

Disaster Risk Financing  
& Insurance Program



**GFDRR**  
Global Facility for Disaster Reduction and Recovery

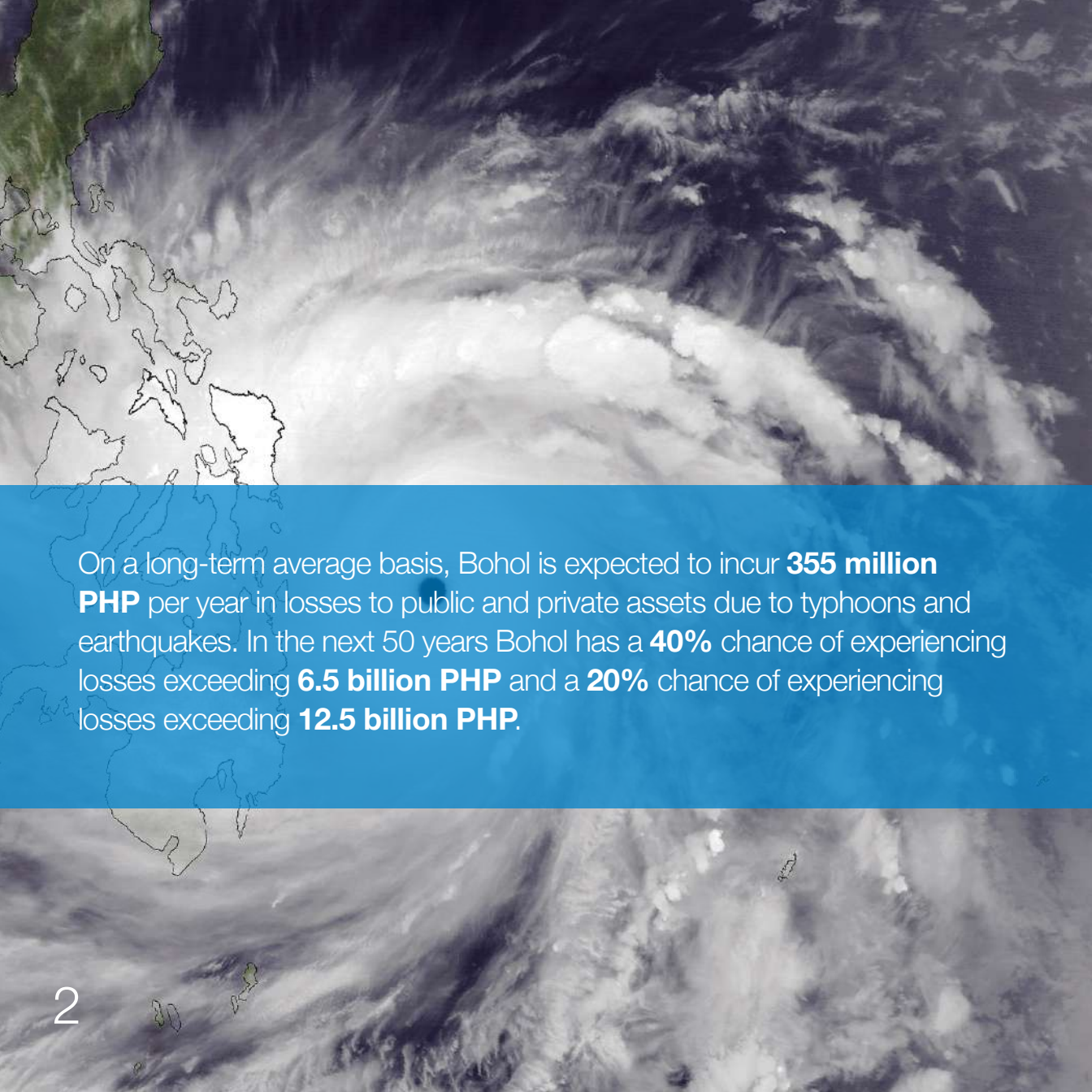


# Province Risk Profile: Bohol

Philippines Catastrophe Risk  
Assessment and Modeling

January 2018



A satellite image of a typhoon over the Philippines, with a map overlay of the country. The typhoon is a large, swirling cloud system with a distinct eye, moving over the Philippine archipelago. The map overlay shows the outline of the Philippines in white against the satellite background. A blue horizontal band is overlaid on the image, containing white text.

On a long-term average basis, Bohol is expected to incur **355 million PHP** per year in losses to public and private assets due to typhoons and earthquakes. In the next 50 years Bohol has a **40%** chance of experiencing losses exceeding **6.5 billion PHP** and a **20%** chance of experiencing losses exceeding **12.5 billion PHP**.

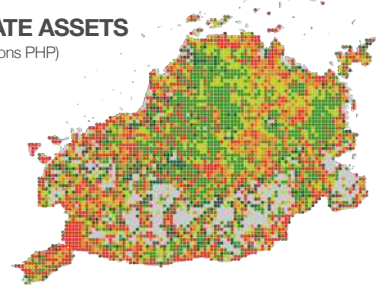
## Bohol Asset Replacement Value (ARV)

A detailed asset exposure database in Bohol includes an inventory of public and private property assets at risk. Private assets include residential, commercial, and industrial buildings. Public assets include airports, ports, hospitals, clinics, power plants, prisons, public administration buildings, public schools & universities, rail tracks & stations, bridges, and roads. The database was assembled using a variety of information from official agencies in the Philippines, including the National Statistics Office, Department of Public Works and Highways, Department of Education, and numerous publicly available sources.

A summary of the total assets in Bohol (as of 2015) in terms of the replacement value is presented here. The replacement value includes replacement costs of both structure and contents, when applicable.

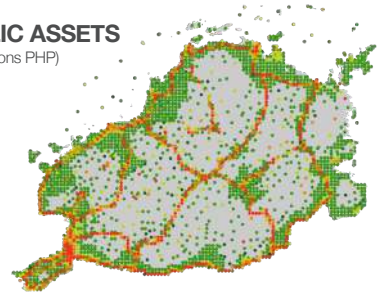
### PRIVATE ASSETS

ARV (Millions PHP)



### PUBLIC ASSETS

ARV (Millions PHP)



**86%** Private Assets  
246 billion PHP



**14%** Public Assets  
41 billion PHP

The boundaries, colors, denominations and any other information shown on the maps in this work do not imply, on the part of the World Bank Group, any judgment on the legal status of any territory, or any endorsement or acceptance of such boundaries



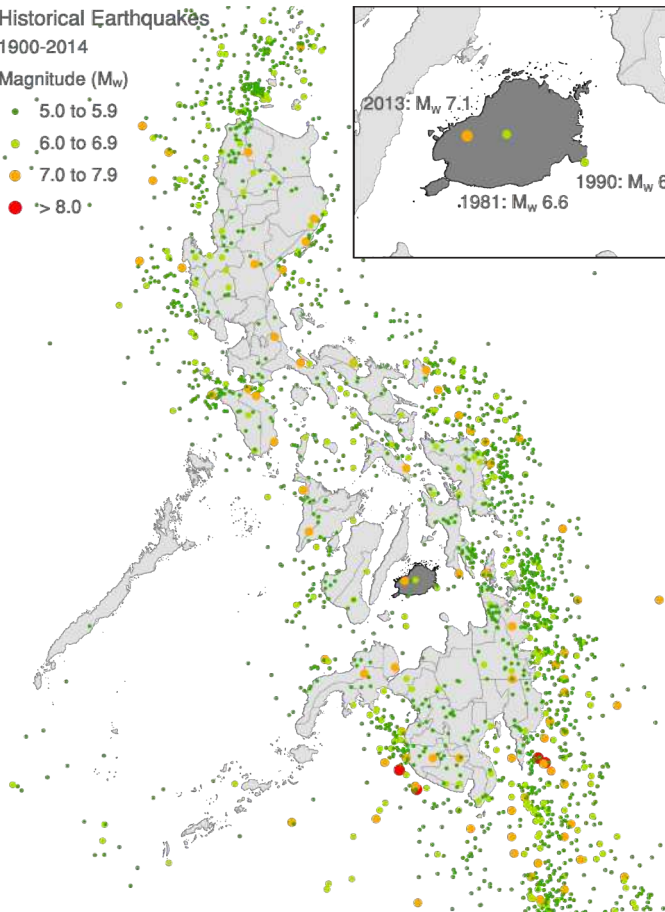
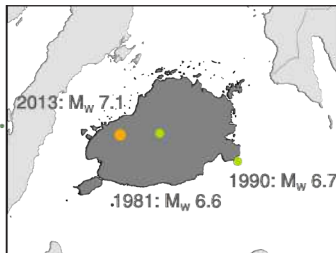


Historical Earthquakes

1900-2014

Magnitude ( $M_w$ )

- 5.0 to 5.9
- 6.0 to 6.9
- 7.0 to 7.9
- > 8.0



The Philippines is situated along the Pacific “Ring of Fire,” which aligns with the boundaries of major tectonic plates. These boundaries contain active seismic zones, capable of generating powerful earthquakes.

AIR’s model is developed using data from more than 80,000 historical earthquakes that have occurred within the model domain between 1600 and 2014.

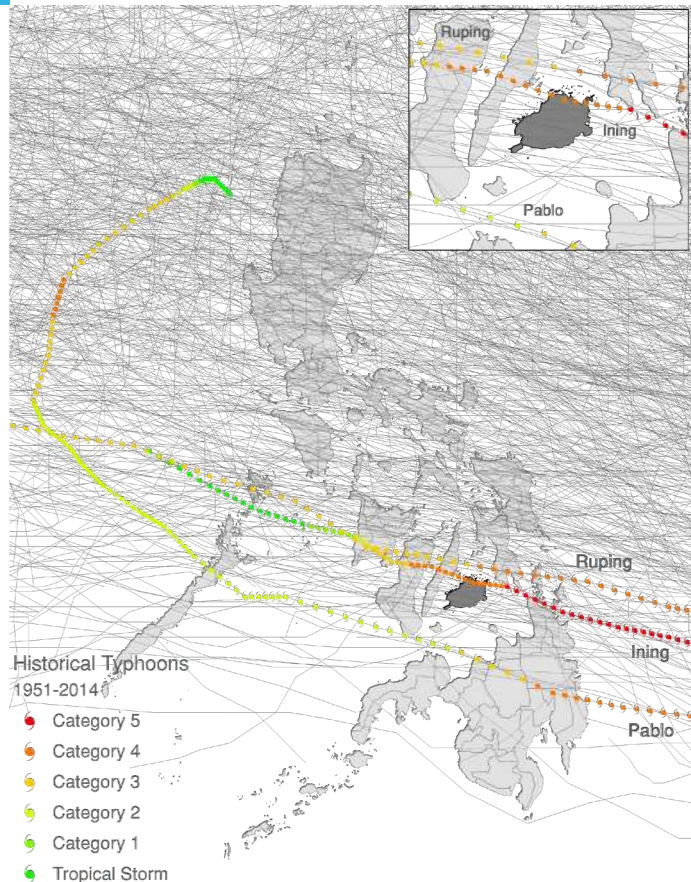
The map to the left depicts historical earthquake activity in the Philippines over the past century. For Bohol, three significant earthquakes by magnitude are highlighted.



The Philippines is one of the most natural hazard-prone countries in the world, due to its location in the Northwest Pacific Basin— known for its high frequency of typhoons and accompanying damaging winds, rain, and storm surge.

According to the JTWC, since 1959, an average of 26.6 typhoons and tropical cyclones have occurred in the Northwest Pacific Basin each year.<sup>1</sup> Typhoon activity in the basin peaks between July and November.

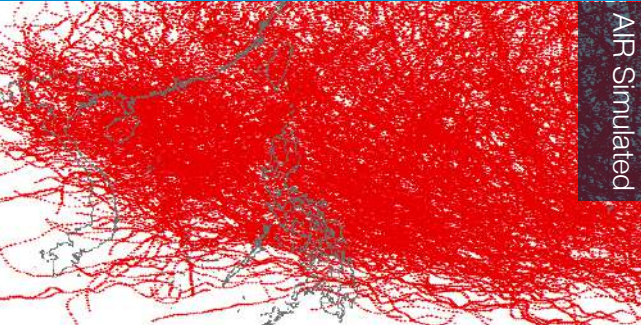
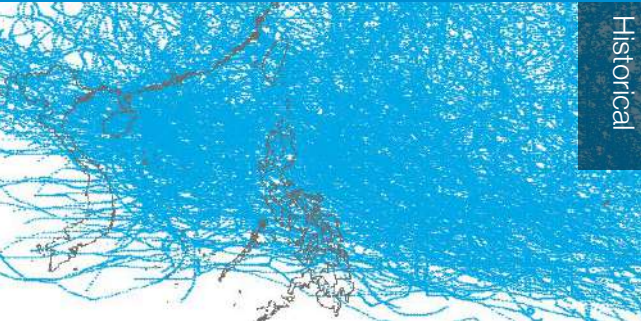
The map to the right depicts the historical record for typhoons in the Philippines between 1951 and 2014. For Bohol, three destructive historical typhoons are highlighted.



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<sup>1</sup>JTWC Annual Tropical Cyclone Report 2016: <https://metoc.ndbc.noaa.gov/ProductFeeds-portlet/img/jtwc/atcr/2016atcr.pdf>

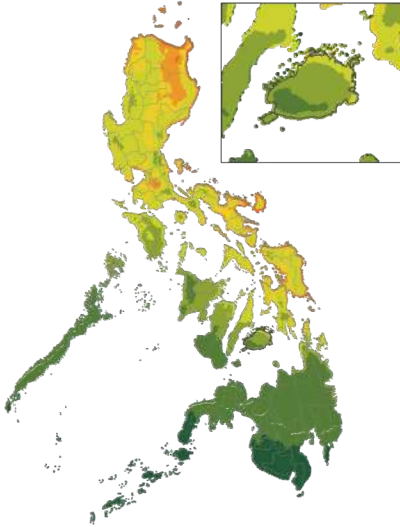
## Event Simulation



Using the historical catalogs of typhoons and earthquakes, AIR's researchers construct stochastic catalogs containing years of simulated activity that best reflect the scientific understanding of potential future events. For example, the illustration to the left compares the historical catalog of typhoons (blue) to the AIR simulated catalog (red). The typhoon and earthquake catalogs each contain 10,000 simulations of next year's event activity.

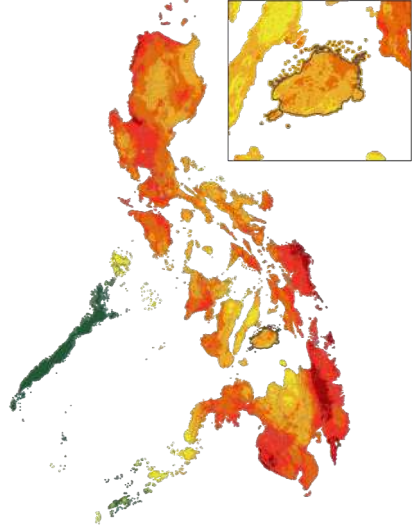
The simulated events are used to calculate the geographic distribution of hazard intensity associated with typhoons and earthquakes, such as wind speed and ground shaking, respectively. These intensity measures are directly related to the destructive potential of each event.

## TYPHOON



Category	Tropical Storm	1	2	3	4	5					
Sustained Winds (km/h)	< 59 – 59	119 – 136	136 – 154	154 – 166	166 – 178	178 – 194	194 – 209	209 – 231	231 – 252	252 – 276	> 276
Potential Damage	Light	Moderate	Extreme	Devastating	Catastrophic	Catastrophic	Catastrophic	Catastrophic	Catastrophic	Catastrophic	Catastrophic

## EARTHQUAKE



Instrumental Intensity	I	II-III	IV	V	VI	VII	VIII	IX	X+				
Peak Acc. (%)	< 0.17	0.17 – 1.4	1.4 – 4	4 – 9	9 – 13	13 – 17	17 – 24	24 – 32	32 – 45	45 – 61	61 – 85	85 – 114	> 114
Potential Damage	None	None	None	Very Light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy	Very Heavy	Very Heavy	Very Heavy	Very Heavy
Perceived Shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme	Extreme	Extreme	Extreme	Extreme

The figures above depict the AIR simulated wind speed from typhoons (left) and ground shaking acceleration from earthquakes (right) that have a **1% probability** of being exceeded each year (i.e. 100-year mean return period). These levels of intensity can cause severe damage to buildings and infrastructure that can lead to large economic losses and casualties.



## Loss Estimates

AIR's simulated event catalogs provide a measure of the likelihood of incurring a loss. These results can be used to calculate a probabilistic loss distribution, which is typically expressed as a loss exceedance probability (EP) curve. The EP curve represents the probability that a loss will be met or exceeded in any given year. The mean of this distribution is the average annual loss (AAL), or the expected loss per year, which represents the average loss a province is expected to incur each year.

In each simulated year, loss values are expressed as either the summation of all event losses (aggregate) or the maximum event loss (occurrence). Aggregate losses, or the total losses in a simulated year, are presented herein.

## Calculating the Probability of Exceeding Loss Levels

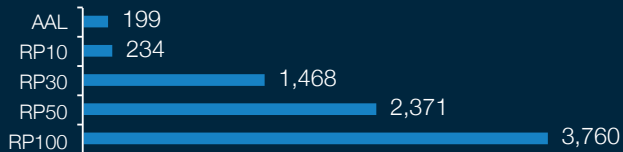
To generate AIR modeled losses, first the catalog of simulated events is run against the public and private asset database discussed on page 3. Next, the loss for each event in each of the 10,000 simulated years is calculated. Each simulated year's losses are summed and the years are ranked from largest to smallest by the amount of loss experienced during that year. The largest year's loss in the catalog is met only 1 time in 10,000 simulated years, which corresponds to an EP of 1/10,000, or a 0.01% chance of being met or exceeded in a given year. The graph to the right depicts the relationship between exceedance probability and loss. The chart on page 10 displays the modeled loss totals for Bohol from typhoons and earthquakes at different frequencies of occurrence. A 10% exceedance probability implies that Bohol has a 10% chance of meeting or exceeding that loss amount next year.



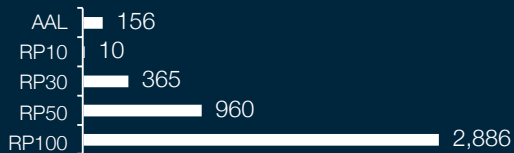


## Modeled Loss in PHP (millions)

### Typhoon



### Earthquake



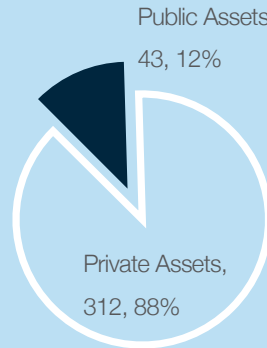
### Typhoon & Earthquake



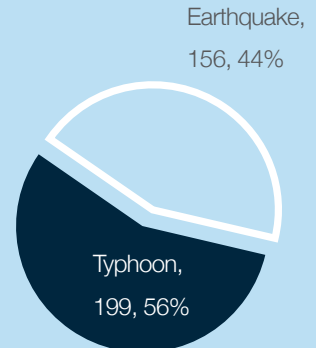
AAL = Annual Average Loss

### Average Annual Loss (AAL) Distribution

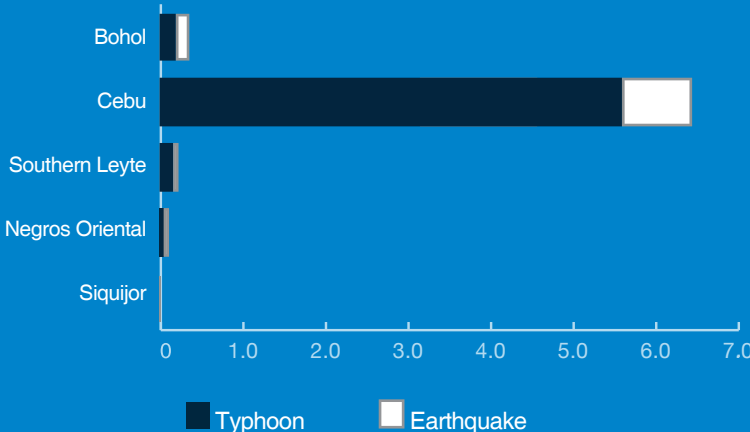
Bohol is likely to incur, on average, 355 million PHP per year in direct loss to modelled private and public assets due to typhoons and earthquakes, of which 12% is related to public assets. Of this annual average loss typhoons contribute 56% and earthquakes 44%.



ALL PERIL AAL DISTRIBUTION BY ASSET TYPE (PHP MILLIONS, % TOTAL)



ALL ASSETS AAL DISTRIBUTION BY PERIL (PHP MILLIONS, % TOTAL)



Average Annual Loss in Philippine Peso billions

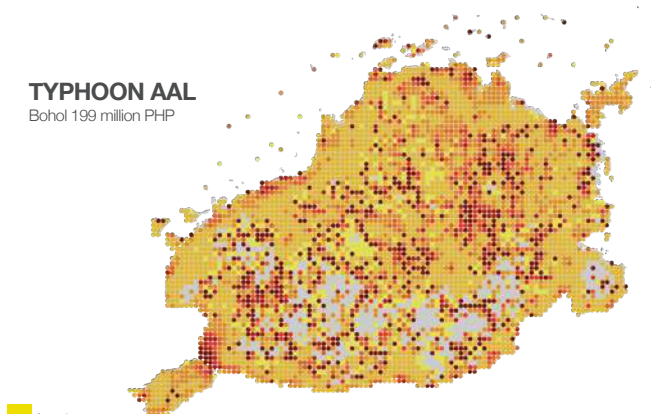
The chart depicts the loss contribution by peril for Bohol relative to neighboring provinces.



PROVINCE RISK PROFILE: BOHOL

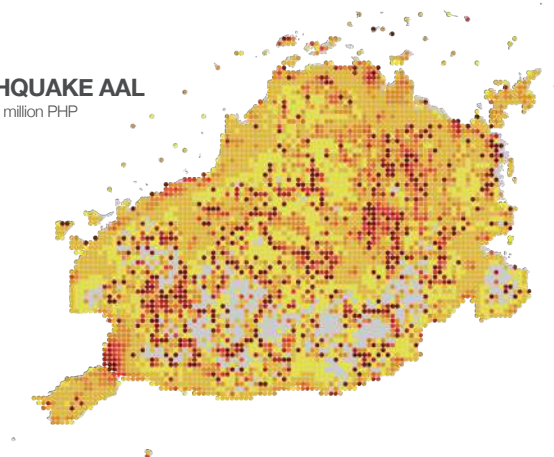
**TYPHOON AAL**

Bohol 199 million PHP



**EARTHQUAKE AAL**

Bohol 156 million PHP



Based on modeled results, Bohol is expected to incur, on average, 199 million PHP per year in direct loss to modeled private and public assets due to typhoons and 156 million PHP per year from earthquakes.

The loss maps to the left illustrate the AAL for Bohol from typhoons and earthquakes on a consistent loss scale enabling direct comparison between the two modeled perils.

Annual Exceedance Probability of Occurrence	AAL	10.0%	3.3%	2.0%	1.0%
Mean Return Period (years)	AAL	10	30	50	100

### Risk Profile: Typhoon

Direct Losses (millions PHP)	199	234	1,468	2,371	3,760
(% Asset Replacement Value)	0.1%	0.1%	0.5%	0.8%	1.3%
Emergency Loss (millions PHP)	31	33	204	334	605

### Risk Profile: Earthquake

Direct Losses (millions PHP)	156	10	365	960	2,886
(% Asset Replacement Value)	0.1%	0.0%	0.1%	0.3%	1.0%
Emergency Loss (millions PHP)	19	1	34	100	332

### Risk Profile: Typhoon & Earthquake

Direct Losses (millions PHP)	355	537	2,242	3,607	6,526
(% Asset Replacement Value)	0.1%	0.2%	0.8%	1.3%	2.3%
Emergency Loss (millions PHP)	49	68	298	523	978

The table above details the modeled loss totals in addition to the proportion of the loss to the asset replacement value for Bohol from typhoons and earthquakes at different frequencies of occurrence. The emergency loss represents an estimate of the loss that the national government may sustain as a result of providing necessary relief and undertaking recovery efforts. This is calculated as a proportion of the direct loss.

# Glossary

## Abbreviations:

**AAL** – Average annual loss

**ARV** – Asset replacement value

**EP** – Exceedance probability

**Aggregate Loss** – The sum of all event losses within each year in AIR's catalog of events (see Stochastic Catalog).

**AIR Model** – AIR develops catastrophe models, or computer programs that mathematically represent the physical characteristics of natural catastrophes, terrorism, pandemics, and cyber attacks. The results from the models help private and public sector entities understand and manage their risk. These models help answer questions such as: Where are future events likely to occur? How large, or severe, are they likely to be? How frequently are they likely to occur? What is the wind speed or ground shaking associated with each potential event? What is the property damage and loss associated with each potential event? The AIR Typhoon and Earthquake Models for Southeast Asia utilized for this project, and referred to in this brochure, were released in June 2016.

**Asset Replacement Value** – The cost to rebuild an entire structure/asset; the replacement value excludes land value and usually refers to part or all of the fixed components of a building or other asset or to its contents.

**Average Annual Loss** – The expected loss per year, averaged over the length of the catalog of events being considered (typically 10,000 simulated years). For example, if the total loss for 10,000

years is 10,000,000 PHP, then the average annual loss would be 1,000 PHP, or 10,000,000 PHP/10,000 years.

**Event Intensity** – The destructive potential of an event. The intensity metric varies by peril and includes ground shaking for earthquakes, wind speed for hurricanes, and the depth of the storm surge or precipitation-based flooding.

**Exceedance Probability** – The probability that any given level of loss will be met or surpassed within a given time period—for example, in the coming year. Loss probabilities can be provided at any geographic resolution—for an entire country's exposure, for a particular subset of buildings, or for an individual property. For example, if a historical typhoon has a 1% exceedance probability for the Philippines, that means that there is a 1% chance that another typhoon will cause losses equal to or greater than that in the Philippines next year.

**Exposure Database** – A collection of data containing counts of properties and their respective replacement values, along with information about occupancy (residential, commercial, industrial, etc.) and the physical characteristics of the structures, such as construction type (wood, steel, concrete, etc.), year built, and height classifications (1, 2, 3 stories, etc.).

**Historical Catalog** – A data set containing events that have previously occurred in the region. For typhoons, this includes meteorological and track information from the Japan Meteorological Agency (JMA) and the Shanghai Typhoon Institute (STI) for more than 1,800 storms that occurred in the Northwest Pacific Basin dating back to 1951. Precipitation data from the Tropical Rainfall Measurement Mission (TRMM) as well as satellite imagery from Digital Typhoon were primarily used to specify precipitation characteristics for the data set.



**Mean** – An average; the value obtained by dividing the sum of several quantities by their number.

**Occurrence Loss** – The largest event loss within each year in AIR’s catalog of events (see Stochastic Catalog).

**Peril** – A natural or man-made hazard, i.e., typhoon, earthquake, flood, terrorism, pandemic, cyber attack, etc.

**Probabilistic Model** – A statistical model designed to simulate actual events based on probability theory or the fact that randomness plays a role in determining future events. AIR generates catalogs of potential future events (described under Stochastic Catalog), which form the basis for drawing conclusions such as the likelihood that a peril will strike, where it will strike, its intensity, and the range of potential losses it may incur.

**Probability Distribution** – A statistical function that describes all the possible values and likelihoods that a random variable can take within a given range between the minimum and maximum statistically possible values. These distributions are used to calculate the likelihood that a given amount of loss will occur based on a spread of possible losses.

**Return Period** – The time period over which you should expect, on average, to see a loss of the same or greater magnitude. Return Periods are an alternative way to express exceedance probabilities. For example, the loss associated with a return period of 20 years has only a 5% chance of being equaled or exceeded this year, or in one year out of 20, on average. Return Period = 1 / Exceedance Probability.

**Simulated Activity/Events** – AIR’s models contain hypothetical years of typhoon/earthquake events, which are stored in event catalogs. These catalogs of computer-simulated catastrophes represent the broad spectrum of plausible events, with modeled years containing different numbers of events. The process of generating these events is described under Stochastic Catalog.

**Stochastic Catalog** – Catastrophe models simulate many years of natural disaster activity to capture a range of potential losses. These simulated events are contained in a stochastic catalog, with each year in the catalog representing one realization of what can happen in an upcoming year. To create a typhoon catalog, AIR first collects information on historical events (location, wind speed, central pressure, etc.) and subsequently develops probability distributions around these key variables. Once AIR creates the distributions for each of the variables, AIR samples from there to develop full catalogs based on their understanding of typhoons. For example, AIR starts by sampling from the annual frequency distribution, as this will determine the number of storms in any given year. Location frequency will determine where on the coast a typhoon will make landfall. The central pressure distribution will assign intensity to each event. The radius of maximum winds will tell AIR about the size of the typhoon. Forward speed can indicate the amount of damage that is likely to occur as slower storms frequently cause more damage. Finally, landfall angle plays a key role in understanding the potential impact of storm surge, or the rise of water above typical tidal levels resulting from a storm. This process allows AIR to account for events that are possible but may not have been recorded historically.



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