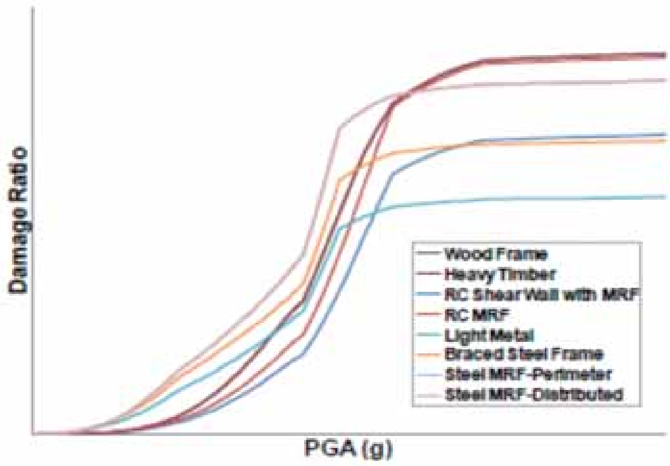
Understanding the Characteristics of Philippine Buildings: The Evolution of Building Codes

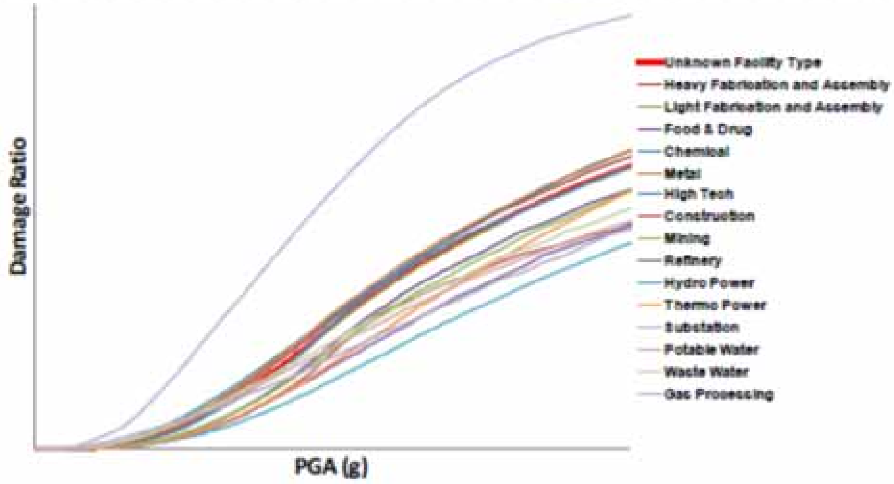


Philippine building codes have been traditionally based on US codes

Overview of AIR's US Damage Functions

- US earthquake model is one of AIR's flagship models
- The building damage functions are derived using nonlinear dynamic analysis of detailed 3D frame models, along with use of historical loss data and damage observations
- The damage mechanisms are explicitly modeled
- Covers a wide range of residential, commercial and industrial building types





Overview of AIR’s US Damage Functions

Construction and Occupancy Classes Supported

Categories of Construction Classes	Categories of Occupancy Classes
Wood	Residential
Masonry	Commercial
Concrete	Industrial
Steel	Religion and Nonprofit
Special	Government
Mobile Homes	Education
Bridges	Transportation
Pavements	Utilities
Dams	
Tunnels	
Storage Tanks	
Pipelines	
Chimneys	
Towers	
Equipment	

Seismic design levels supported

Seismic Design Levels	UBC Zone
California	4
Pacific Northwest	3
Rest of US	1, 2

Age bands supported

Region	Construction Classes	Age Bands
California	Wood (101, 102, 104)	Pre-1941 1941–1960 1961–1975 1976–1995 Post-1995
	Masonry (112–115, 119)	Pre-1951 1951–2000 Post-2000
	Steel–Light Metal (152)	Pre-1961 1961–1975 1976–2000 Post-2000
	Other Classes (103, 111, 116–118, 131–151, 153–155)	Pre-1951 1951–1975 1976–2000 Post-2000
	Mobile Homes (191–194)	Pre-1981 1911–1995 Post-1995
Oregon and Washington	Steel–Light Metal (152)	Pre-1961 1961–1975 1976–2000 Post-2000
	Masonry (112–115, 119)	Pre-1951 1951–2000 Post-2000
	Other Classes (101–104, 111, 116–118, 131–135, 137, 151, 153–155)	Pre-1951 1951–1975 1976 – 2000 Post-2000
All States except California, Oregon, and Washington	Steel–Light Metal (152)	Pre-1961 1961–2000 Post-2000
	Other Classes (101–151)	Pre-1951 1951–2000 Post-2000

Understanding the Characteristics of Philippine Buildings: Seismic Design

- As per NSCP 1992, majority of the Philippines should be designed as per UBC Zone 4 seismic loads

- Survey of typical construction practice and code enforcement

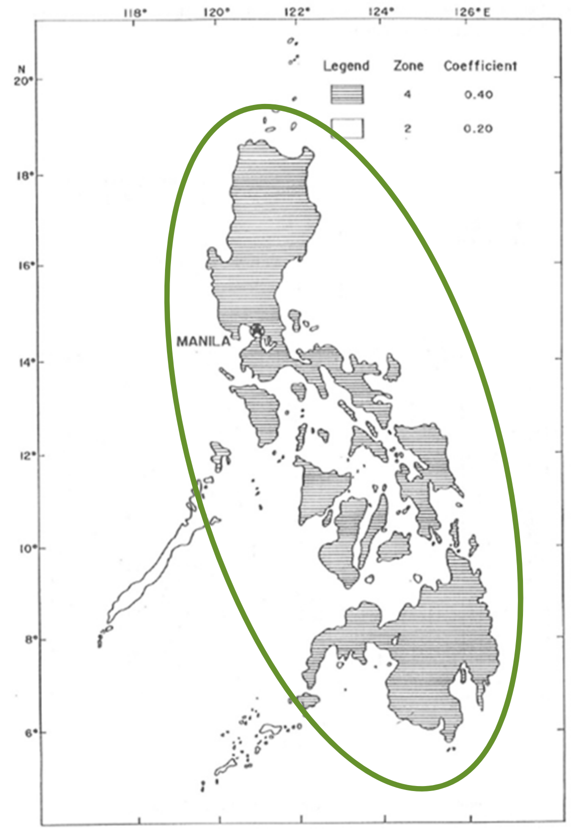
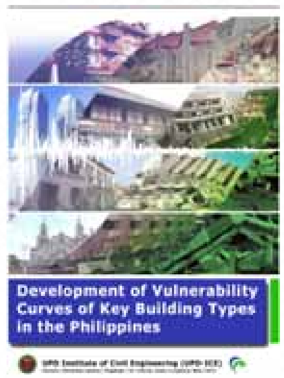
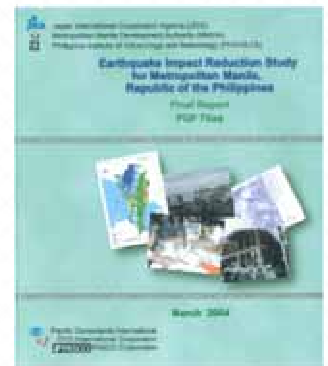


Figure 2.2-B. Seismic Zone Map of the Philippines

Literature Review was Conducted to Understand Seismic Performance of Philippine Construction

Major studies on seismic vulnerability of buildings in the Philippines





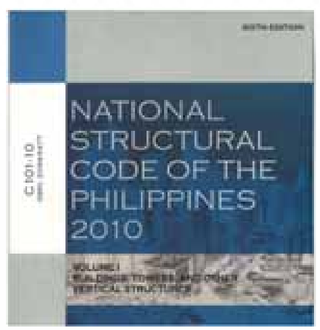
Other Major Sources of Literature

FEMA

USGS
science for a changing world

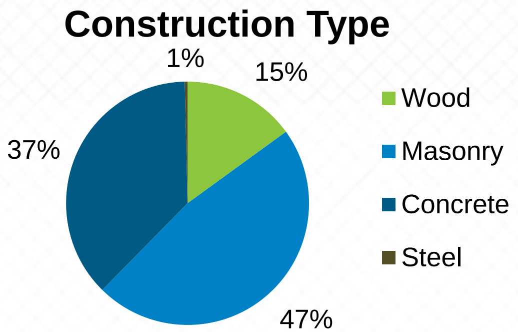
ASSOCIATION OF STRUCTURAL ENGINEERS OF THE PHILIPPINES
ASEP
1961

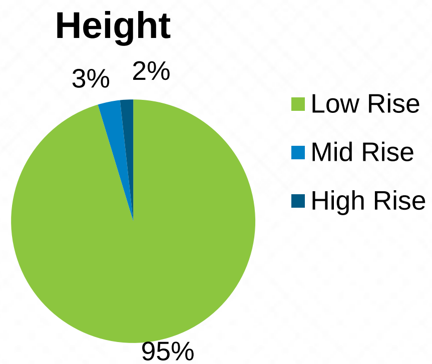
PHIVOLCS

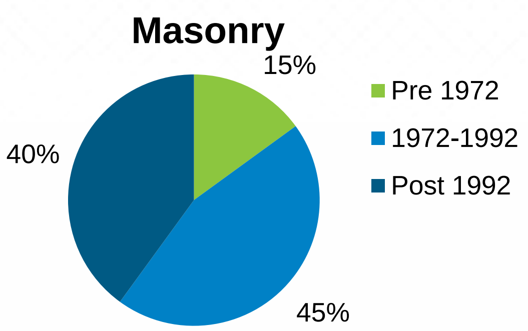


Overview of the Adopted Methodology to Assess Philippine Building Vulnerability

- Buildings are classified based on construction class, occupancy class and year built.
- **Base** damage functions are developed for post 1992 built, **low-rise concrete** and **masonry** buildings in Philippines using a combination of analytical and empirical approach.
- The base damage functions are validated using observed damage data and existing literature.
- The damage functions for other building classifications are developed by assessing their vulnerabilities relative to the base model base types.





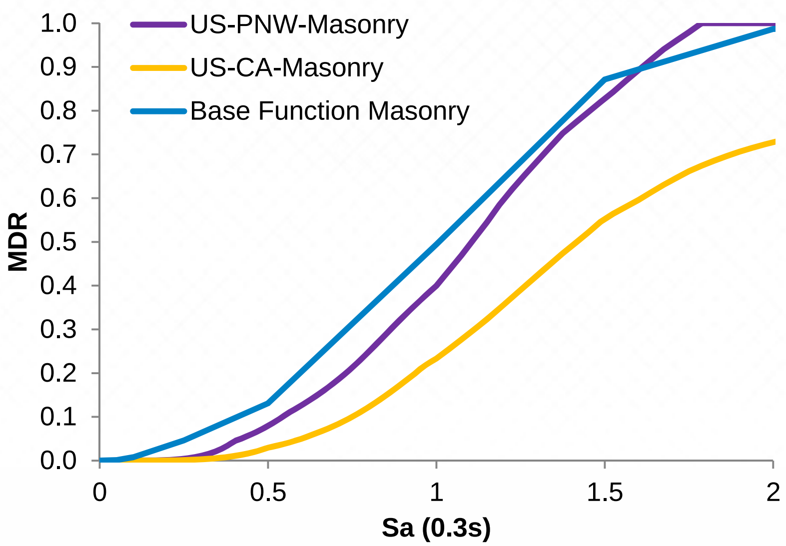


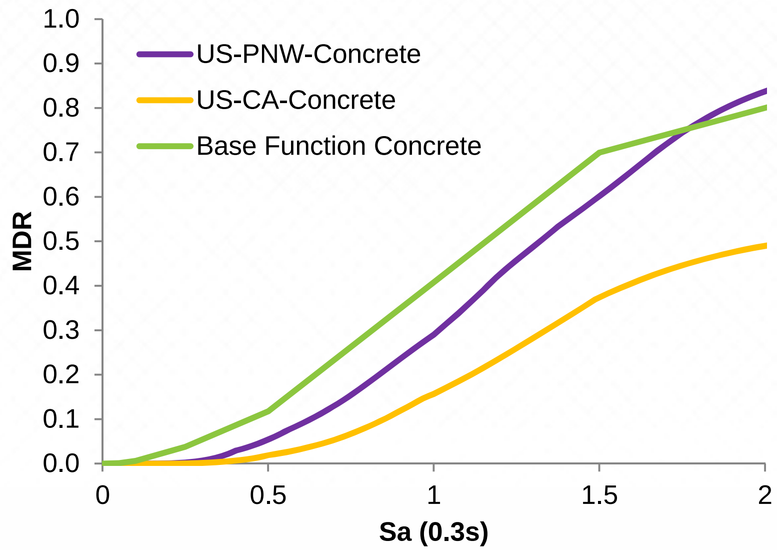
Modeled Building Classifications

Construction Class	Occupancy Class	Height	Year Built
Wood frame (modern)	General residential	Low Rise	Built Pre 1972
Masonry	Permanent dwelling: single-family	Mid Rise	Built between 1972 and 1992
Unreinforced masonry bearing wall	Permanent dwelling: multi-family	High Rise	Built Post 1992
Reinforced masonry	Apartment/Condo		
Reinforced concrete	General commercial		
Reinforced concrete shear wall with MRF	Health care services		
Reinforced concrete shear wall without MRF	General industrial		
Reinforced concrete MRF —ductile	General services		
Pre-cast concrete	Emergency services		
Reinforced concrete MRF	Universities, colleges and technical schools		
Reinforced concrete MRF w/ URM	Agriculture		
Steel	Hydro-Electric Power Systems – General		
Light metal	Thermo-Electric Power Systems – General		
Braced steel frame			
Steel MRF—perimeter			
Steel MRF			

Comparison between US and Philippine Base Damage Functions

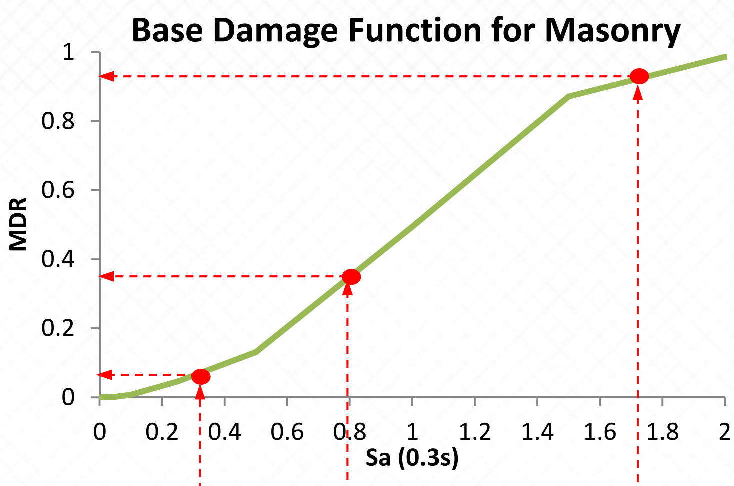
- Seismic vulnerability of low rise masonry and concrete buildings is found to be similar to buildings in NW Pacific region of US (zone 3)
- Therefore, zone 3 damage functions are used to estimate the **relative vulnerabilities** for Philippine buildings





Although NSCP 1992 recommends UBC Zone 4 for seismic design, the vulnerability of the existing buildings may be higher due to prevailing construction practices

Validation of Damage Estimates: Shake Table Test

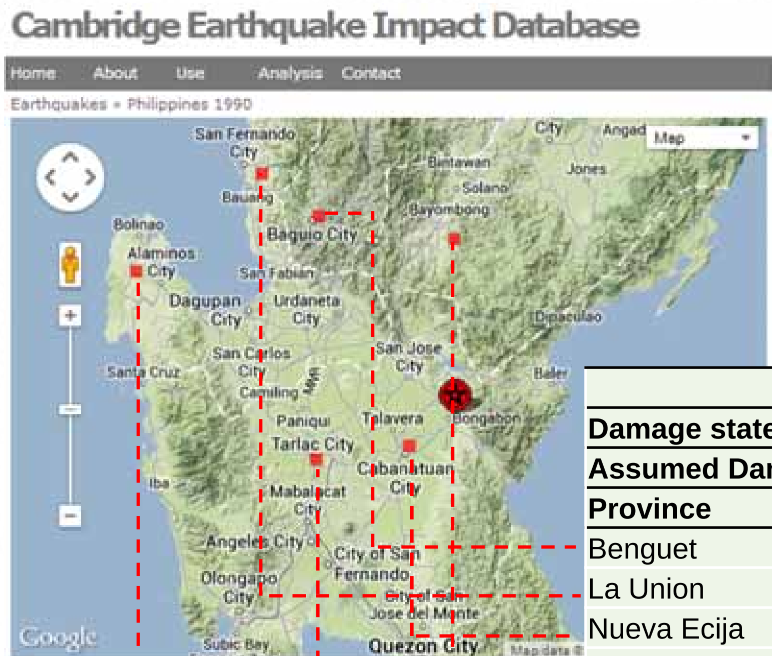


- Imai et al (2012) performed shake table tests for two full scale models of masonry buildings – one built as per NSCP 2010 and the other built as per locally prevailing practices

Shake table test of full scale masonry buildings buildings in the Philippines (Imai et al 2012)

PGA (g)	As per NSCP 2010	Locally Prevailing Practices
0.17	No damage	No damage
0.4	No damage	Moderate damage
0.85	Heavy Damage	Collapse

Validation of Damage Estimates: 1990 Luzon EQ

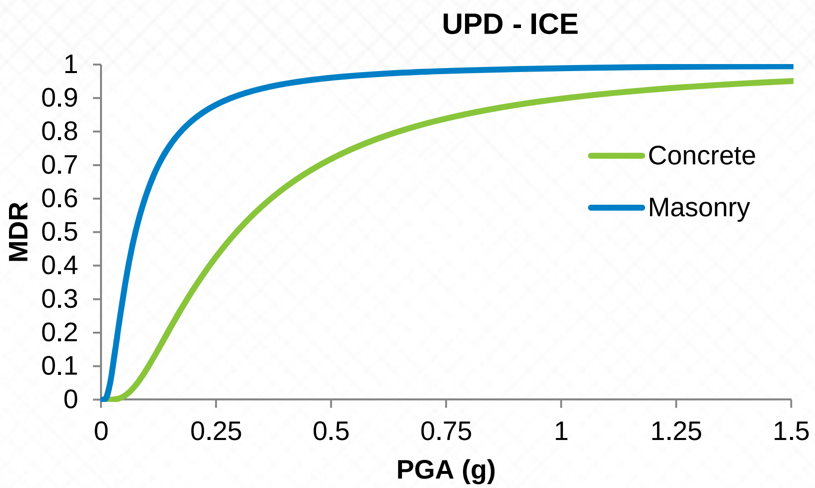


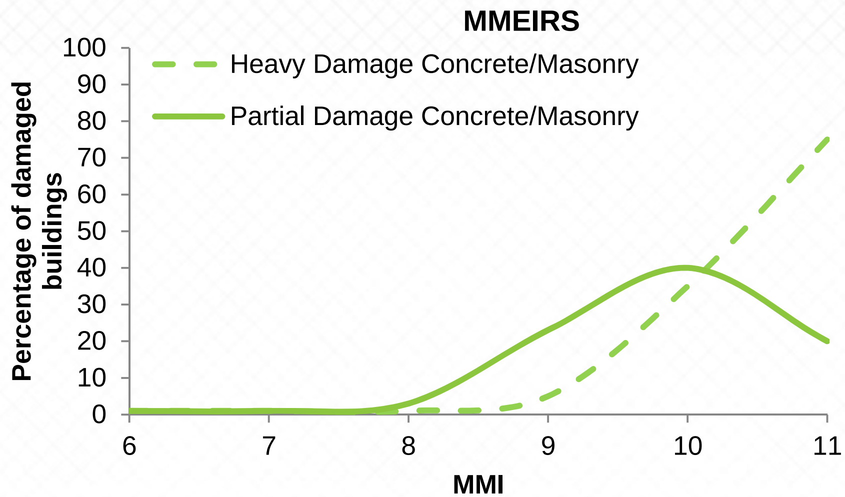
- The resulting damage functions were used to simulate the 1990 Luzon EQ.

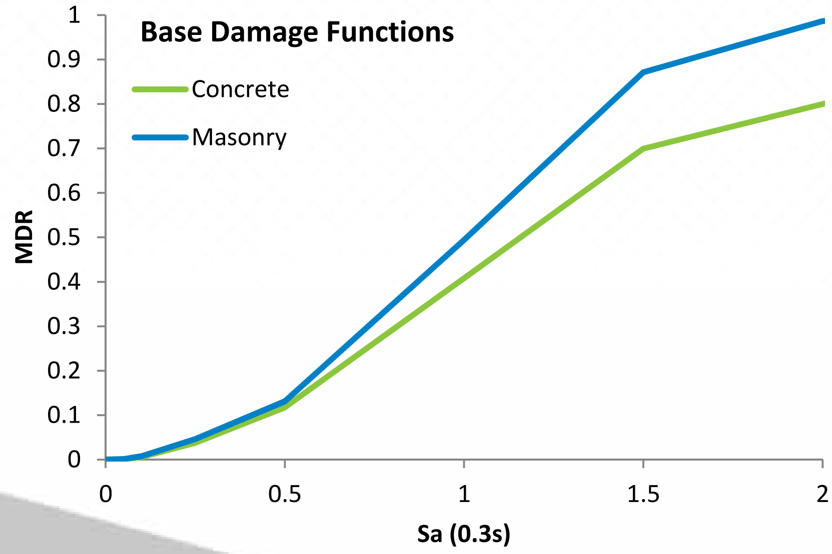
- The percentage of buildings in particular damage states were compared to historical damage data.

Luzon 1990 Earthquake Damage			
Damage state	**No damage**	**Partial damage**	**Complete damage**
Assumed Damage Ratio	**Less than 2%**	**2% to 70%**	**Greater than 70%**
Province	**Cambridge EQ Impact Database (number of buildings)**		
Benguet	72293	14618	7970
La Union	82722	16066	3583
Nueva Ecija	223839	14339	1679
Nueva Vizcaya	50250	5352	2620
Pangasinan	360692	16764	3044
Tarlac	147582	10736	3396
Total	**937378**	**77875**	**22292**
Percentage	**90.35%**	**7.51%**	**2.15%**
Model Predictions	**91.91%**	**7.75%**	**0.34%**

Comparison of Damage Functions



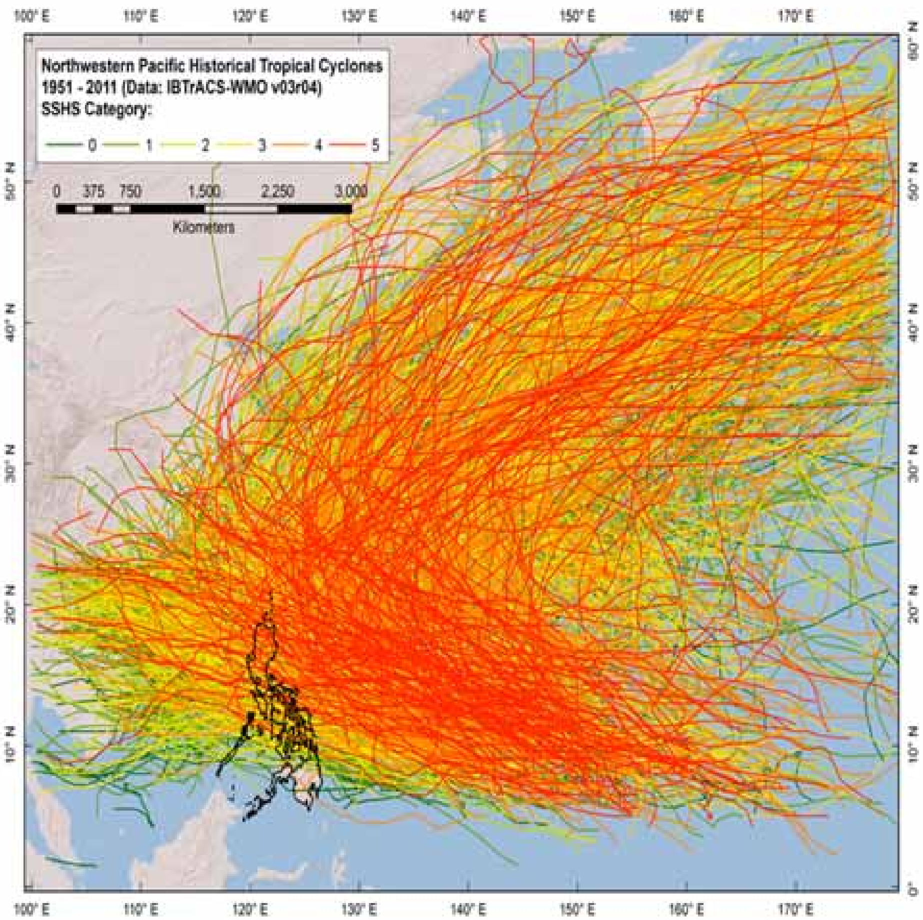




Luzon 1990 Earthquake Damage			
Damage state	No Damage	Partial Damage	Complete Damage
Cambridge EQ Impact Database	90.35%	7.51%	2.15%
Model Predictions using developed DFs	91.91%	7.75%	0.34%
Model Predictions using UPD-ICE DFs	57.22%	41.56 %	1.23%

Tropical Cyclone Model

Tropical Cyclone Historical Database



- Data Source: The International Best Tracks Archive for Climate Stewardship (IBTrACS)

- Scope: over 1,600 cyclones occurring in the northwest pacific basin covering the period from 1951 to 2011

AIR Historical Database

- An average of 6 tropical cyclones make landfall in the Philippines annually with another 3 passing close enough to cause loss.

Example from Tropical Cyclone Historical Database: Typhoon Ketsana / Ondoy 2009

- **The tropical cyclone historical database contains parametric information about the events**

Tropical Cyclone Track

Serial_num	Season	Num	Name	ISO_date	ISO_hour	Nature	Latitude	Longitude	Pres_mb	Track_type	SS_scale
2009268N14128	2009	17	KETSANA	40083	0	TS	15.2	116.5	985	main	1
2009268N14128	2009	17	KETSANA	40083	6	TS	15.2	115.5	985	main	1
2009268N14128	2009	17	KETSANA	40083	12	TS	15.6	114.5	980	main	1
2009268N14128	2009	17	KETSANA	40083	18	TS	15.7	113.7	975	main	2

Year

Location

IBTrACS Serial Number

WMO Name

Saffir-Simpson Scale

Source: International Best Track Archive for Climate Stewardship (IBTrACS).

Consequence Database: Tropical Cyclone Events and Non-Tropical Cyclone Flood

- Data Sources:
  - Emergency Events Database (EMDAT), maintained by the Centre for Research on the Epidemiology of Disasters (CRED)
  - The Global Active Archive of Large Flood Events maintained by the Dartmouth Flood Observatory (DFO)
  - The National Disaster Coordinating Council Office of Civil Defense Operations Center (NDCC/NDRRMC) Database of Destructive Typhoons
  - The online information repository "ReliefWeb" (e.g., NDCC/NDRRMC reports/updates, OCHA reports, etc.)
  - Disaster information reports issued by the Asian Disaster Reduction Center (ADRC)

- ~520 significant tropical cyclone and flood events dating 1905 to 2013

- Main Data Fields: Deaths, Injuries People Affected, Buildings Damaged, Buildings Destroyed, Economic Damage

Summary of Tropical Cyclone Events in the Consequence Database

Time period	Number of Events	Number of Catastrophic Events	Estimated Economic Damage (Current Million USD)	Estimated Economic Damage (Trended Million 2012 USD)	Estimated Deaths	Estimated Deaths (Trended 2012 Value)
Pre-1950s	12	10	10	N/A	2,858	N/A
1950s	8	8	50	N/A	2,023	N/A
1960s	16	14	112	4,604	1,655	5,637
1970s	60	35	628	11,258	3,402	8,471
1980s	59	48	1,996	14,588	5,348	9,636
1990s	91	72	2,818	12,276	9,851	14,613
2000s	85	76	1,881	3,761	6,669	7,509
2010 – 2013	22	19	1,247	1,326	2,866	2,898

Example from Tropical Cyclone and Flood Consequence Database: Typhoon Bopha / Pablo 2012

- **A tropical cyclone event is uniquely identified.**

Consequence ID	Main Type	Year	Approximate Start Date	Approximate End Date	Date(s) of Event Source	Affected Areas	WMO Storm Name	PAGASA Storm Name
517	Typhoon	2012	December 4, 2012		GLIDE	Ilocos (I), Mimaropa (IV-B), Western Visayas (VI), Central Visayas (VII), Northern Mindanao (X), Soccsksargen (XII), ARMM, and Caraga	Bopha	Pablo

Consequence ID

Chronological information and data source

Location

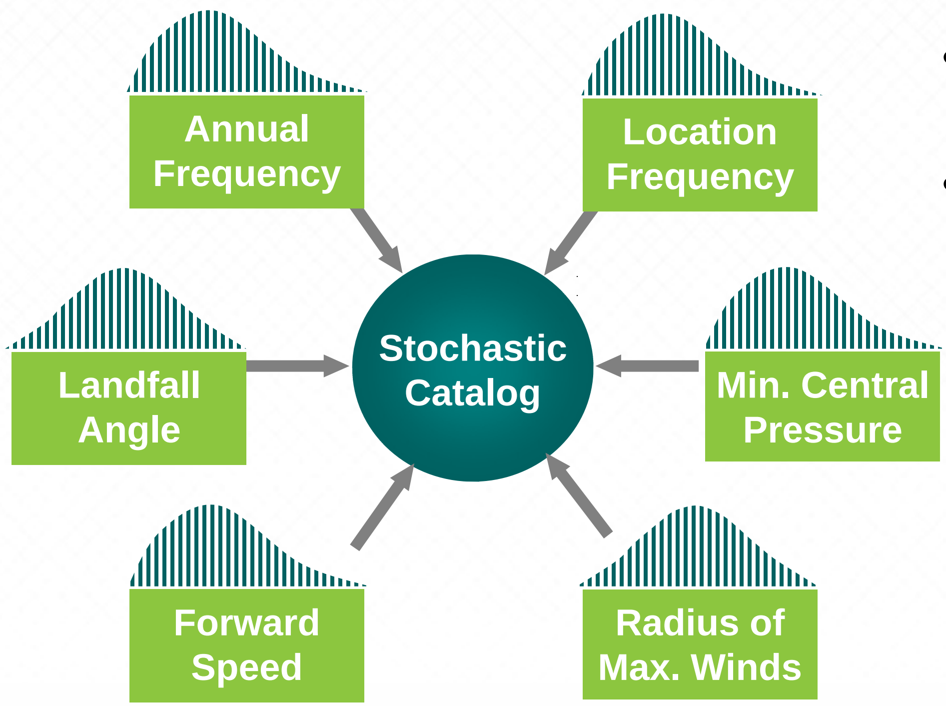
TC Name

Significant fields enumerate the human and economic losses. Columns are labeled Minimum, Maximum, or Preferred with a data source for each field. For this example, a reliable source of available data was from the NDRRMC.

Min People Displaced	Min People Displaced Source	Max People Displaced	Max People Displaced Source	Preferred People Displaced	Preferred People Displaced Source
60000	DFO	973207	NDRRMC	973207	NDRRMC

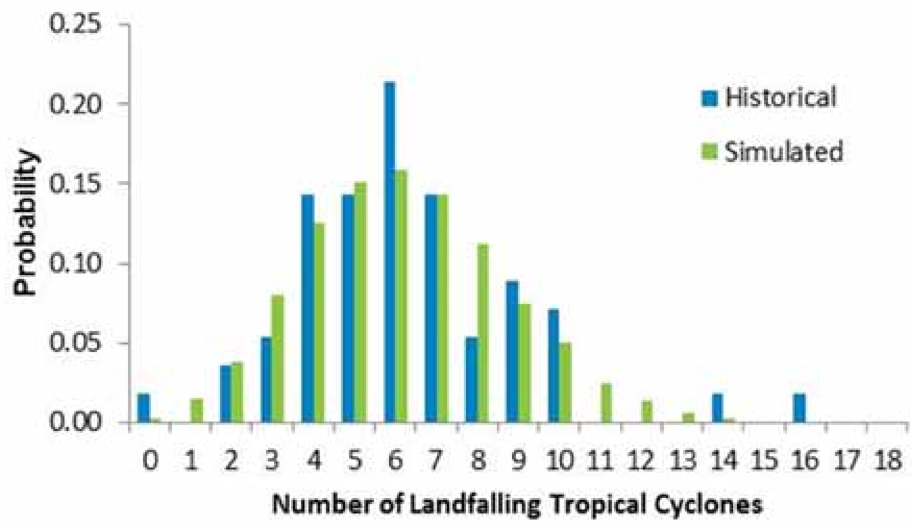
- **Preferred Deaths = 1067**
- **Preferred Missing = 834**
- **Preferred Displaced = 973,207**
- **Preferred Affected = 6,243,998**
- **Preferred Partially Destroyed Buildings = 102,506**
- **Preferred Destroyed Buildings = 76,198**
- **Economic Damage = 34,409.4 (million Pesos)**
- **Preferred Economic Damage = 827.3 (million USD) (converted from Pesos)**

Stochastic Catalog of Typhoon Events

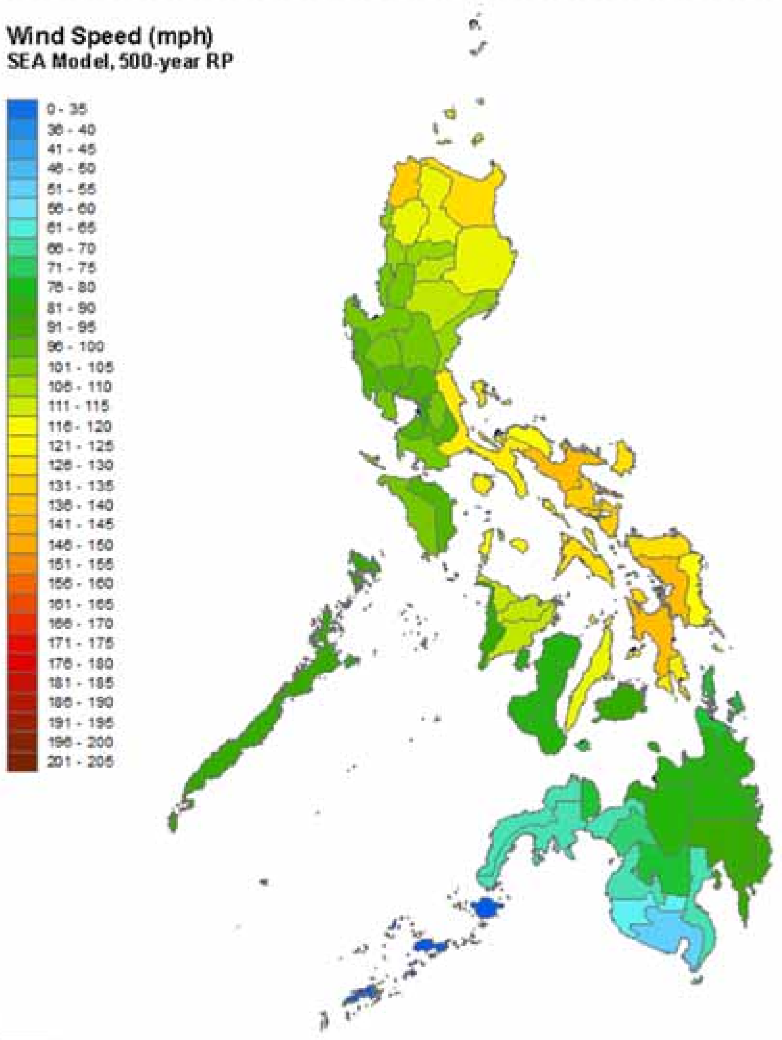


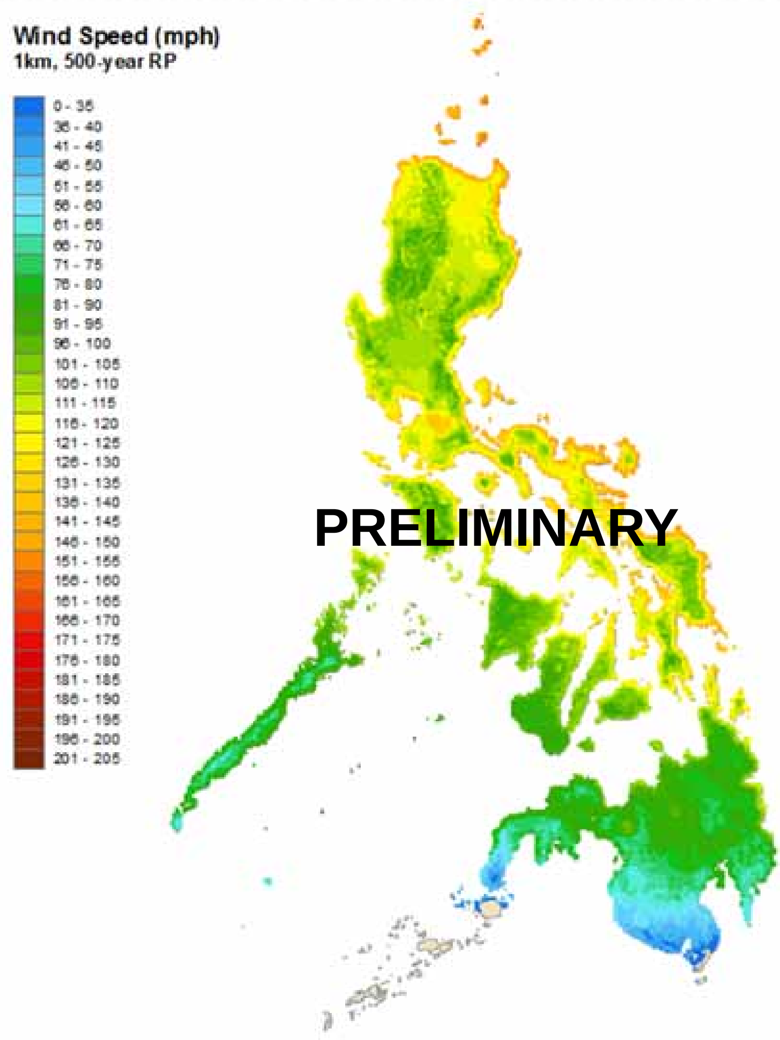
AIR Typhoon Model for Southeast Asia:

- 10,000-year catalog (> 293,000 events)
- 61,924 events landfalling in the Philippines
- 30,325 events bypassing the Philippines but close enough to cause loss



High Resolution Model Update: Wind Hazard





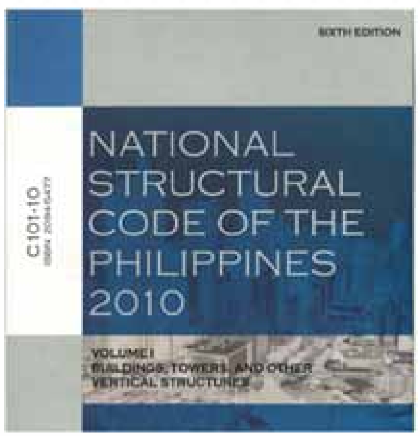
Wind Damage Estimation

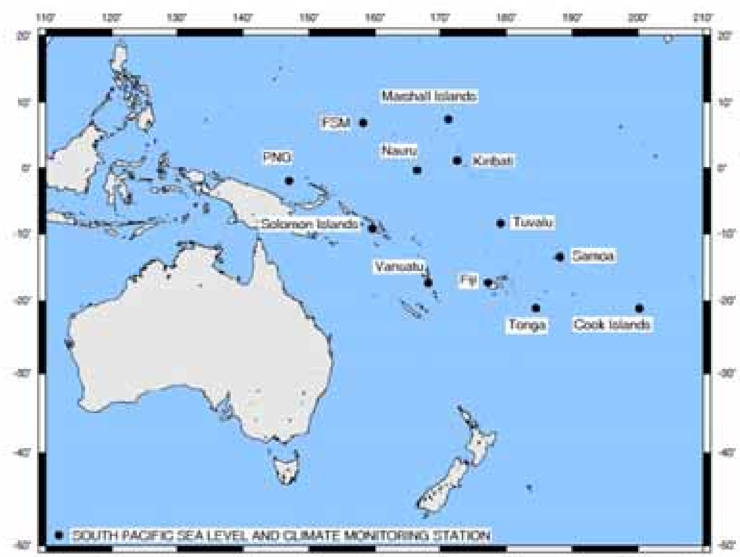
- Vulnerability is computed separately for wind and precipitation
- Damage functions relate maximum (1 minute sustained at 10m) wind speed to mean damage ratio
- Wind damage functions are developed based on engineering analyses and account for building code evolution and enforcement
- Uncertainty in damage is captured in the model by probability distributions around the mean damage ratio

Wind Vulnerability Based on Building Code Evaluation and Data from Neighboring Regions

- Detailed data on wind damage and losses is scarce for the Philippines

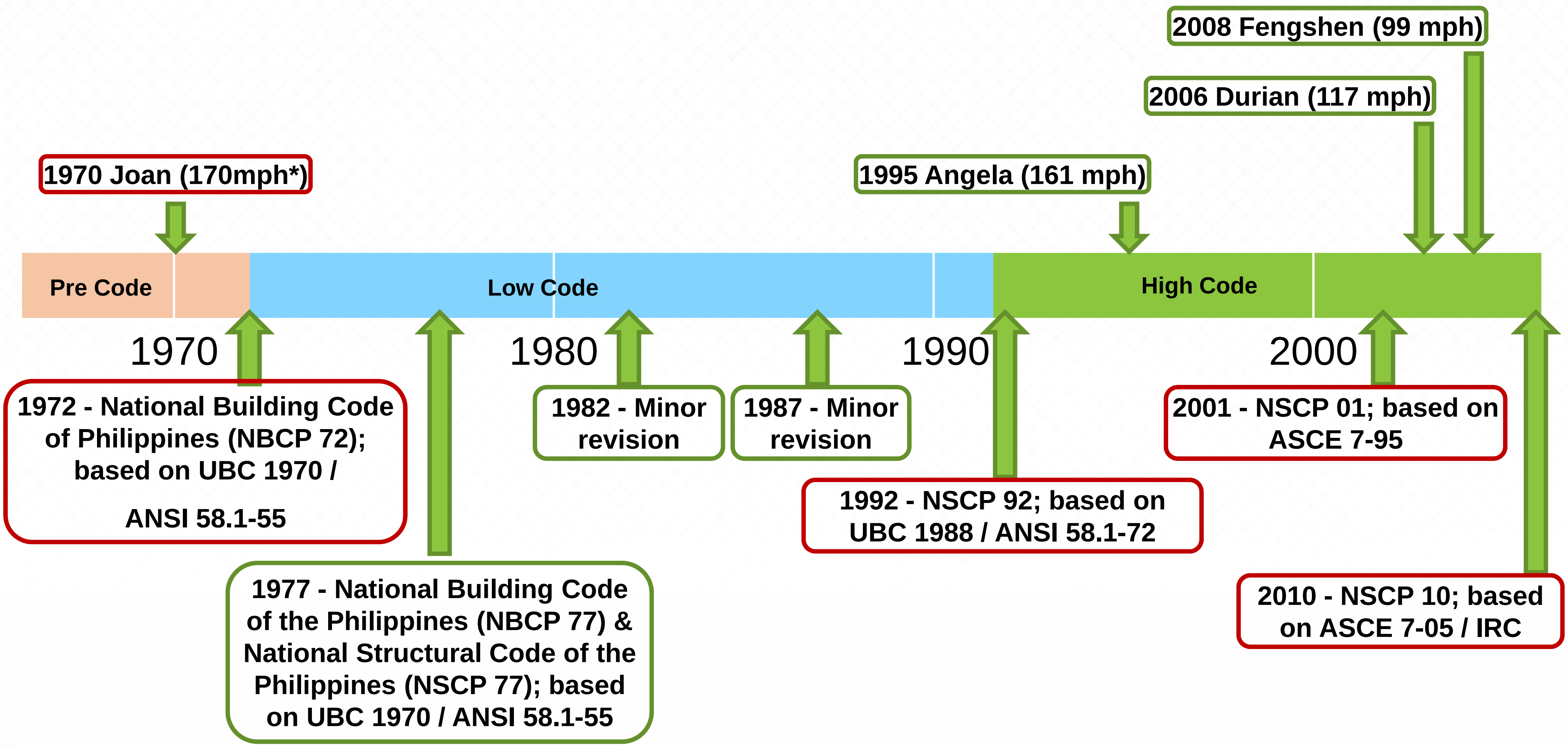
- Leveraged validated damage functions from other regions based on the following criteria:
  - Regions with similar building codes (United States); especially for engineered buildings
  - Regions close to the Philippines (e.g., South Pacific Island Nations); especially for non-engineered buildings





Evolution of Building Codes in the Philippines

Philippine building codes have traditionally been based on US codes

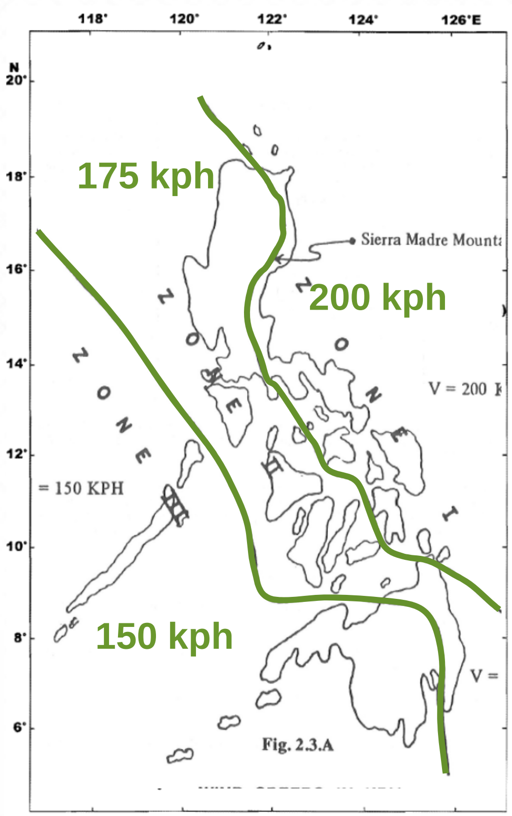


*Max sustained wind estimates from www.Typhoon2000.ph

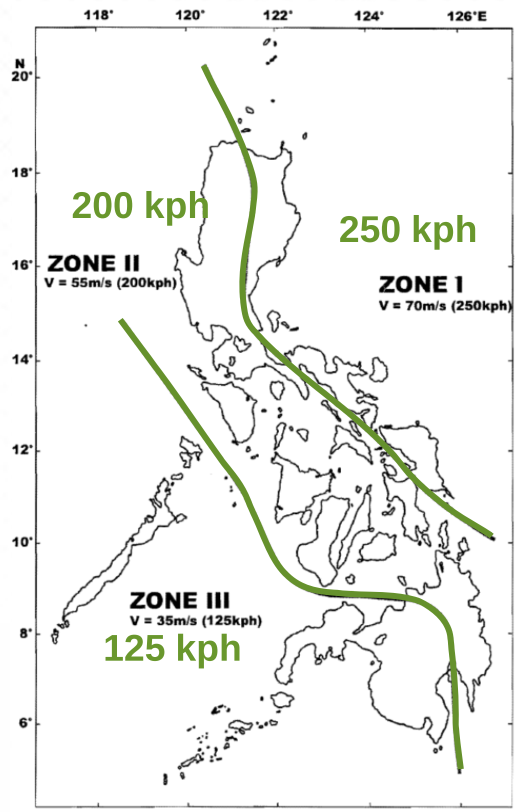
Wind Zone Maps

Wind zones have remained relatively consistent but design wind speeds have changed

NSCP – 1992



NSCP – 2001



- Building codes in the Philippines suggest vulnerability similar to that of buildings in the following US regions:
  - Key West, FL for NSCP Zone I
  - New Orleans, LA for NCSP Zone II
  - Houston, TX for NSCP Zone III

Wind Vulnerability Accounting for Building Characteristics Representative of the Philippines

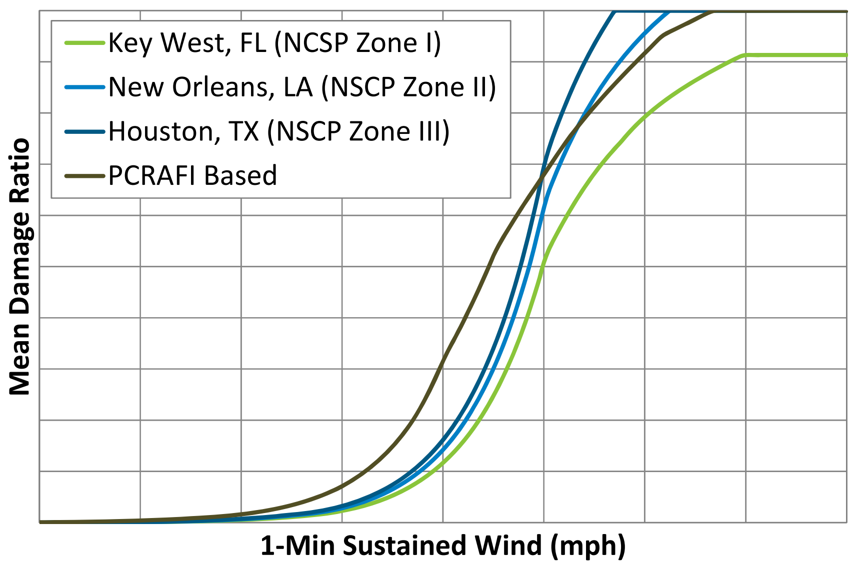
- Construction in the Philippines often lacks characteristics typical of hurricane prone regions in the U.S. based on literature review of building characteristics:
  - Stringent code enforcement
  - Use of engineered window shutters, strong building-foundation connections, impact resistant glass, etc.

- Damage functions were modified to reflect local materials, labor and material costs, and construction practices
  - Based on a review of the building characteristics it was determined that wind vulnerability of Philippine buildings, on average, is more comparable to that of buildings in the Houston, TX region

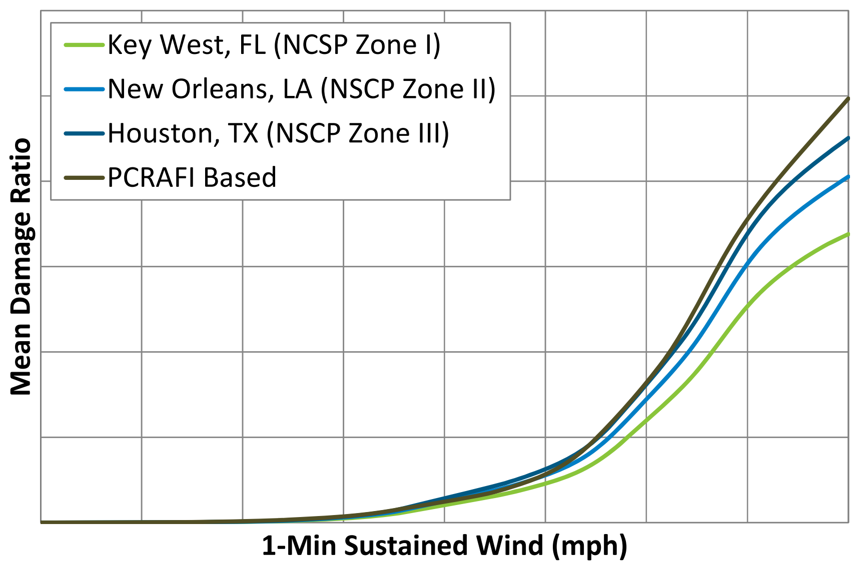
Wind Vulnerability Comparisons

- Although subject to similar wind design provisions as buildings in the US, the vulnerability of typical buildings in the Philippines higher due to prevailing construction practices and code enforcement
- PCRAFI damage functions were leveraged to capture expected vulnerability of buildings in Philippines, especially residential construction

RESIDENTIAL LOW-RISE WOOD FRAME

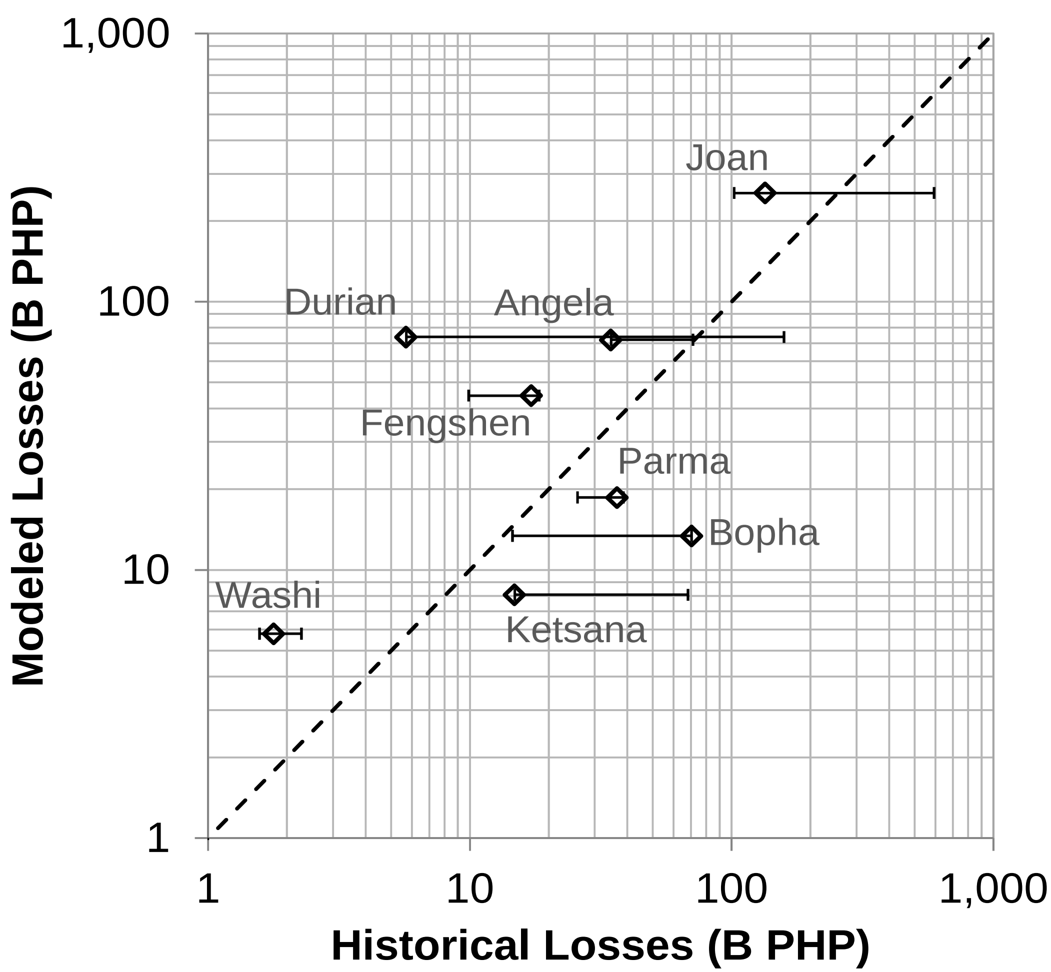


COMMERCIAL MID-RISE RC SHEAR WALL



Validating TC Wind and Precipitation Losses: Marquee Events

- All losses trended to 2012 Philippine Pesos
- Modeled losses validated with EMDAT reported loss values
- EMDAT consistently provides losses for each marquee event & reports total economic losses
- Error bars represent reported loss estimates from SwissRe, MunichRe, AXCO, ROHK, GuyCarp, and NDRRMC



Non-Tropical Cyclone Induced Precipitation Model

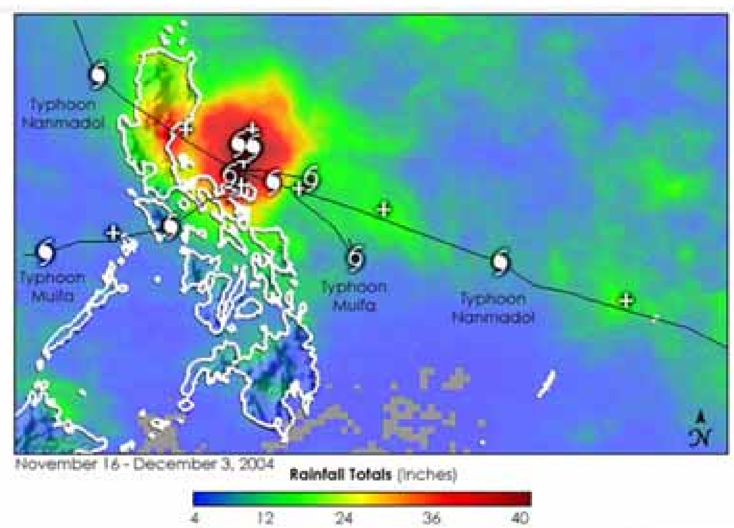
AIR

Framework

- Methodology for non tropical cyclone (non-TC) rainfall extraction
  - Previous work in the literature
  - Processing of Tropical Rainfall Measuring Mission (TRMM) satellite data
  - Validation
  - Generation of Results

- Generation of non-TC rainfall over the Philippines
  - Spatial and temporally correlated stochastic rainfall
  - Results and validation

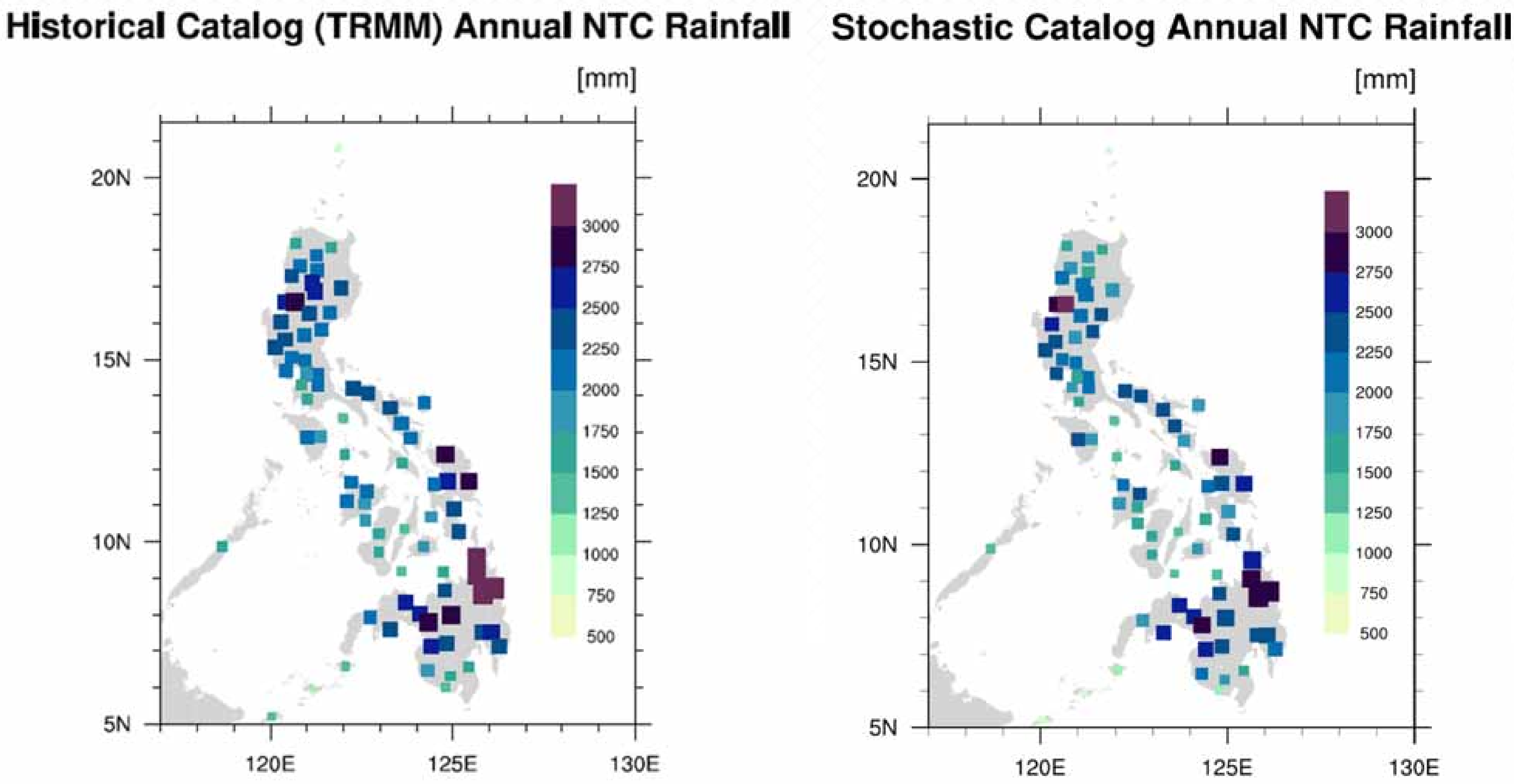
- Flood Event Definition
  - Event definition
  - Validation against historical record



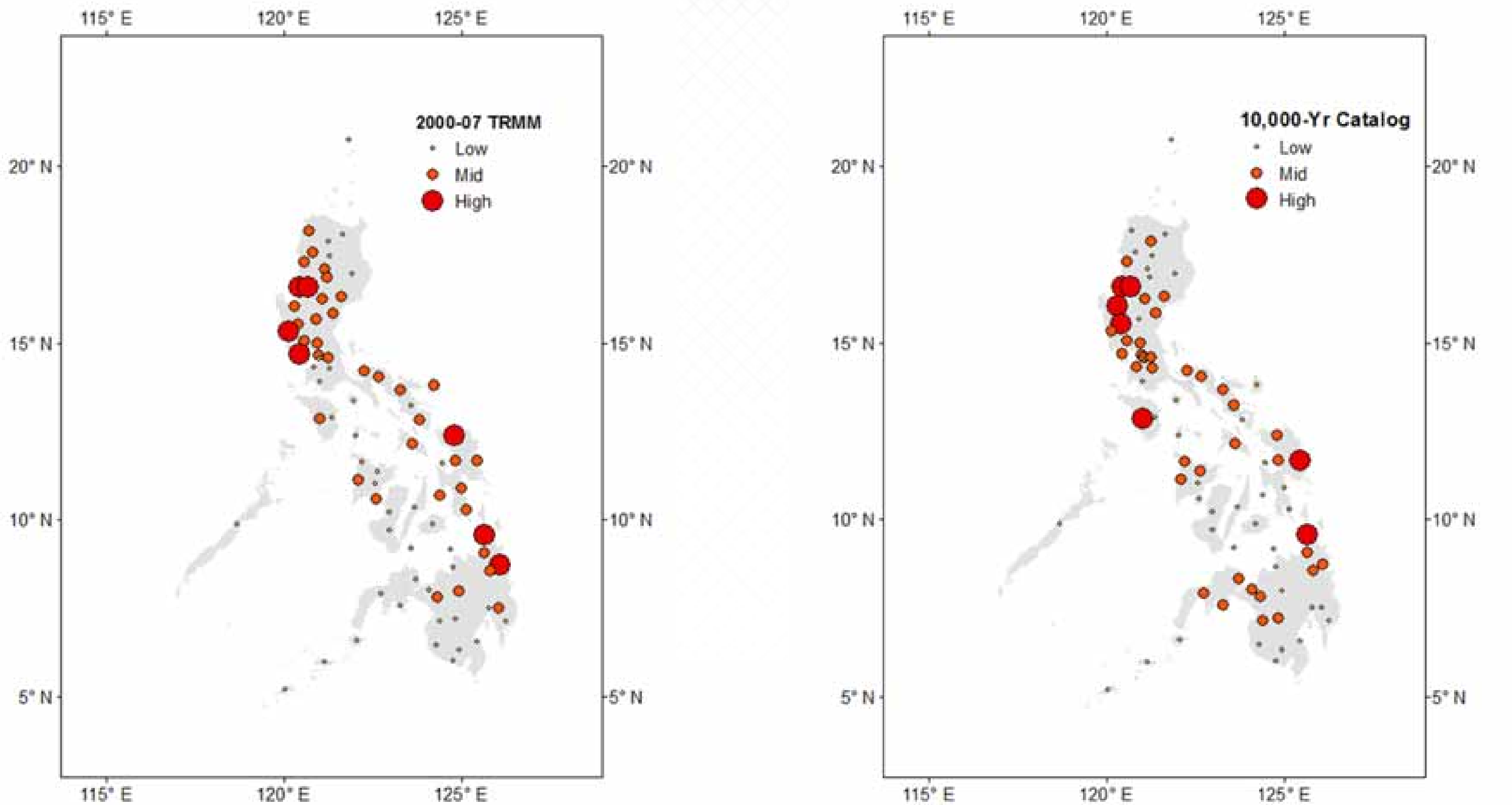
Steps to Formulating NTC Climatology

1. Collect and process 3B42 3hourly TRMM data from 2000-2008.
2. Interpolate six hourly JMA best track data to three hourly points for all storms-central pressure latitude and longitude
3. Extract all rainfall within a 500km radius of central latitude and longitude at all time-steps of storm event
4. Aggregate to daily and yearly timescales for validation, comparisons, and generation of rainfall.

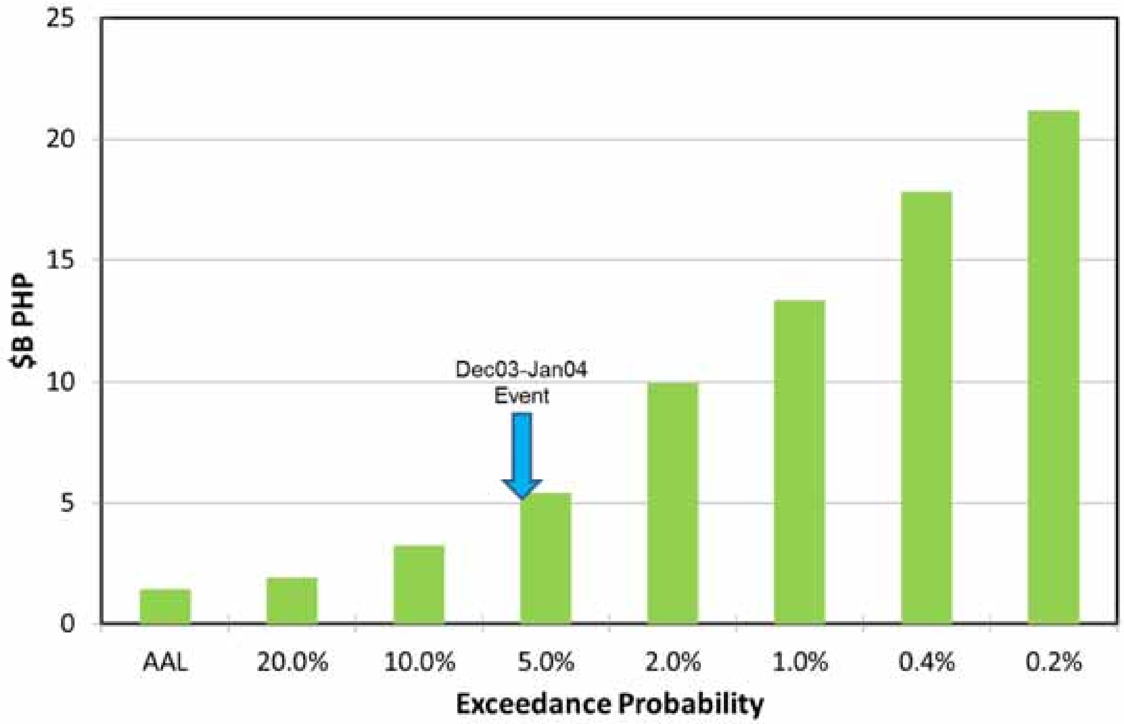
Annual NTC Rainfall – Historical & Stochastic Catalog

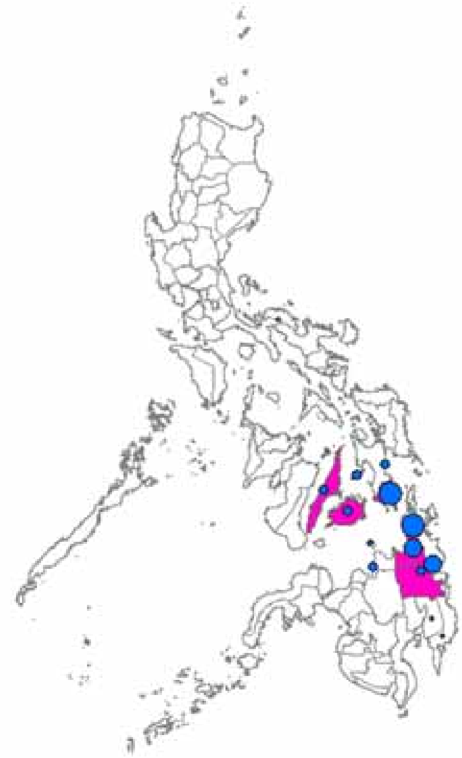


NTC Flood Events – Spatial Frequency



Loss Results – EP Curve



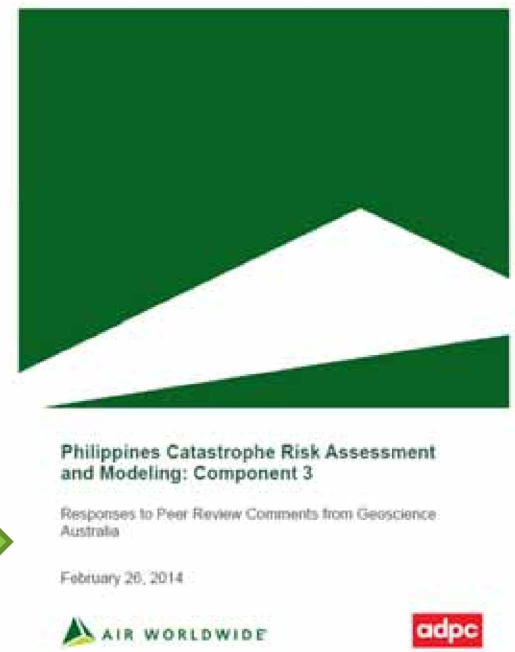


Peer Review

AIR

Project Peer Review

- The World Bank retained Geoscience Australia (GA) for the peer review
- Several presentations, discussions, and Q/A with GA as part of the peer review
- AIR provided GA with technical documentation on the underlying AIR catastrophe risk models and comprehensive presentations on the work being carried on the project
- The peer review addressed the following:
  - Industry Exposure Database
  - Government Asset Database
  - Earthquake Hazard
  - Earthquake Vulnerability
  - Typhoon/TC (Wind and Rainfall) Model for the Phili
  - Wind Damage Functions
  - Flood Damage Functions
- The peer review is available as a 129 page document from Component 3


Philippines Catastrophe Risk Assessment and Modeling: Component 3

Responses to Peer Review Comments from Geoscience Australia

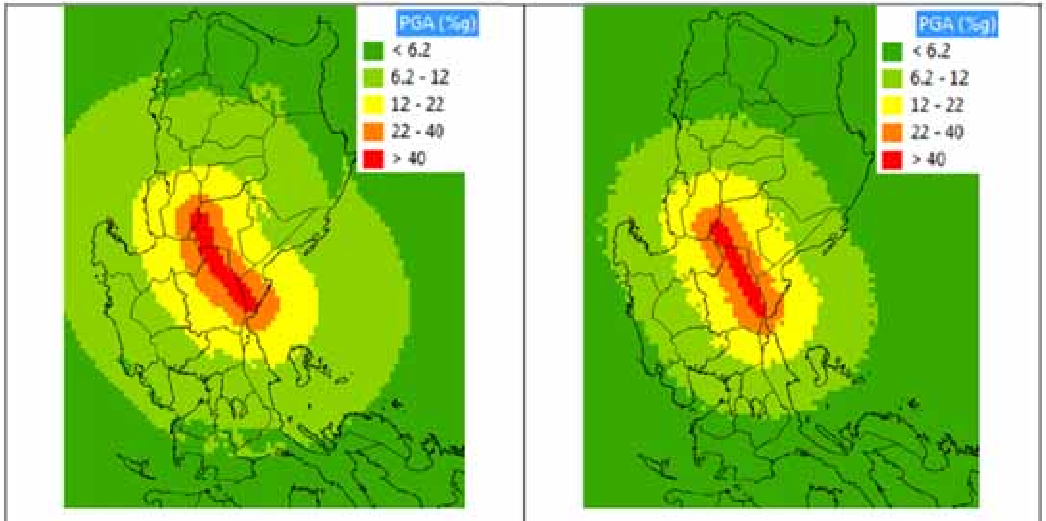
February 26, 2014

AIR WORLDWIDE

adpc

Peer Review: EQ Example

- GA: *"1990 Luzon earthquake is simulated to validate damage estimates using the developed damage functions. The simulated damage estimates are in good agreement with the historical damage data. How does simulated ground motion compare with observed one?"*
- AIR Response: "Unfortunately, there is virtually no ground motion recording data close to epicenter available from the 1990 Luzon earthquake. One available point of comparison is the Shakemap computed by USGS. The figure below shows the comparison of the mean PGA values for Luzon 1990 earthquake provided by USGS Shakemap and simulated by AIR's model.



USGS Shakemap Atlas

AIR Simulated Mean

Peer Review Comments: Exposure

- *"The development of the Industry Exposure Database and Government Asset database for the Philippines is understandably challenging, given the limited public data and difficulties in obtaining suitable data from agencies and custodians."*

- *"From the material presented, the approach seems sensible, and aspects of it align very well with Geoscience Australia's exposure information development methodologies."*

Peer Review Comments: Vulnerability

- *EQ: “The damage functions for Philippine buildings are analytically developed and validated with empirical data. The methodology seems appropriate given the fact that there is not much of data available at the moment.”*

- *Typhoon: “Overall the methodology seems appropriate given the fact that there is not much of building damage data available at the moment.”*

Peer Review Comments: Typhoon Model

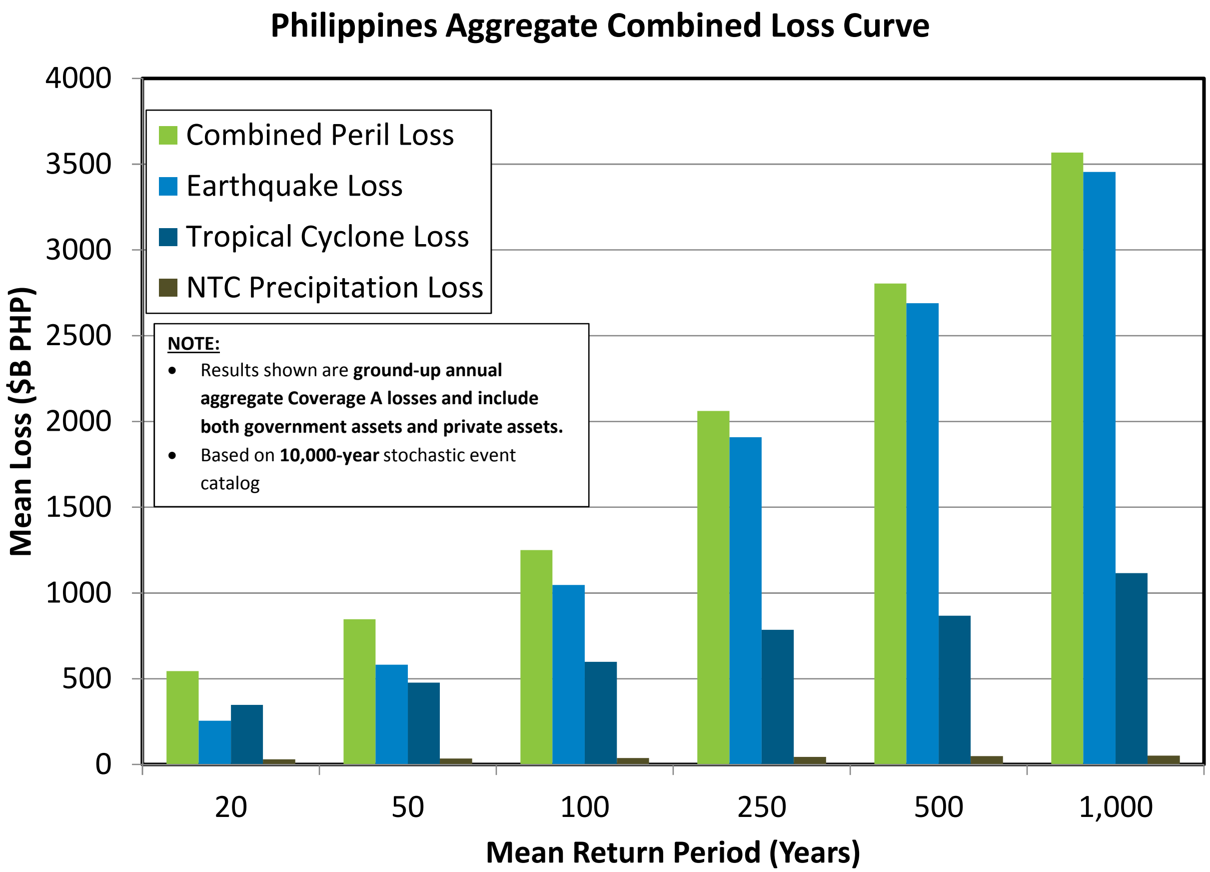
- *“The nation-wide estimation of damages from TC's and non-TC rainfall for the Philippines is a challenging task. The general approach of this study appears to be reasonable, appropriate and robust for a nation-wide study of this nature, given the available data and the time-frame.”*

- *“Good use is made of available databases, including remotely sensed rainfall information, to get an idea of the spatial distribution of events, wind speed, rainfall and losses.”*

Summary of Loss Results

A I R

Philippines Building Loss EP Curves



AAL = 206.4 B PHP

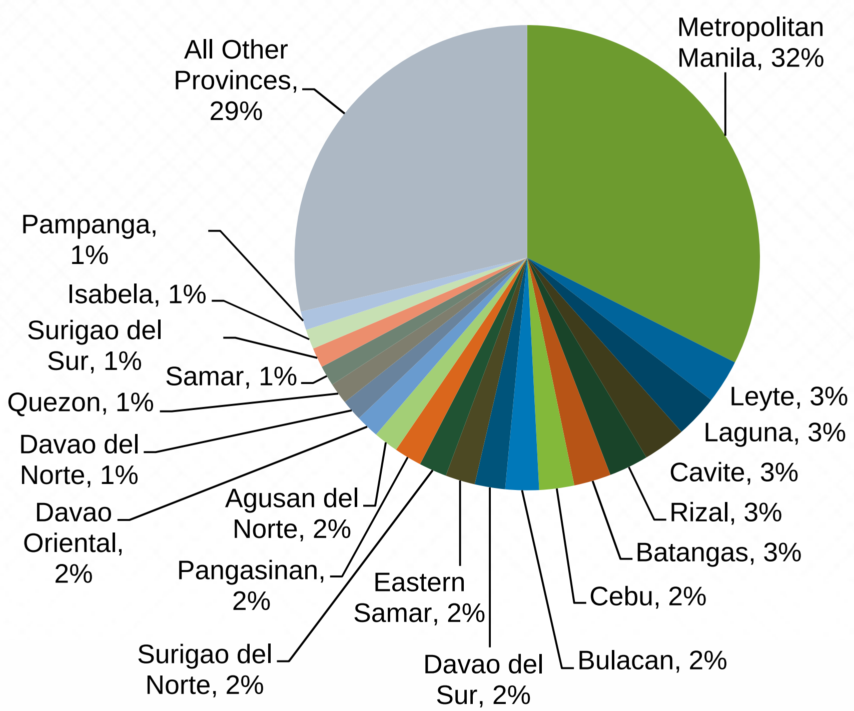
MRP (Years)	Aggregate Loss ($B PHP)			
	EQ Loss	TC Loss	Non-TC Precip. Loss	Combined Peril Loss
20	256	347	30	545
50	582	477	35	847
100	1,047	598	38	1,250
250	1,908	786	44	2,062
500	2,689	868	49	2,804
1,000	3,456	1,117	52	3,568

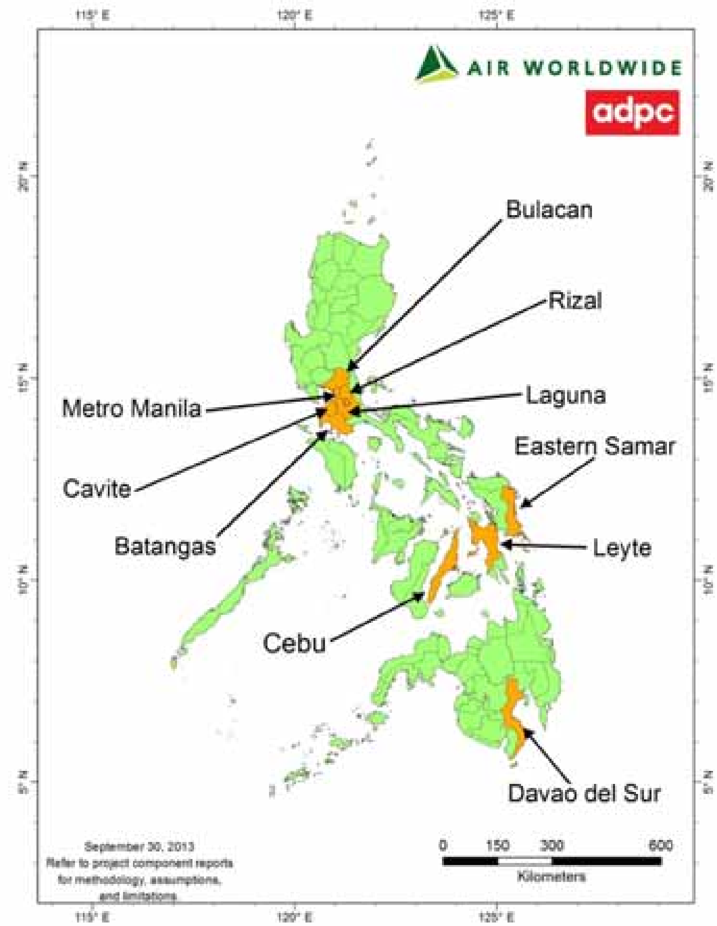
Replacement Values (Coverage A):

Total = 25,000 B PHP
Private Property = 22,000 B PHP
Government Assets = 2,700 B PHP

GDP = 11,405 B PHP

Earthquake Loss: AAL by Province



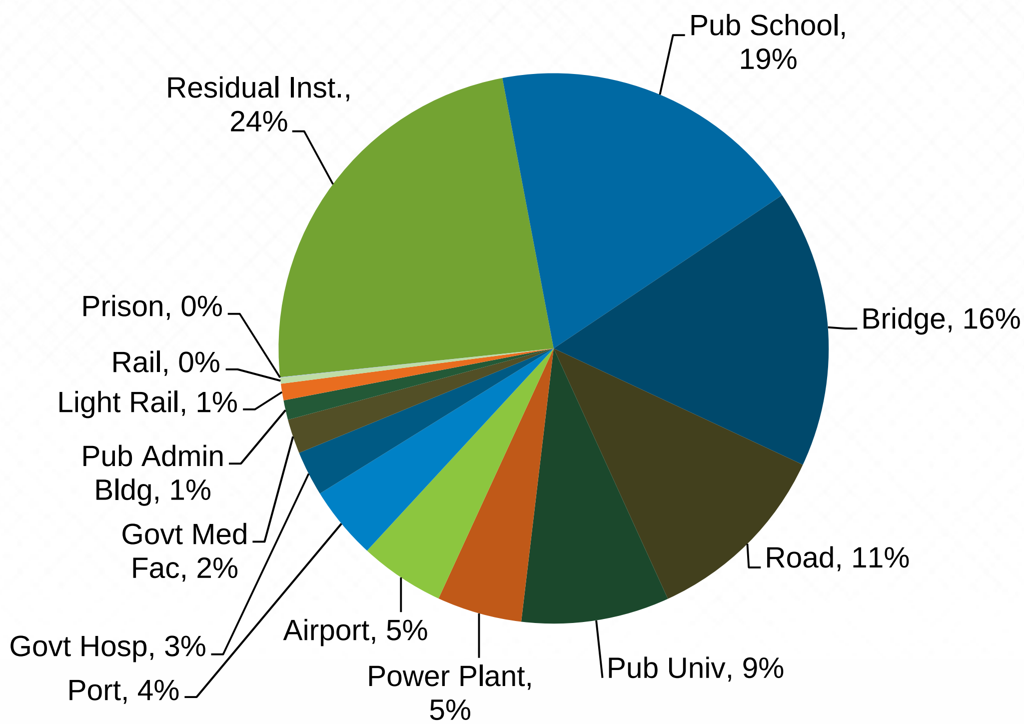


AAL = 73 B PHP

TIV = 25,000 B PHP

Earthquake Loss: AAL by Sector

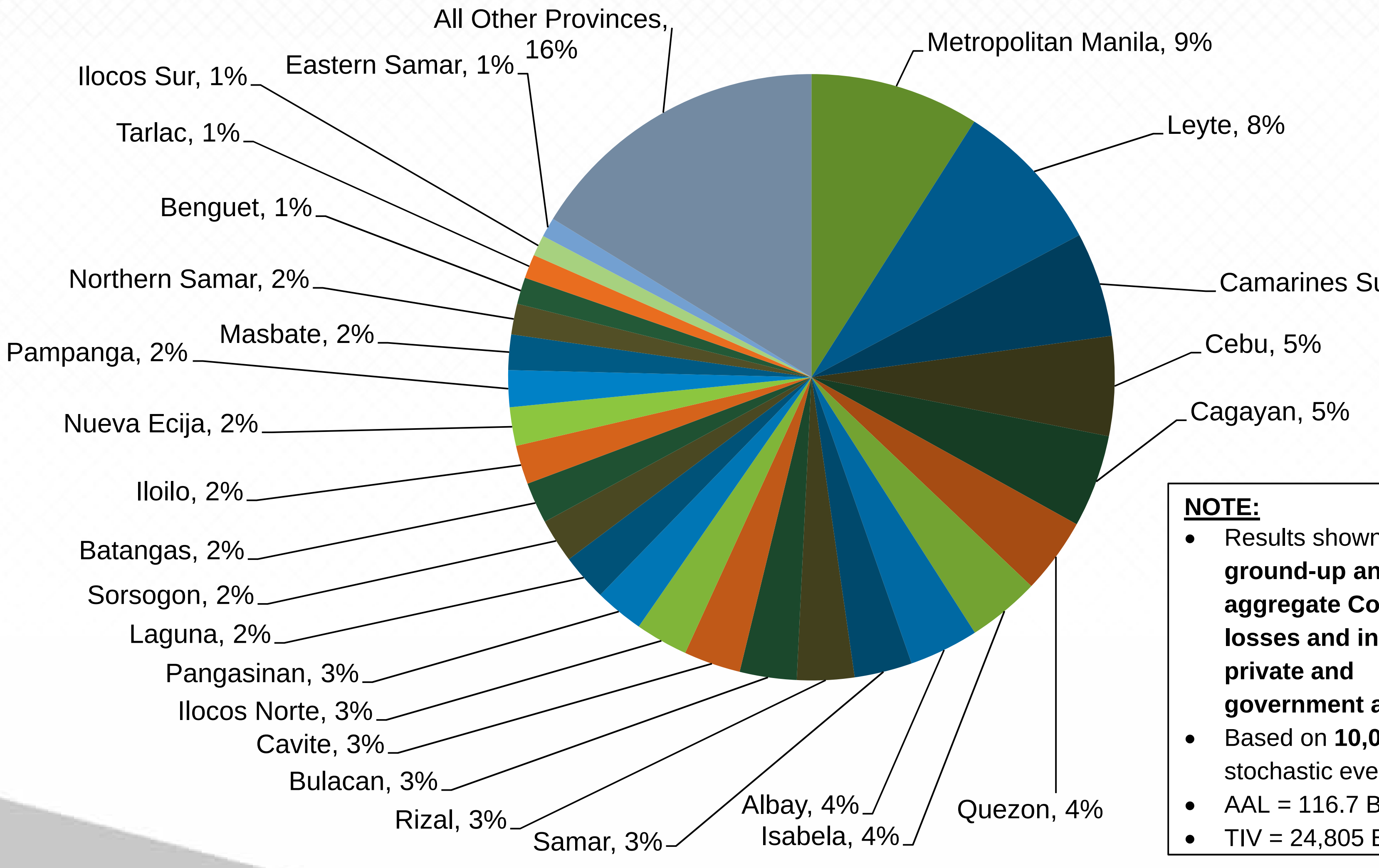
Government Asset AAL Disaggregation by Sector



AAL = 8.3 B PHP

TIV = 2,700 B PHP

Tropical Cyclone Loss: AAL by Province



NOTE:

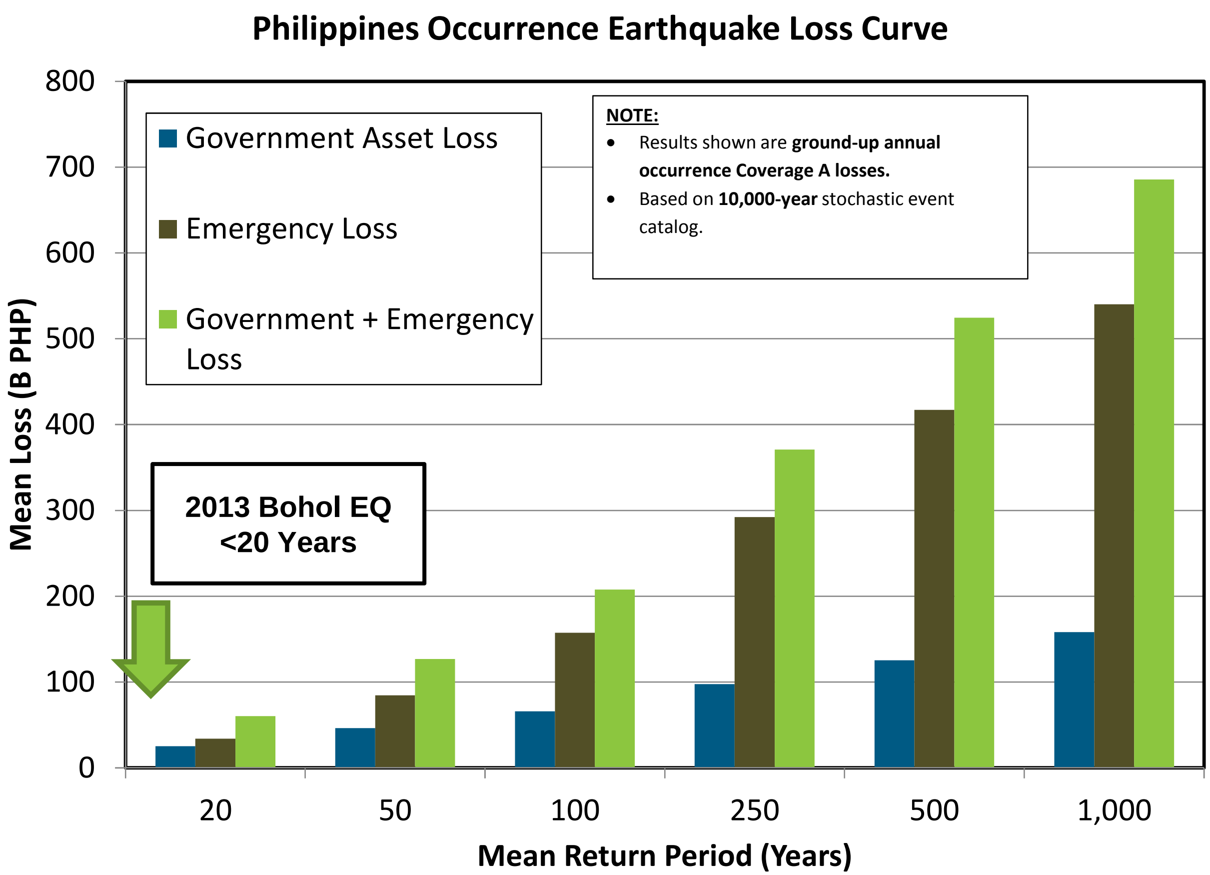
- Results shown are **ground-up annual aggregate Coverage A losses and includes private and government assets.**
- Based on **10,000-year** stochastic event catalog
- AAL = 116.7 B PHP
- TIV = 24,805 B PHP

Emergency Loss

- **Definition**: expenses associated with necessary relief and recovery efforts
  - e.g. such efforts include debris removal, setting up shelters, supplying medicine and food, among others
  - does not include repair and reconstruction costs

- **Computation**: estimated as a percentage of direct physical damage modelled losses
  - Based on past research work, an "average" estimate of the emergency loss, as a percentage of the direct losses suffered by private and public assets, is about:
    - 16% for earthquake ground shaking
    - 23% for tropical cyclones and flood
  - Approach has been applied for MultiCat and PCRAFI structures

Earthquake Loss: Government Asset and Emergency Loss



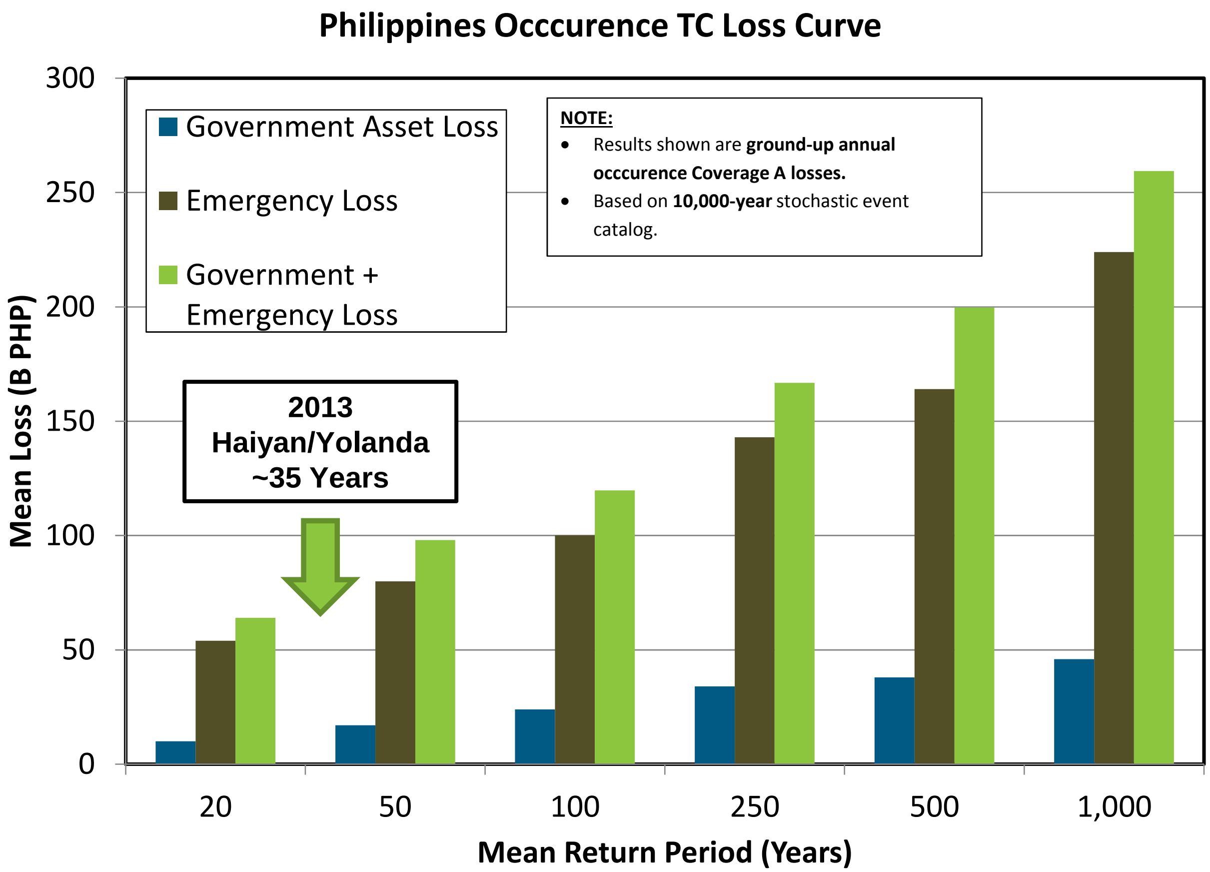
MRP (Years)	Occurrence Loss (B PHP)		
	Gov't Asset Loss	Emergency Loss	Gov't + Emergency Loss
20	25	34	60
50	46	85	127
100	66	158	208
250	98	292	371
500	125	417	525
1,000	158	540	686

Replacement Values (Coverage A):

Total = 25,000 B PHP
Private Property = 22,000 B PHP
Government Assets = 2,700 B PHP

GDP = 11,405 B PHP

Tropical Cyclone Loss: Government Asset and Emergency Loss



MRP (Years)	Occurrence Loss (B PHP)		
	Gov't Asset Loss	Emergency Loss	Gov't + Emergency Loss
20	10	54	64
50	17	80	98
100	24	100	120
250	34	143	167
500	38	164	200
1,000	46	224	259

Replacement Values (Coverage A):

Total = 25,000 B PHP
Private Property = 22,000 B PHP
Government Assets = 2,700 B PHP

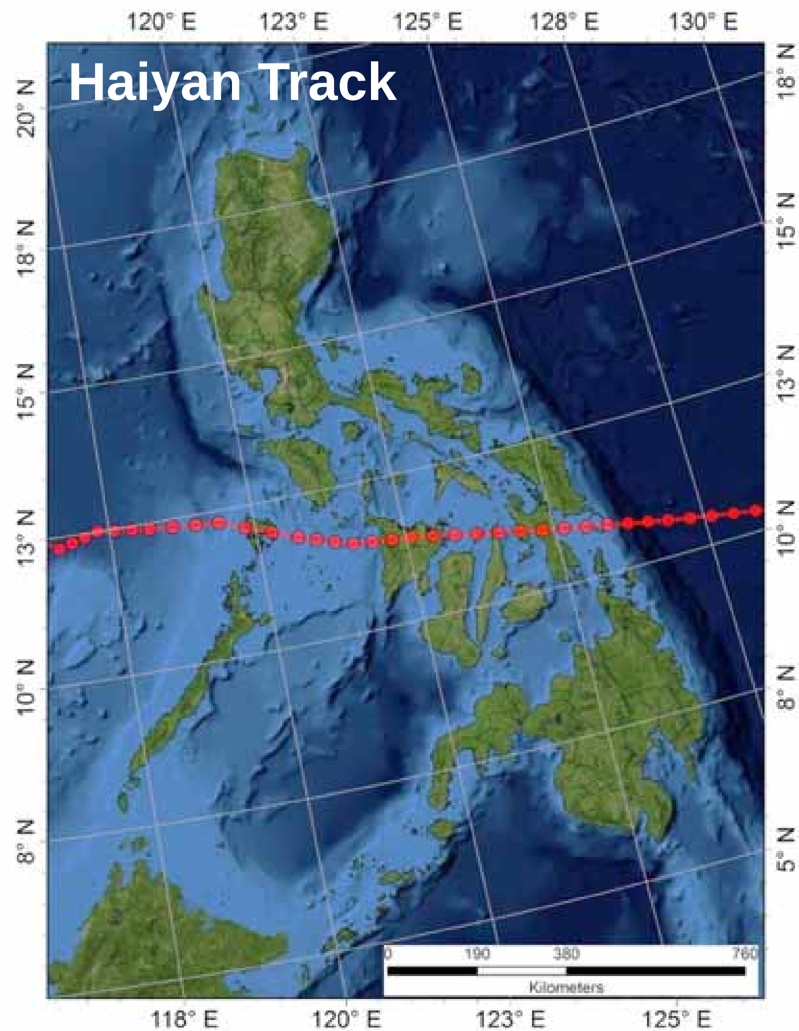
GDP = 11,405 B PHP

TC Wind and Precipitation Losses: Typhoon Haiyan

Typhoon Haiyan/Yolanda:

- Landfalling windspeeds: 165-195 mph
- Central pressure: 895 mb
- Largest impact in Samar, Leyte, Cebu, and Iloilo
- Estimated Losses:

	Private Property*	Gov't Assets	Emergency
Modelled Loss (B PHP)	**282.4**	**22.3**	**70.0**



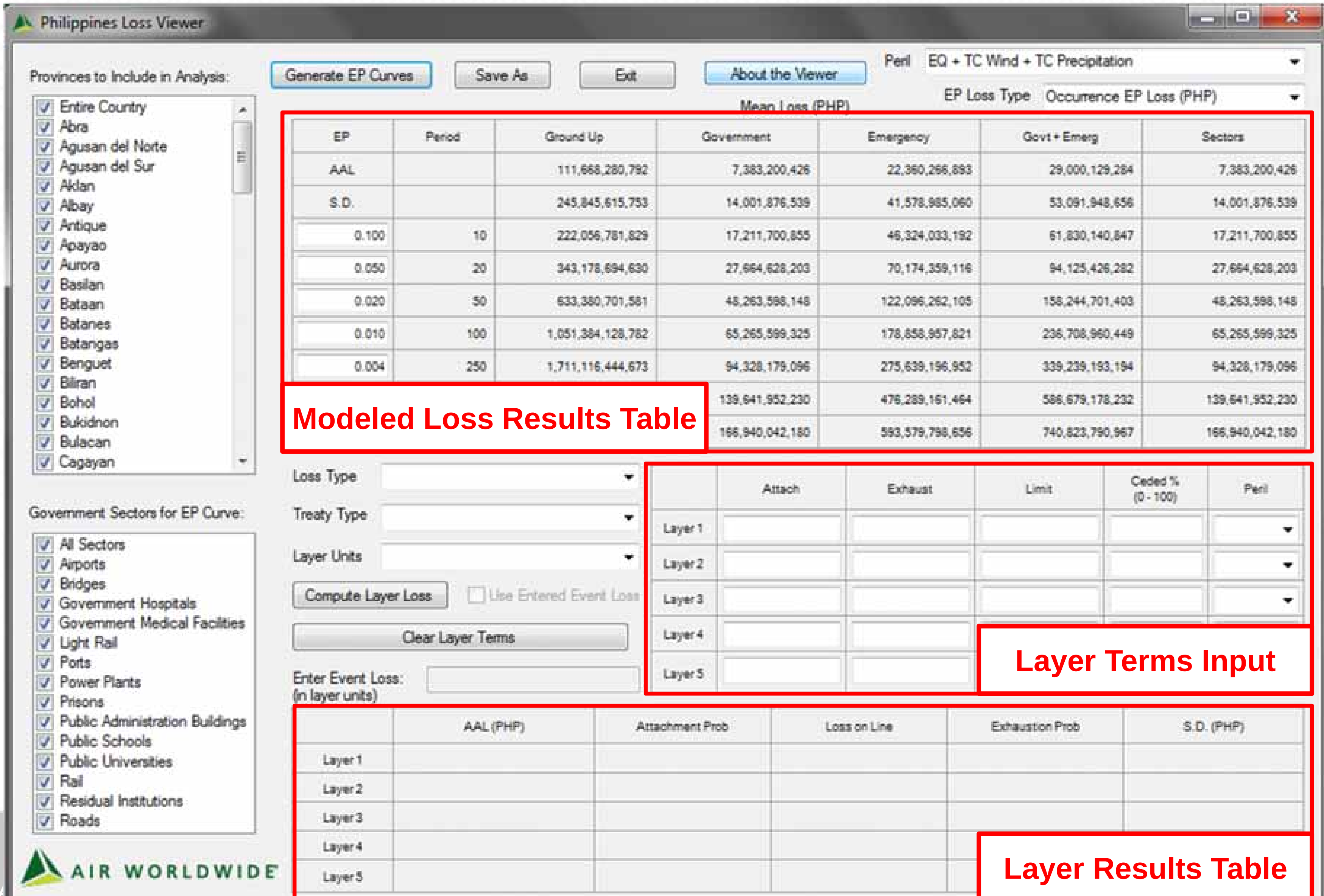
Modeled Loss: Historical TC Events

EVENT	Modeled (Private+Gov't IED) [B PHP]	Modeled Emergency Loss [B PHP]
Joan 1970	255	58.7
Angela 1995	72	16.6
Durian 2006	74	17.0
Fengshen 2008	45	10.4
Ketsana 2009	8.1	1.9
Parma 2009	19	4.4
Washi 2011	5.8	1.3
Bopha 2012	13	3.0

Philippines Loss Viewer Tool and Modeled Loss Structures

AIR

Loss Viewer Tool Live Demonstration



EP	Period	Ground Up	Government	Emergency	Govt + Emerg	Sectors
AAL		111,668,280,792	7,383,200,426	22,360,266,893	29,000,129,284	7,383,200,426
S.D.		245,845,615,753	14,001,876,539	41,578,985,060	53,091,948,656	14,001,876,539
0.100	10	222,056,781,829	17,211,700,855	46,324,033,192	61,830,140,847	17,211,700,855
0.050	20	343,178,694,630	27,664,628,203	70,174,359,116	94,125,426,282	27,664,628,203
0.020	50	633,380,701,581	48,263,598,148	122,096,262,105	158,244,701,403	48,263,598,148
0.010	100	1,051,384,128,782	65,265,599,325	178,858,957,821	236,708,960,449	65,265,599,325
0.004	250	1,711,116,444,673	94,328,179,096	275,639,196,952	339,239,193,194	94,328,179,096
			139,641,952,230	476,289,161,464	586,679,178,232	139,641,952,230
			166,940,042,180	593,579,798,656	740,823,790,967	166,940,042,180

	Attach	Exhaust	Limit	Ceded % (0 - 100)	Peril
Layer 1					
Layer 2					
Layer 3					
Layer 4					
Layer 5					

	AAL (PHP)	Attachment Prob	Loss on Line	Exhaustion Prob	S.D. (PHP)
Layer 1					
Layer 2					
Layer 3					
Layer 4					
Layer 5					

Modeled Loss Structures with USD 500M Limits and 2.0% EL

Loss Type: Emergency

Treaty Type: Occurrence with Agg Limit

Layer Units: PHP

Compute Layer Loss | Use Entered Event Loss

Clear Layer Terms

Enter Event Loss: (in layer units)

	Attach	Exhaust	Limit	Ceded % (0 - 100)	Peril
Layer 1	72975958394	94475958394	21500000000	100	EQ
Layer 2	69553176329	91053176329	21500000000	100	TC
Layer 3	110553852799	132053852799	21500000000	100	EQ+TC
Layer 4					
Layer 5					

	AAL (PHP)	Attachment Prob	Loss on Line	Exhaustion Prob	S.D. (PHP)
Layer 1	429,111,785	2.25 %	2.00 %	1.79 %	2,945,291,960
Layer 2	428,825,636	2.86 %	1.99 %	1.42 %	2,819,524,471
Layer 3	435,034,753	2.34 %	2.02 %	1.76 %	2,953,552,273
Layer 4					
Layer 5					

- US $500M (21.5B PHP) limit
  - Expected Loss Target: 2% across each peril and combined
  - Region: entire country
  - 2.2-2.9% attachment probability (35-45 year return period)
  - AAL approximately 430M PHP (US $10M)

Example Parametric Structure: Earthquake (2% EL)

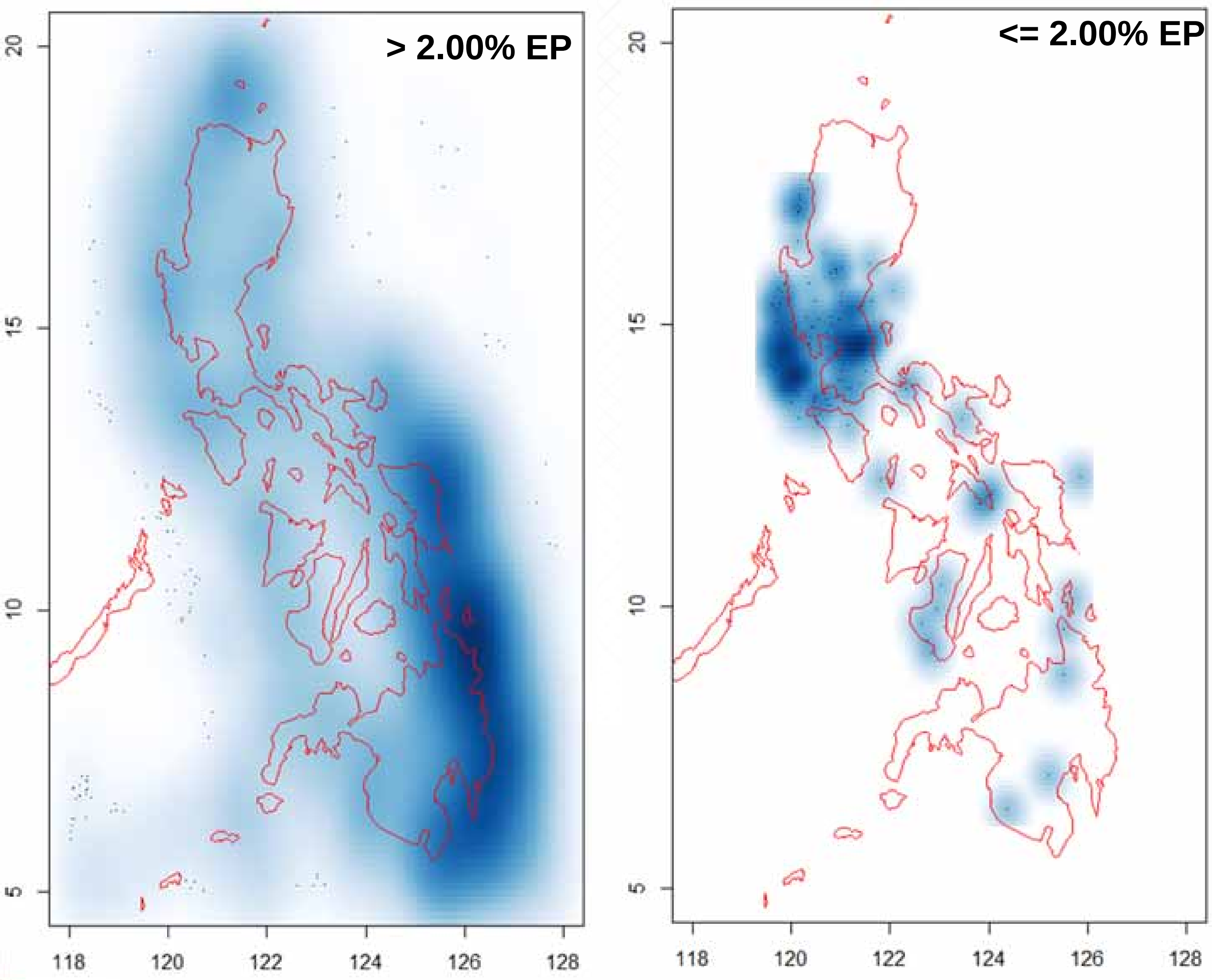
Parametric Structures Overview

- DoF input (consistent with modeled loss structures):
  - US $500M cover
  - Expected Loss Target: 2%
  - Region: entire country

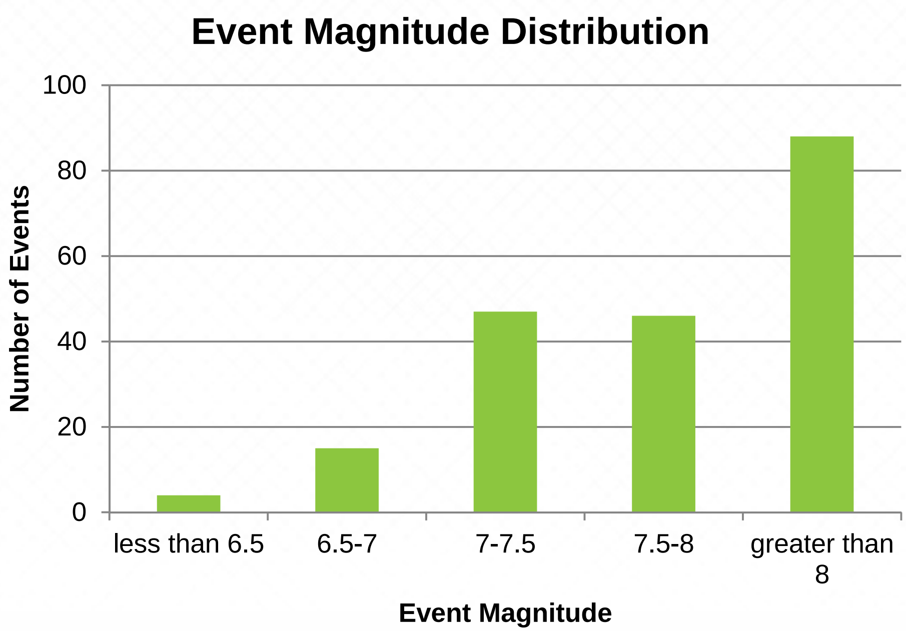
- Current analysis:
  - First generation Cat-in-the-box structures
  - Independent Earthquake and Tropical Cyclone structures
  - Allows various customizations, e.g.,:
    - any proportion across perils (e.g., 250M each across EQ and TC)
    - Incorporation of geographical preferences (e.g., specific locations)
  - Optimization of basis risk

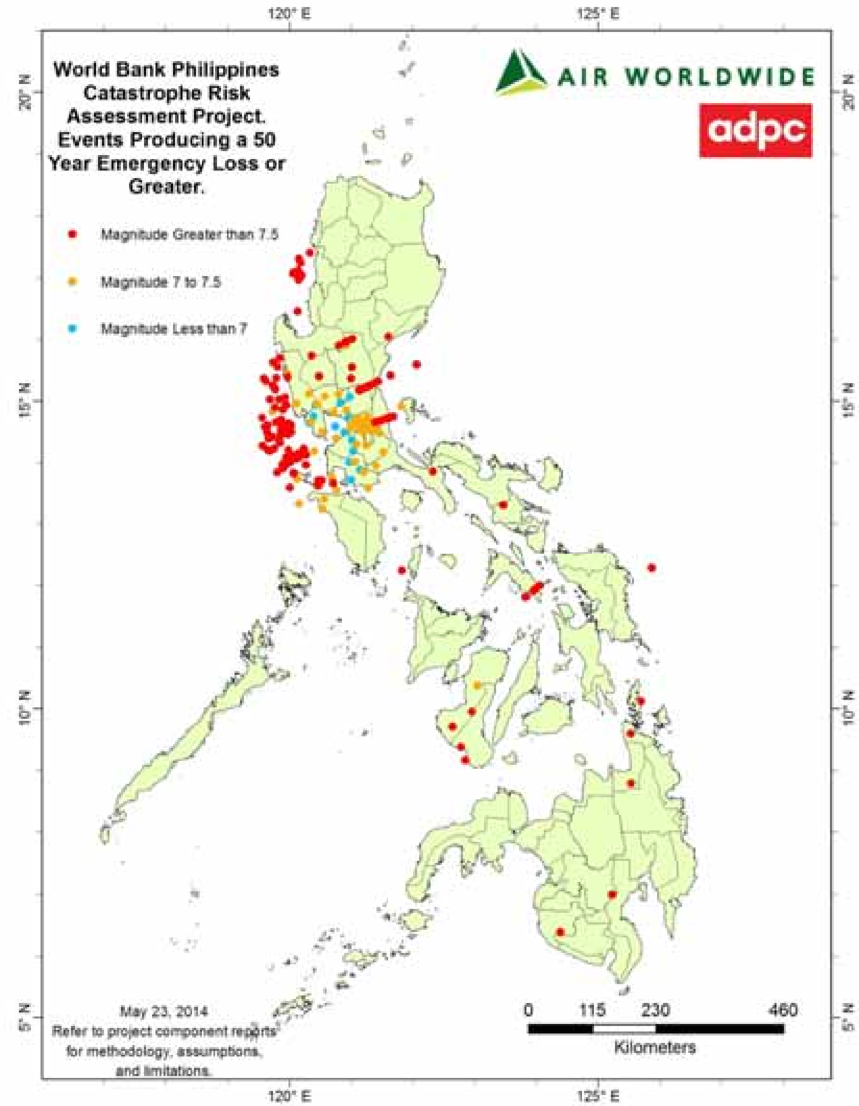
- Availability of risk model allows for integration of hazard, exposures, and loss potentials … as opposed to working only on the basis of hazard

Frequency Distribution
>2.00% EP vs <= 2.00% EP



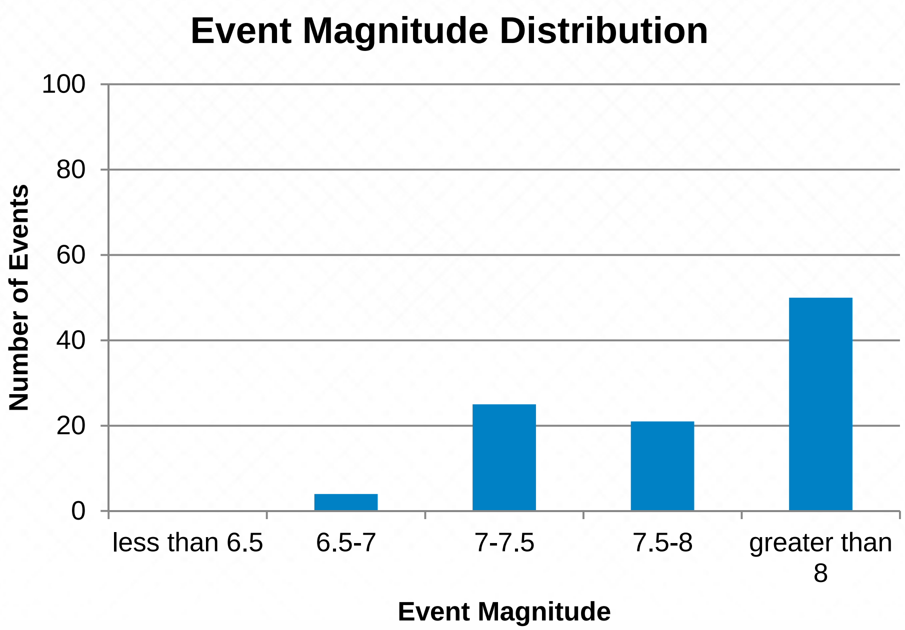
Earthquake Events Causing
50 year Emergency Loss or Greater

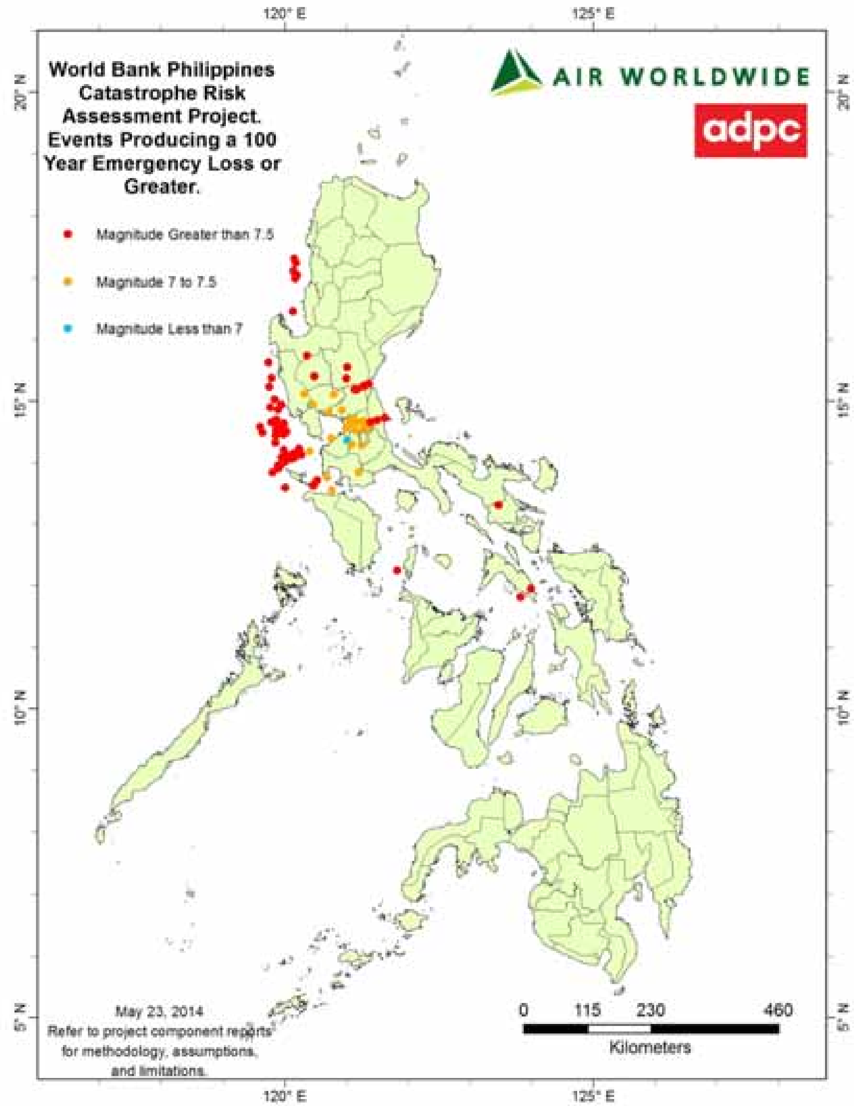




Emergency Occurrence Loss = 82B PHP

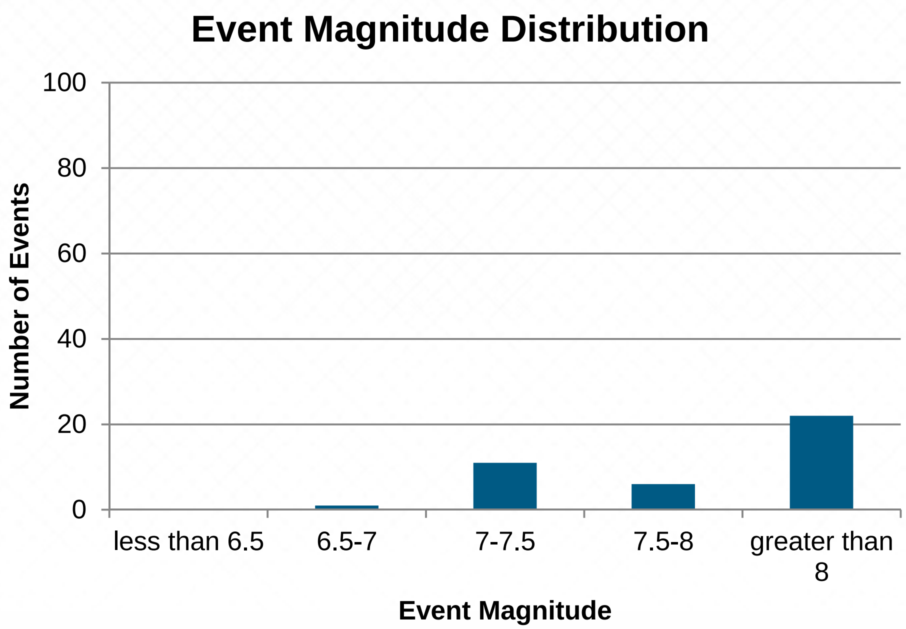
Earthquake Events Causing 100 year Emergency Loss or Greater

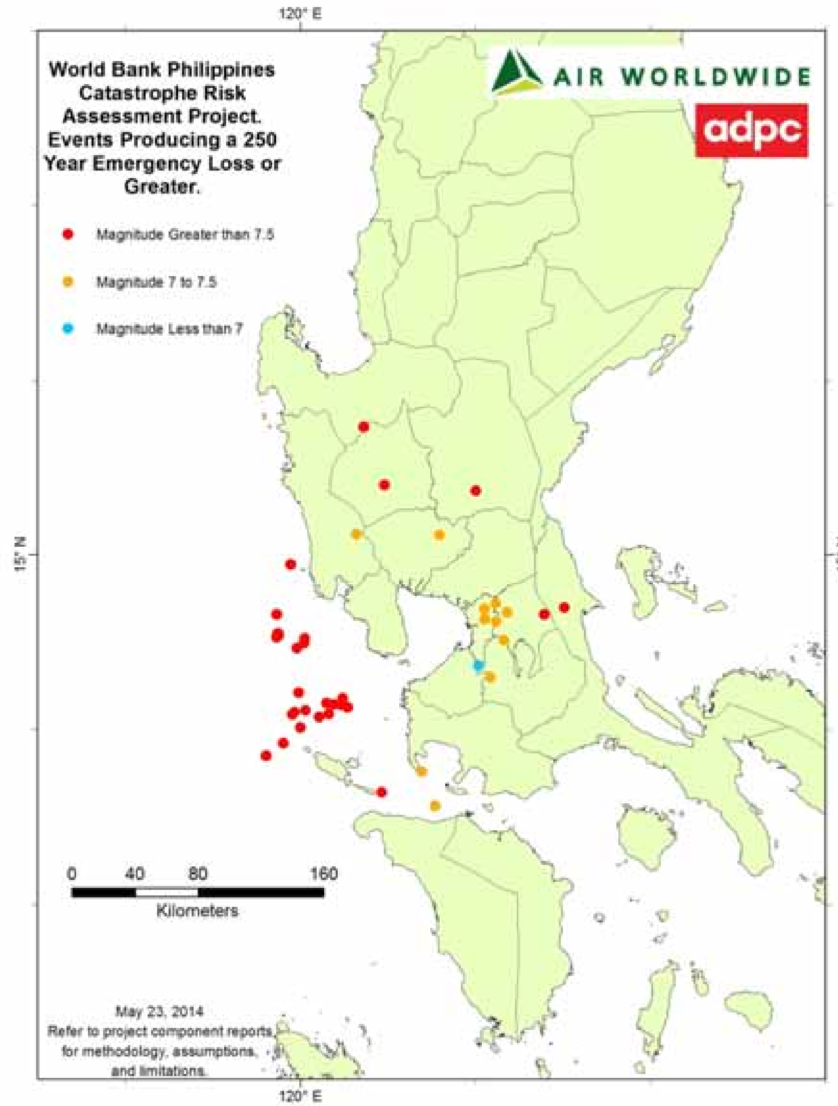




Emergency Occurrence Loss = 162B PHP

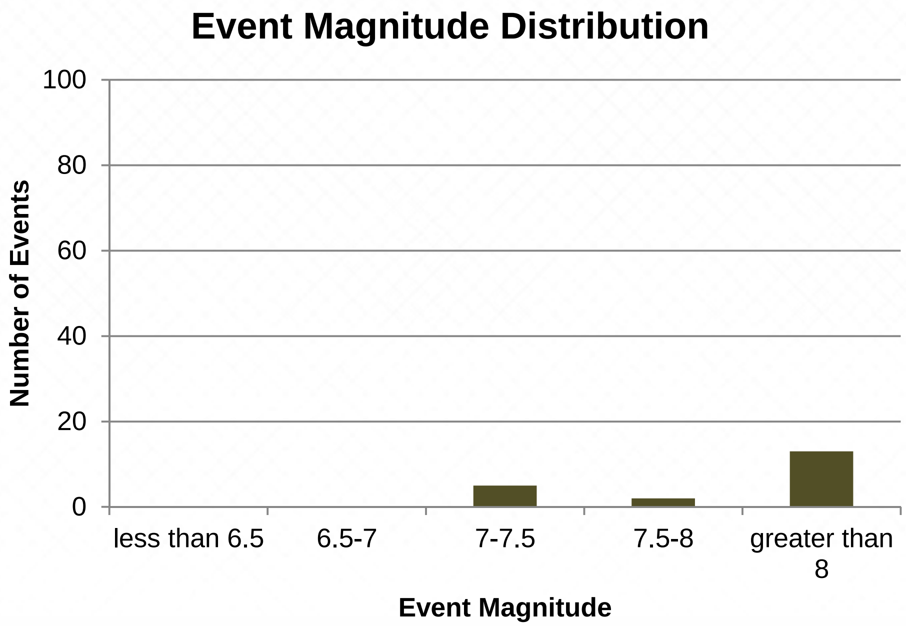
Earthquake Events Causing
250 year Emergency Loss or Greater

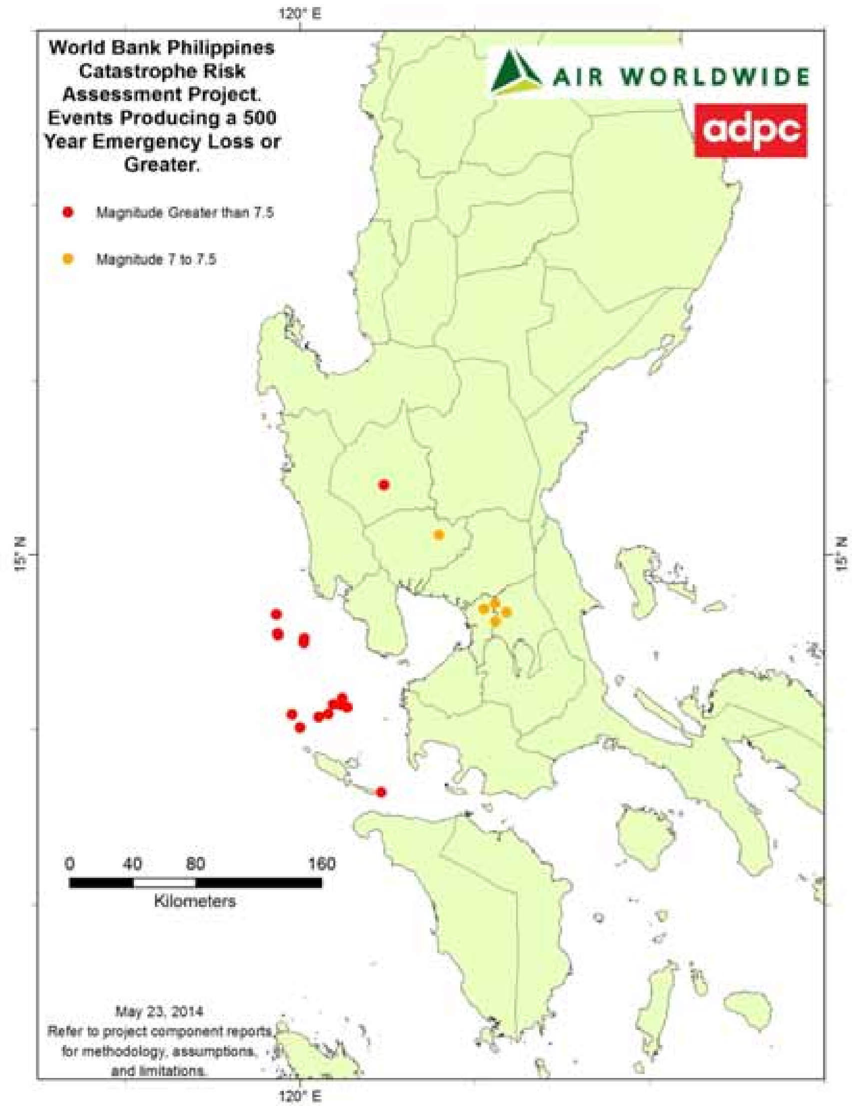




Emergency Occurrence Loss = 271B PHP

Earthquake Events Causing 500 year Emergency Loss or Greater

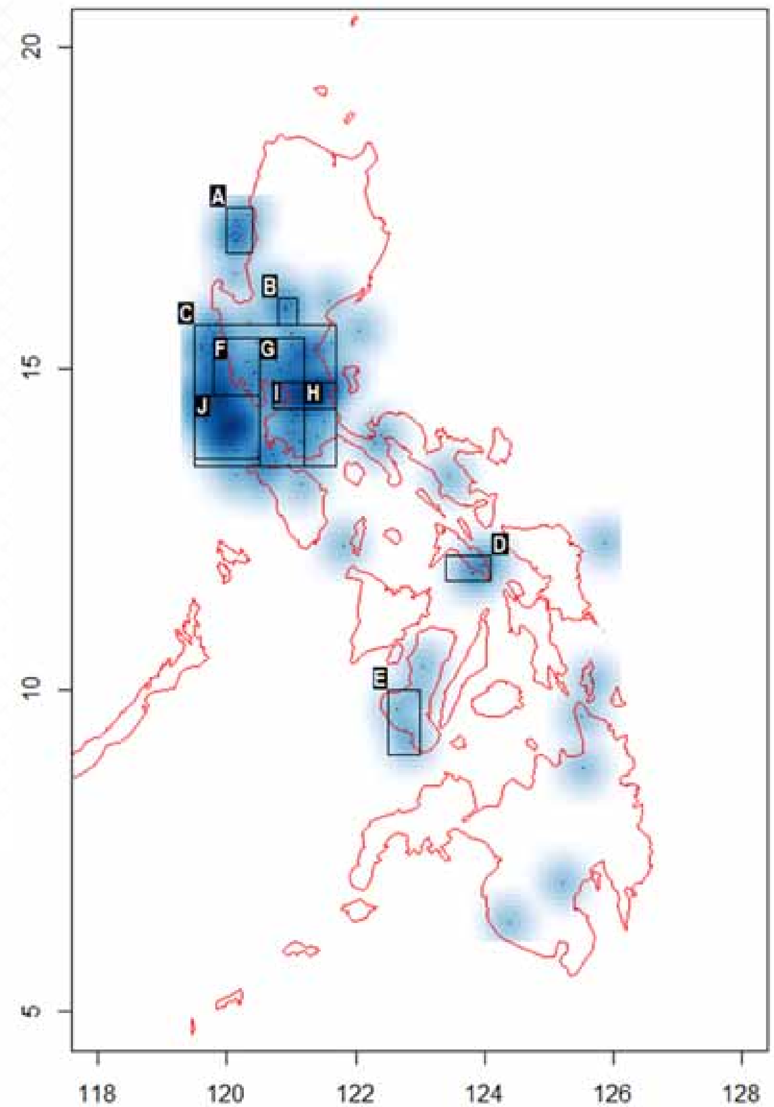




Emergency Occurrence Loss = 468B PHP

Example: Parametric Boxes

	Mag	NW Corner	SE Corner
A	8.0	17.5,120.0	16.8, 120.4
B	8.0	16.1, 120.8	15.7, 121.1
C	7.9	15.7, 119.5	13.5, 121.7
D	7.8	12.1, 123.4	11.7, 124.1
E	7.7	10.0, 122.5	9.0, 123.0
F	7.5	15.5, 119.8	14.6, 120.5
G	7.1	15.5, 120.5	13.5, 121.2
H	6.8	14.8, 121.2	14.4, 121.7
I	6.5	14.8, 120.7	14.4, 121.2
J	7.8	14.6, 119.5	13.6, 120.5



Earthquake Parametric Structure Summary

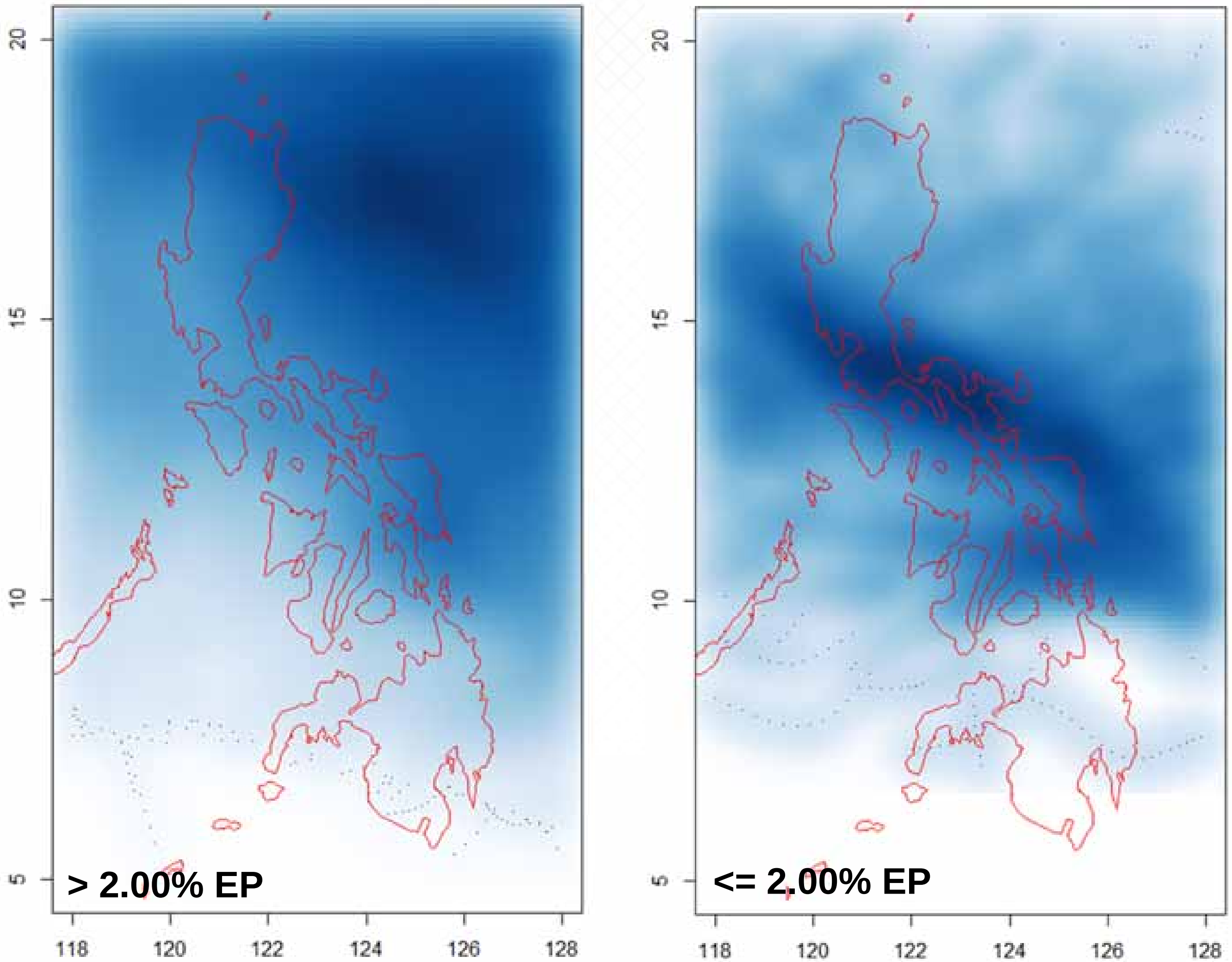
		Modeled Loss Year		
		<= 2.0% OEP	**>2.0% OEP**	**Total**
Qualifying Parametric Events	**Triggering Year**	142	51	193
	Non-Triggering Year	58	9749	9807
	Total	200	9800	10000

- Key findings:
  - Current structure provides approximately 2% expected loss (EL) target
  - Basis risk within reasonable range (51/193 < 30%)

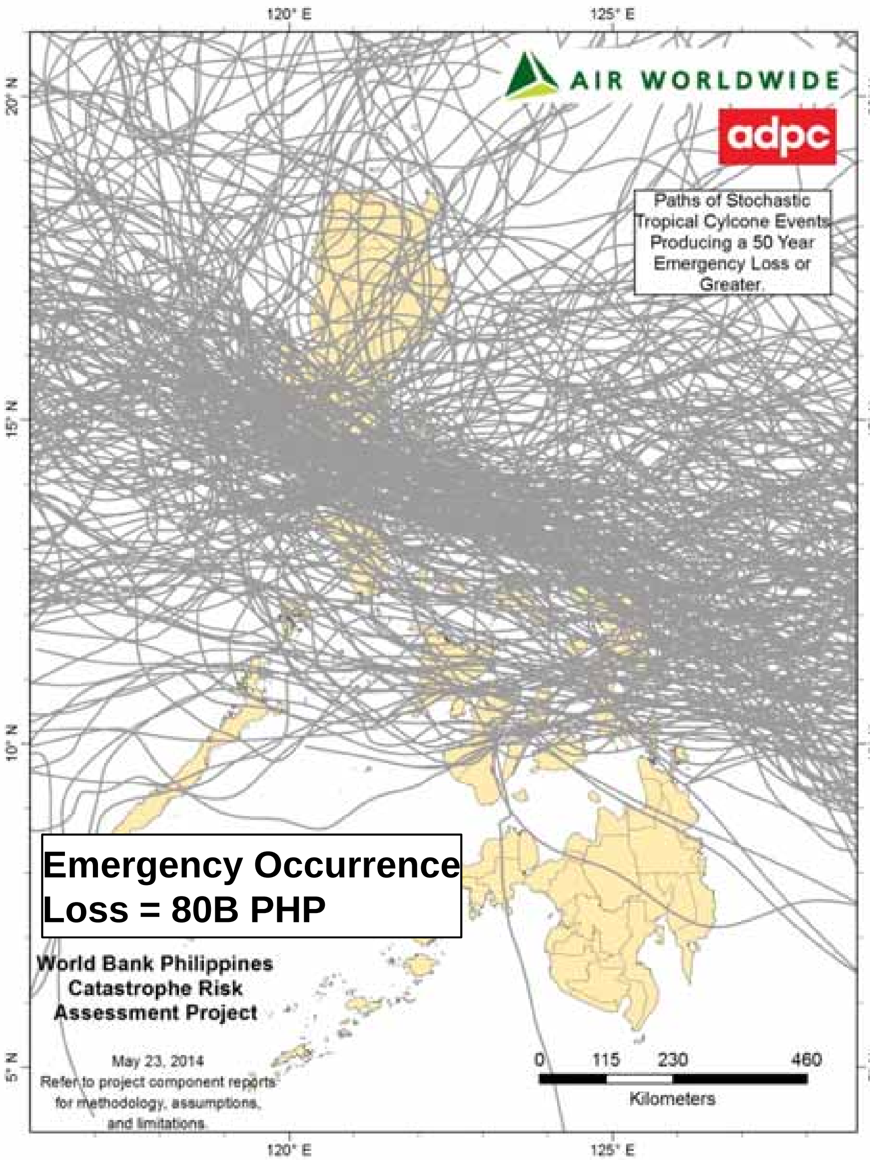
- Additional considerations:
  - Finalize expected loss preference (e.g., 2 or 3%?)
  - Specify any particular geographic preferences

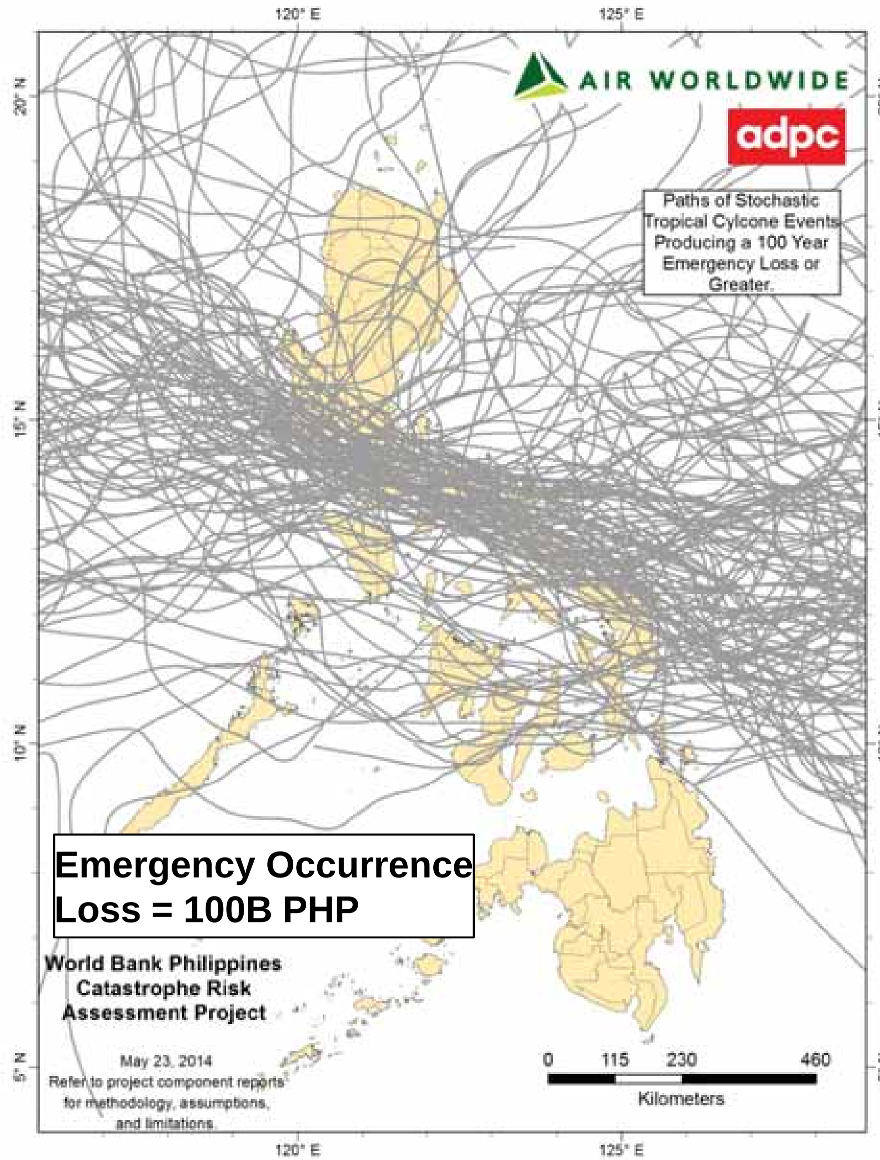
Example Parametric Structure: Tropical Cyclone (2% EL)

Path Frequency Distribution
> 2.00% EP vs <= 2.00% EP, Cat 3+ only

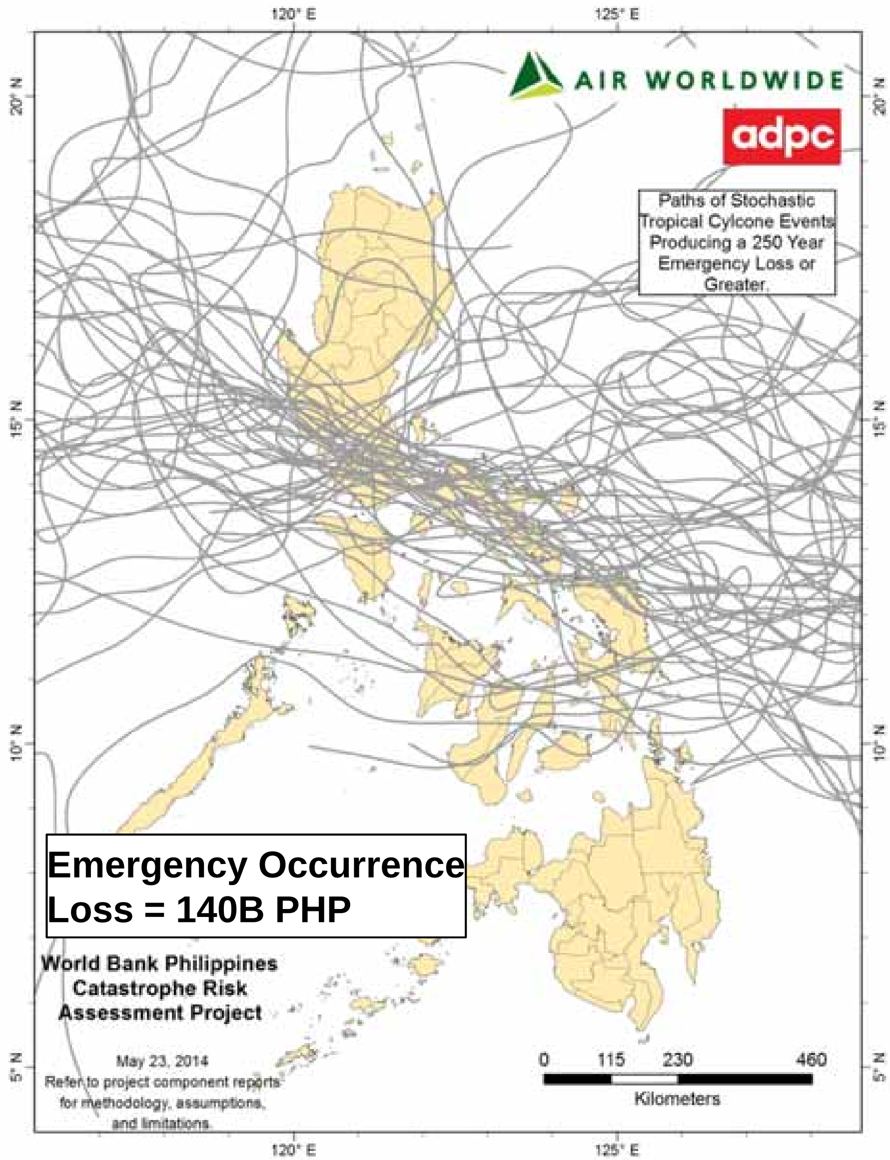


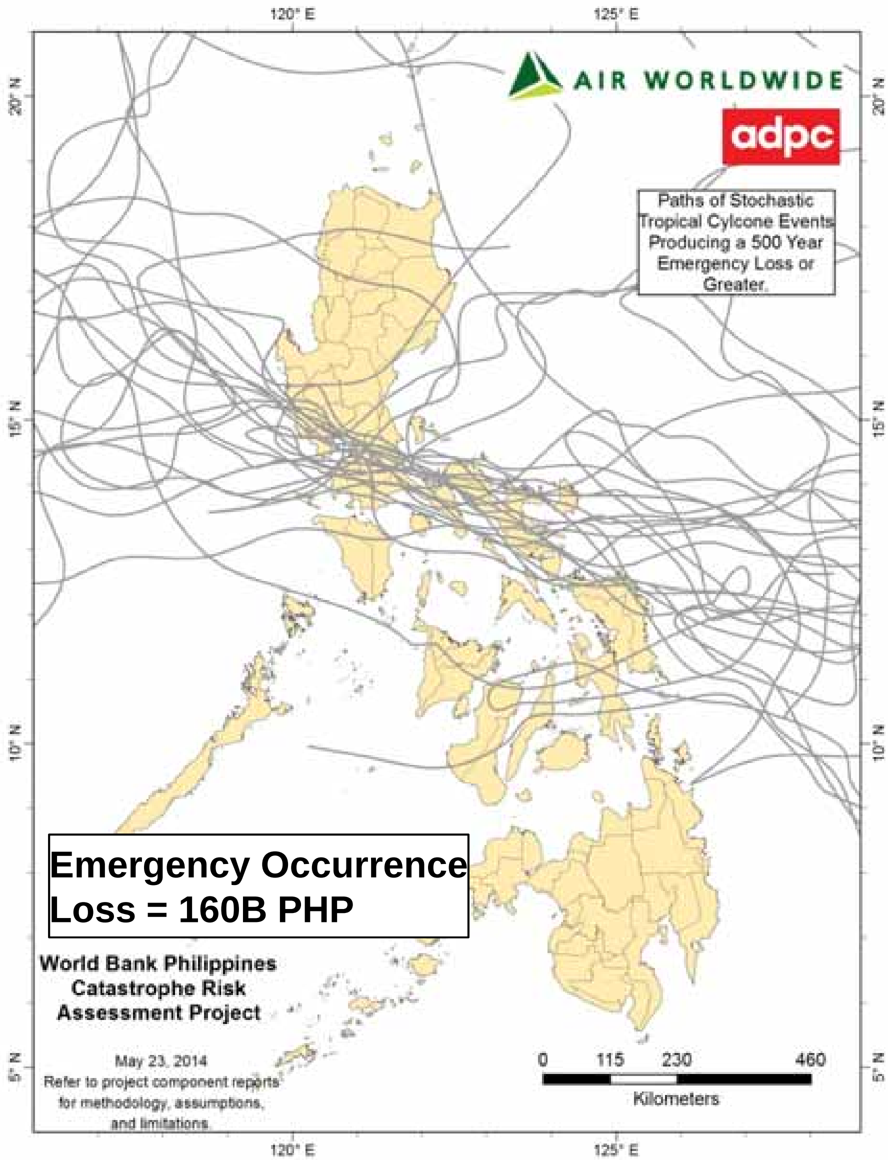
Tropical Cyclone Events Causing 50 and 100 year Emergency Loss or Greater





Tropical Cyclone Events Causing
250 and 500 year Emergency Loss or Greater

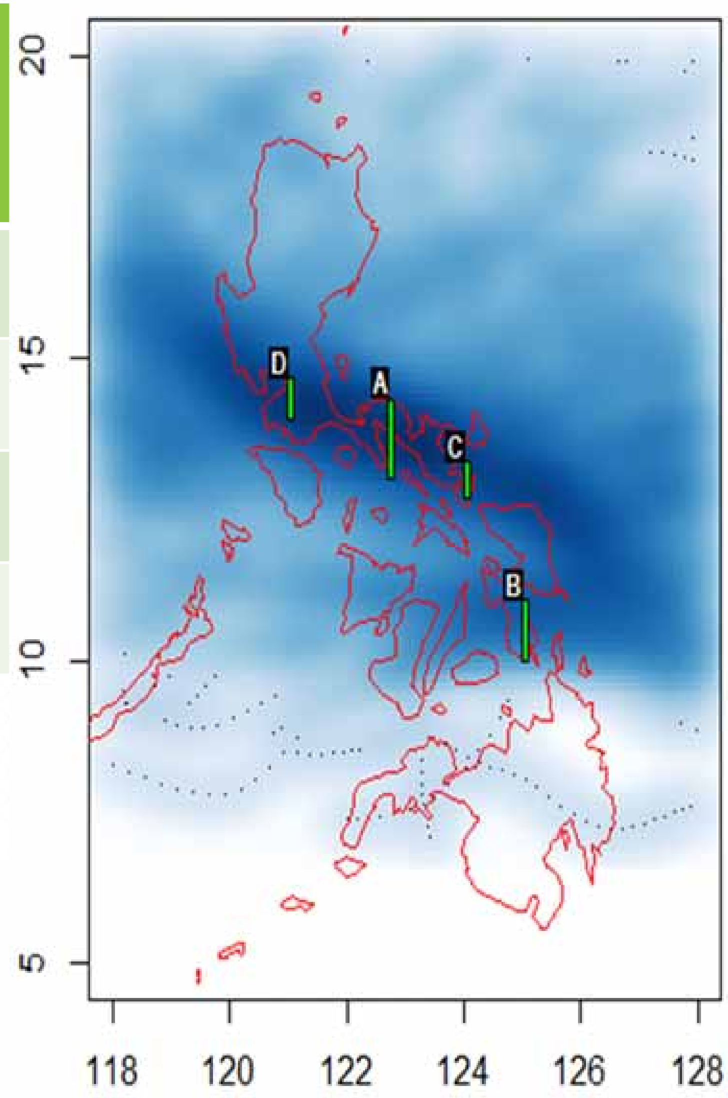




Example: Parametric Boxes

	SS (Central Pressure Threshold)	NW Corner	SE Corner
A	5 (920 mb)	122.7, 14.3	122.8, 13.0
B	5 (920 mb)	125.0, 11.0	125.1, 10.0
C*	4 (944 mb)	124.0, 13.3	124.1, 12.7
D*	3 (964 mb)	121.0, 14.7	121.1, 14.0

*Box C and D require that a single tropical cyclone passes through box C and box D while at category 4 and category 3 or higher strength respectively.



Tropical Cyclone Parametric Structure Summary

		Modeled Loss Year		
		<= 2.0% OEP	>2.0% OEP	Total
Qualifying Parametric Events	Triggering Year	83	94	177
	Non-Triggering Year	117	9706	9823
	Total	200	9800	10000

- Key findings:
  - Further optimization is required (note basis risk is 94/177 > 30%)
  - Expected loss slightly deviates from 2% Expected Loss target

- Additional considerations:
  - Finalize expected loss (2 or 3%?)
  - Specify any particular geographic preferences.

Project Summary

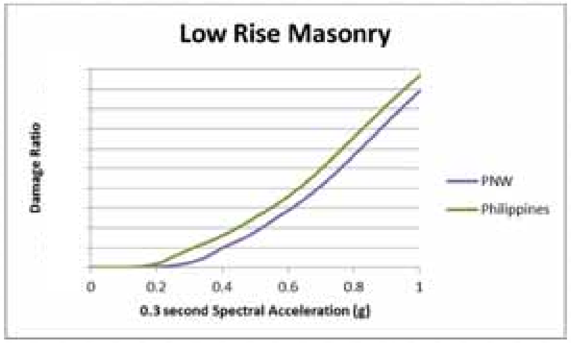
AIR

Project Summary: Outputs

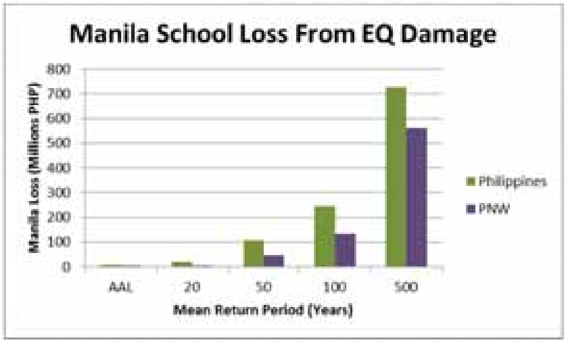
- Development of detailed exposure databases with asset characteristics and replacement values for residential, commercial, industrial, and national government assets
- Enhancement of EQ and TC, and development of non-TC hazard, vulnerability, and loss models
- Catastrophe risk assessment at the national and province resolution, and finer for EQ. Dis-aggregation of risk by hazard, asset type, sector
- Various datasets provided in Excel & GIS format to WB along with technical reports encapsulating methodology, analyses, and results
- Development of a tool and risk metrics supporting modeled loss and parametric risk transfer structures. Tool provided to WB.
- Validation of individual components and overall framework

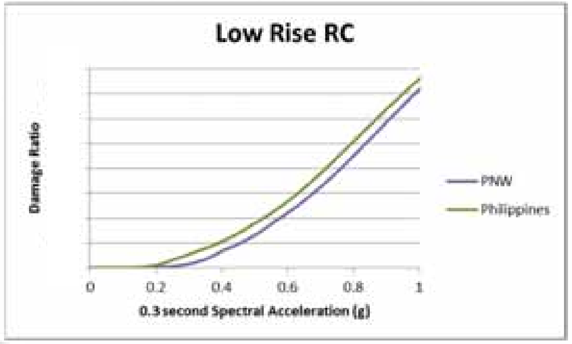
Project Summary: Additional Opportunities

- Availability of datasets and avenues to test various risk management techniques, e.g., evaluation of impact of improved building construction, risk pooling across provinces, sectors / LGUs, etc. e.g., minimal retrofit of schools and hospitals in Manila can result in:

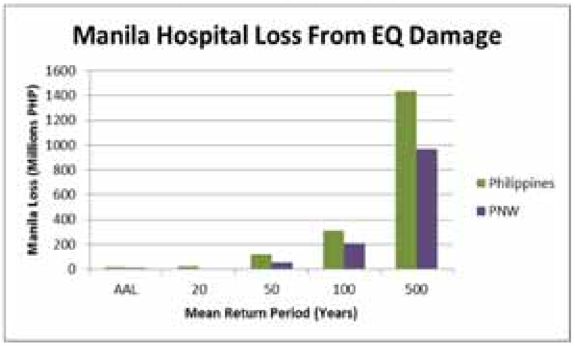


AAL Reduces by 36.9%





AAL Reduces by 37.6%



Project Summary: Overall

- There is room for improvement in parts of the risk modeling framework's application, for instance:
  - Exposures: incorporation of LGU assets, better data sets
  - Hazard: higher resolution for TC, incorporation of storm surge and full riverine flooding
  - Vulnerability: incorporation of observations of building performance from past events
  - Emergency Loss: possible refinement using Philippine specific data

- **Overall, the modeling framework, datasets, and applications are robust and consistent with applications for other countries, so as to draw confidence in the results for risk transfer purposes in the international markets**