Damage assessment from the Mw 7.8 Ecuador earthquake of April 2016 field mission

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Acknowledgements

- John A. Blume Earthquake Center
- Prof. Greg Deierlein
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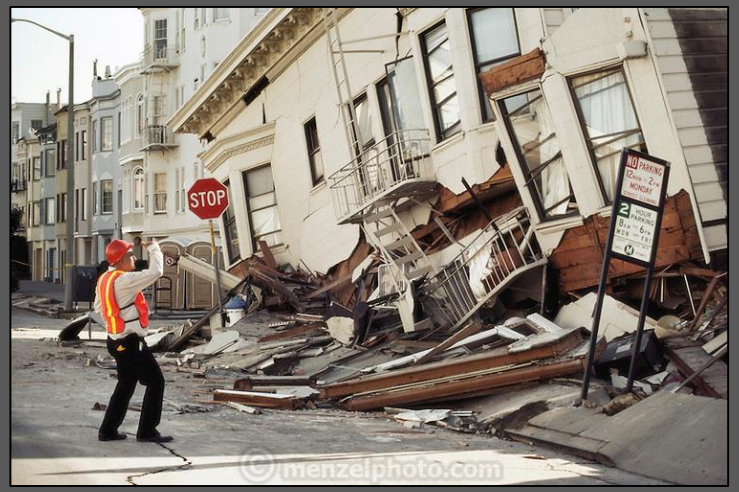
- Prof. Jonathan Bray
- Prof. Pedro Rojas
- Prof. Xavier Vera
- Prof. Sergio Flores

Introduction

(Eduardo Miranda)

October 17, 1989 M_w6.9 Loma Prieta Earthquake



October 17, 1989 M_w6.9 Loma Prieta Earthquake

http://images.mapsofworld.com/around-the-world/loma-prieta-earthquake-usa1.jpg

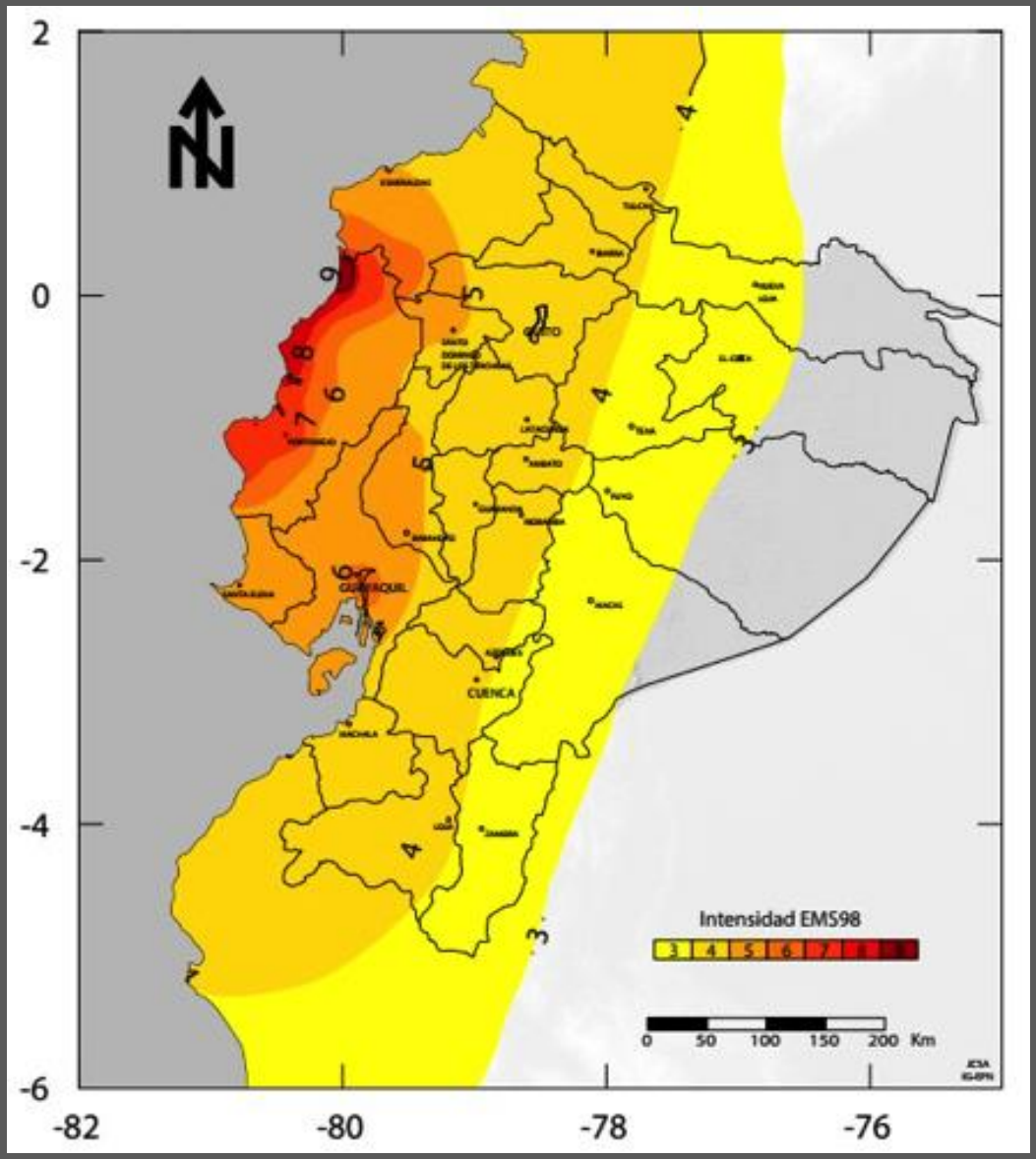
Now Imagine an earthquake 22 times bigger and in a country with a GDP per capita 9 times smaller

That is what we will summarize in the next half hour !

Location of Epicenter

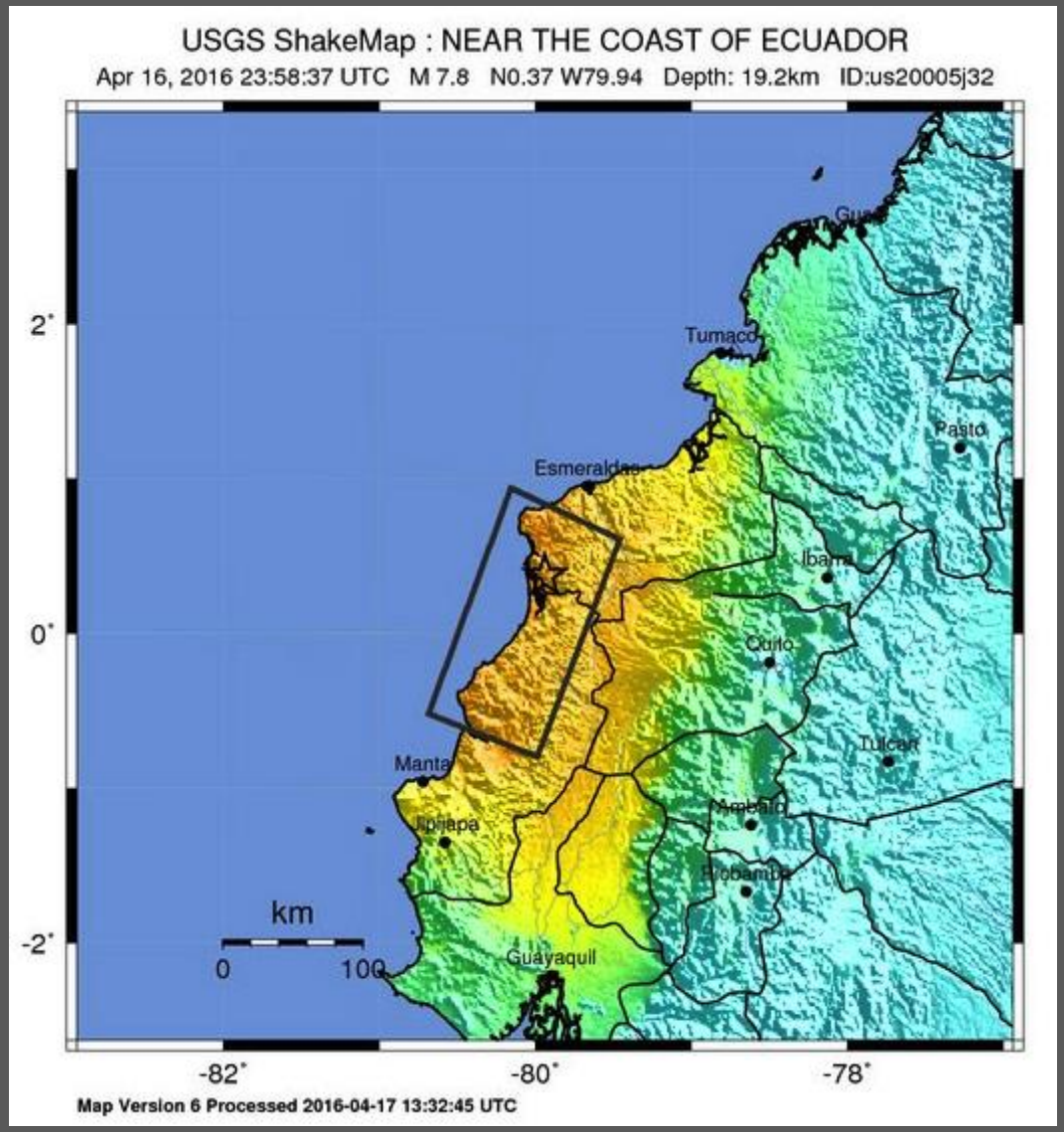
Source: WFFA

Map of Intensities according to EMS-98



Source: Escuela Politecnica Nacional

USGS Shake Map



Source: USGS

April 16, 2016 Ecuador Earthquake

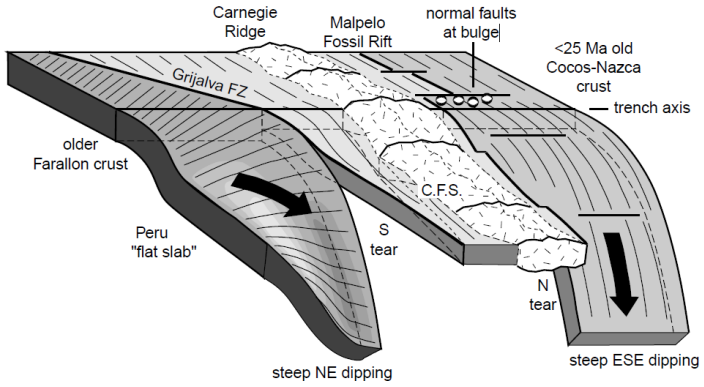
- *Magnitude M_w 7.8*
- *Local time 6:58pm*
- *661 deaths*
- *27,732 injured*
- *30,000 displaced residents*

Seismicity of Ecuador

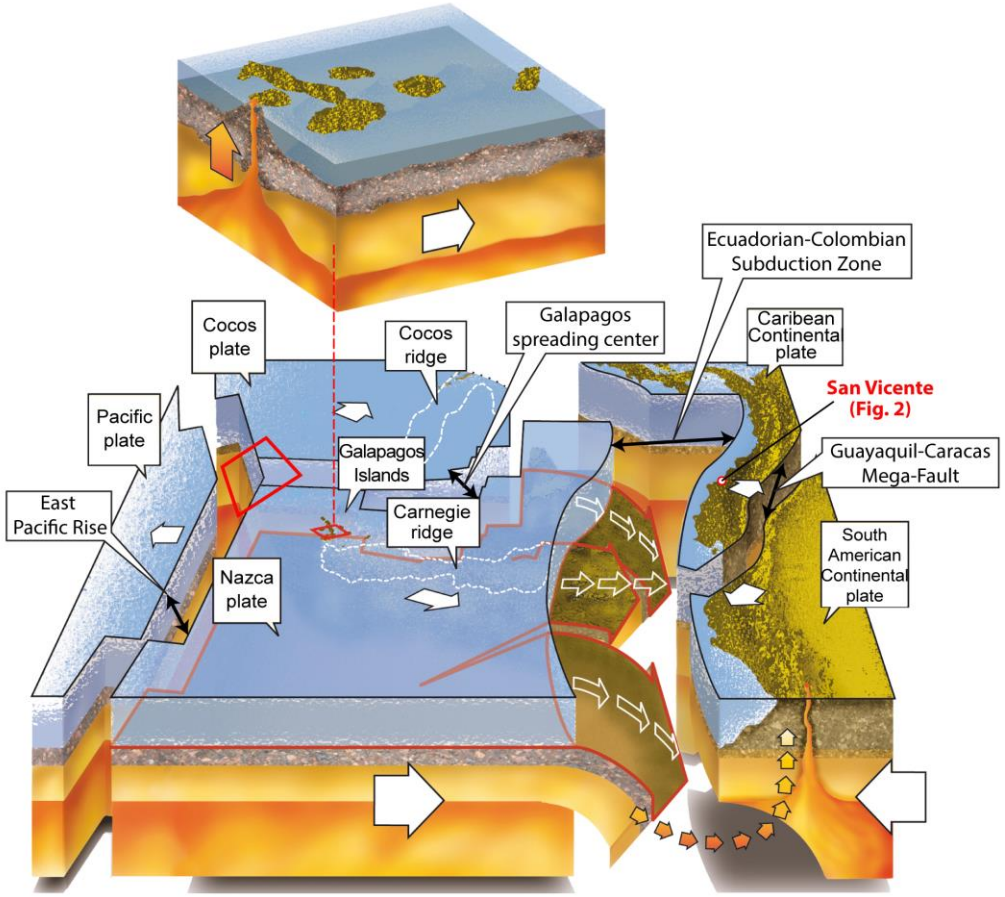
(Roberto)

Seismicity in Ecuador

- Tectonic environments in Ecuador:
  - Subduction
  - Crustal earthquakes
  - Volcanism



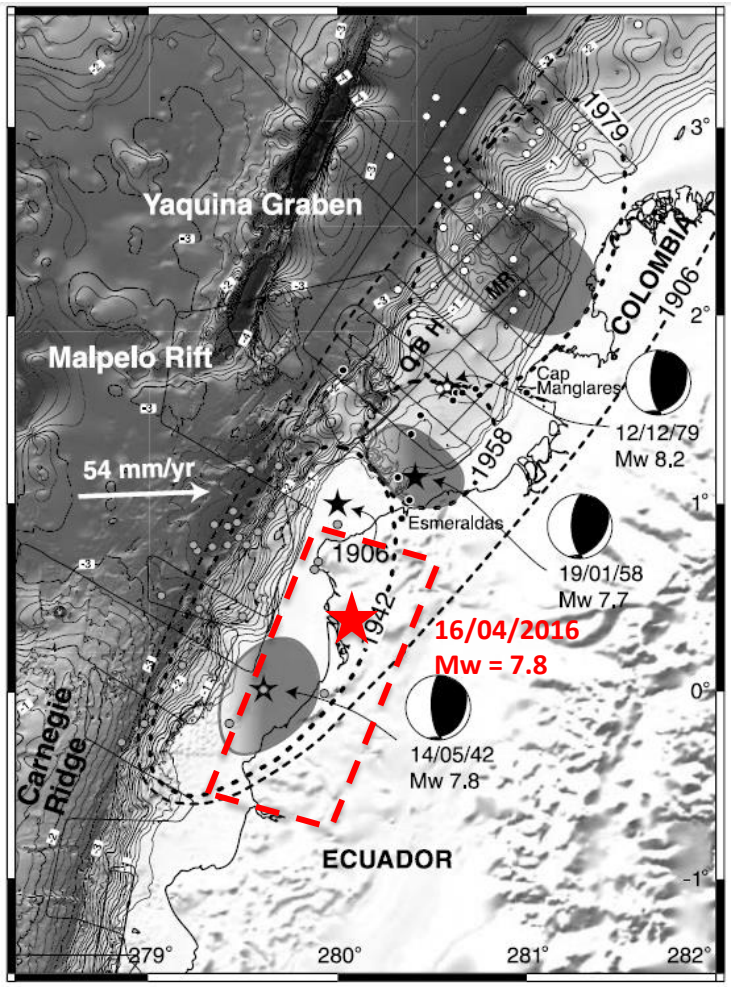
Source: Gutscher et al. (1999)



Source: Dr. Theofilos Toulkeridis

Seismicity in Ecuador

- Previous important subduction earthquakes:
  - 1906 Mw 8.8 Esmeraldas (interface)
  - 1942 Mw 7.8 Jama (interface)
  - 1958 Mw 7.8 Esmeraldas (interface)
  - 1979 Mw 8.2 Colombia (interface)
  - 1998 Mw 7.2 Bahia (intra-plate)
  - **2016 Mw 7.8 Muisne (interface)**



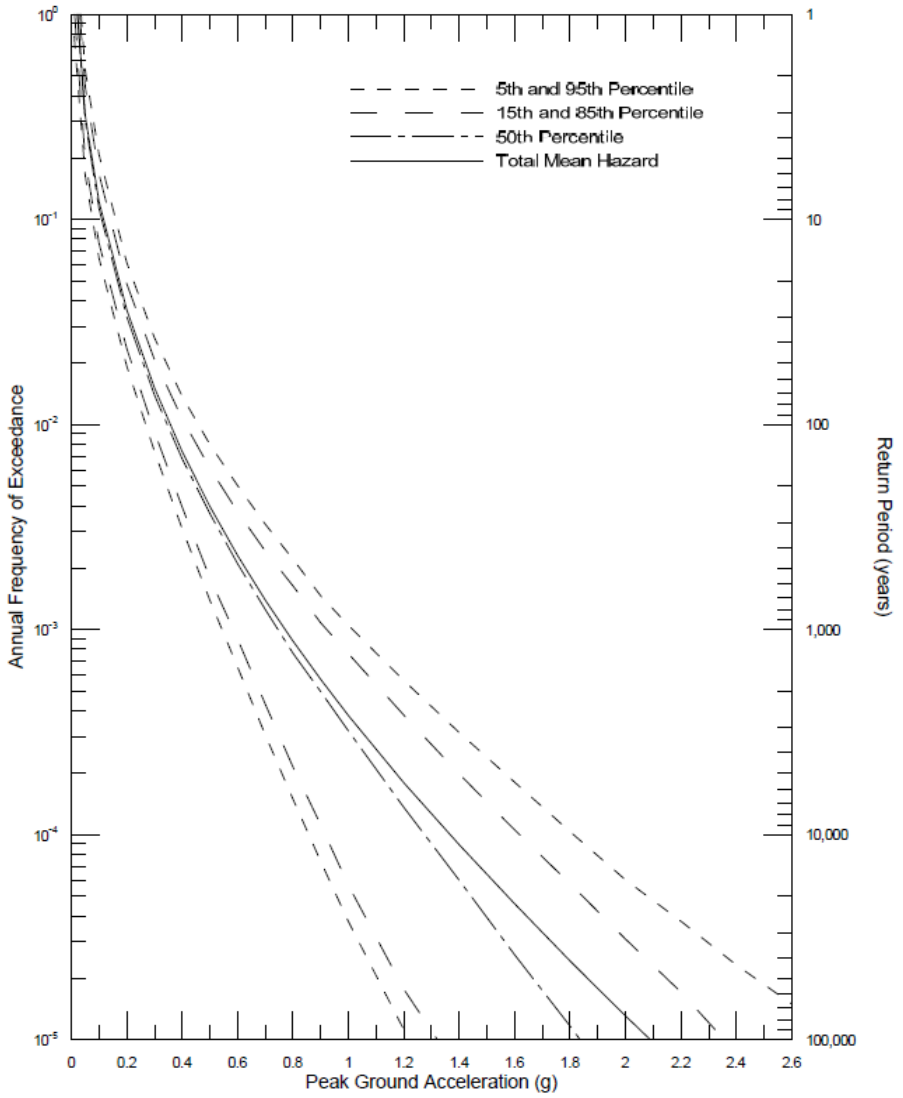
Source: Modified from Collot et al. (2004)

Seismicity in Ecuador

- PSHA for Southernwest Ecuador (Wong, 2011):

	PGA (g)	
	10% in 50 yrs (500 yrs)	2% in 50 yrs (2,500 yrs)
Manta	0.71 / 0.74	1.21 / 1.01
Salinas	0.72 / 0.75	1.23 / 1.10
Guayaquil	0.45 / 0.50	0.80 / 0.76
Machala	0.39 / 0.45	0.64 / 0.66

- High variability in source characterization



Recorded ground motions

(Roberto)

Ground Motion Observations

- Courtesy of IG-EPN:
  - Provided 90 records from 30 stations for 3 components
  - Three networks (RENAC, OPC, IRD)

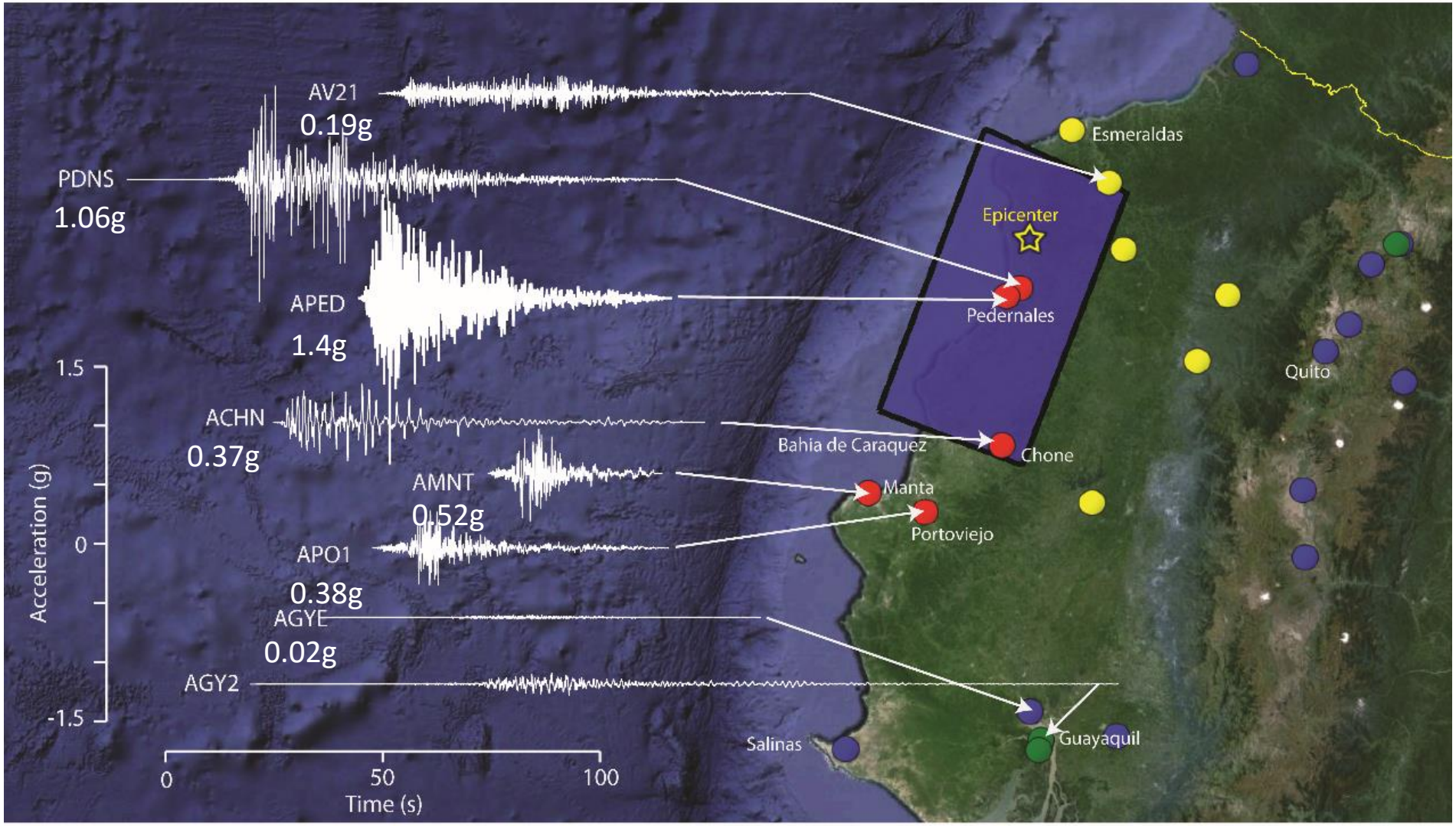
Instituto Geofísico — Escuela Politécnica Nacional

- Ground motion processing according to PEER standard procedure (Ancheta et al., 2014)

- Largest recorded motion in Pedernales (APED) EW component: 1.4 g!

Ground Motion Observations

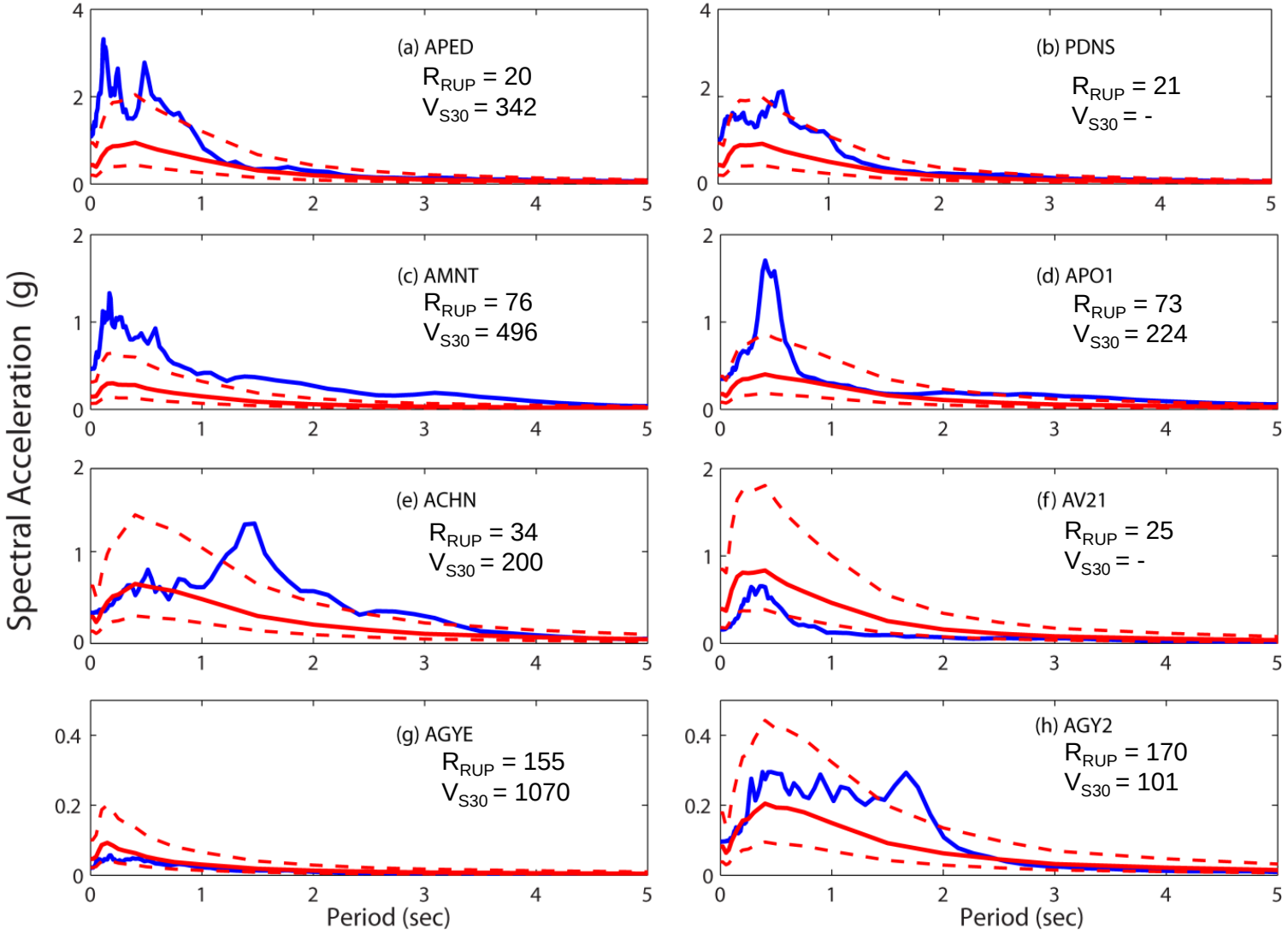
Acceleration time histories for the EW component



Source: IG-EPN

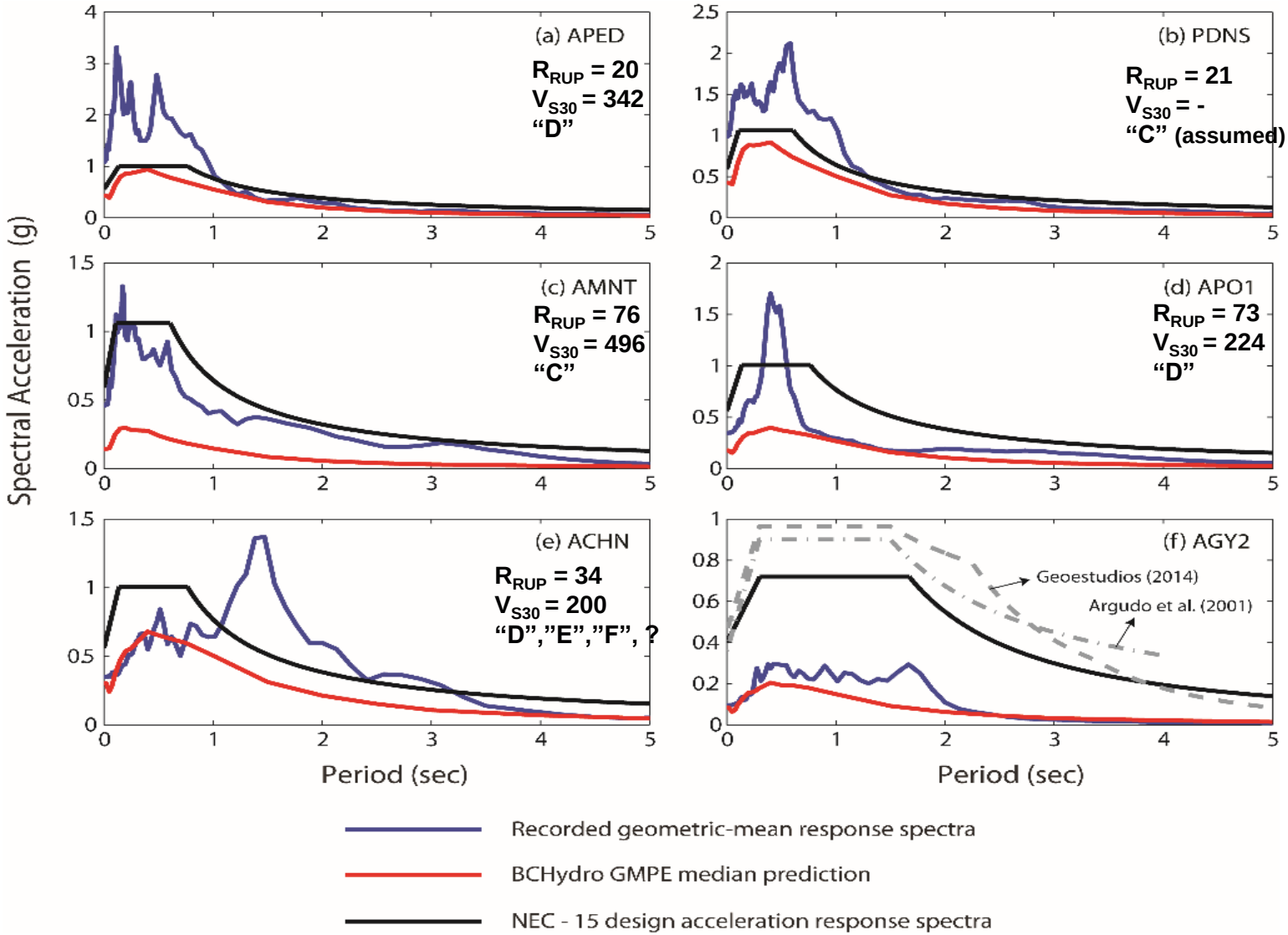
Ground Motion Observations

Comparison to BCHydro Subduction GMPE



Ground Motion Observations

Comparison to Ecuadorian Construction Code (NEC-15)



Most Affected Cities After the Earthquake

Source: Google Earth

Pedernales

22k inhabitants

Source: Google Earth

Pedernales

Source: https://lodijeron.files.wordpress.com/2011/07/pedernales-ac3a9rea.jpg

Pedernales

Heavy damage

Source: http://newsok.com/gallery/6034202/pictures/4215524

Pedernales

Before

Google Maps

After

Photo by E. Miranda

After

Photo by E. Miranda

Pedernales

After

Photo by E. Miranda

Pedernales

Soft story collapse


AGROSOL
SOLUCIONES AGROPECUARIAS
AGROSOL
AGROSOL

Pedernales

Practically no sign of an earthquake

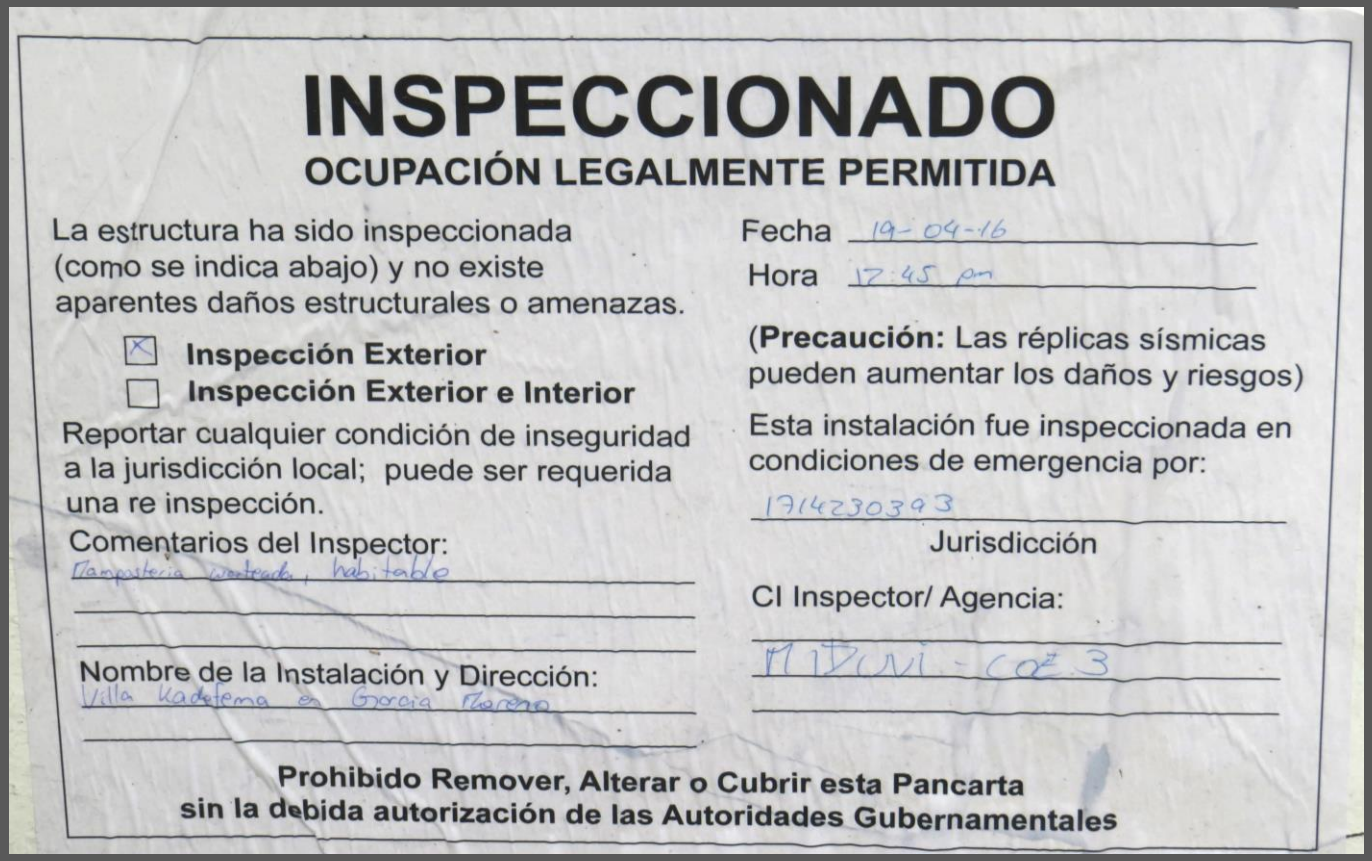
Photo by E. Miranda

Pedernales

Practically no sign of an earthquake

Photo by E. Miranda

ATC-20-like tagging



INSPECCIONADO

OCUPACIÓN LEGALMENTE PERMITIDA

La estructura ha sido inspeccionada (como se indica abajo) y no existe aparentes daños estructurales o amenazas.

☒ **Inspección Exterior**

☐ **Inspección Exterior e Interior**

Reportar cualquier condición de inseguridad a la jurisdicción local; puede ser requerida una re inspección.

Comentarios del Inspector:
Ramposteria Inestable, habitable

Nombre de la Instalación y Dirección:
Villa Kadefema en Garcia Moreno

Fecha 19-04-16

Hora 12:45 pm

(**Precaución:** Las réplicas sísmicas pueden aumentar los daños y riesgos)

Esta instalación fue inspeccionada en condiciones de emergencia por:

1714230393
Jurisdicción

CI Inspector/ Agencia:

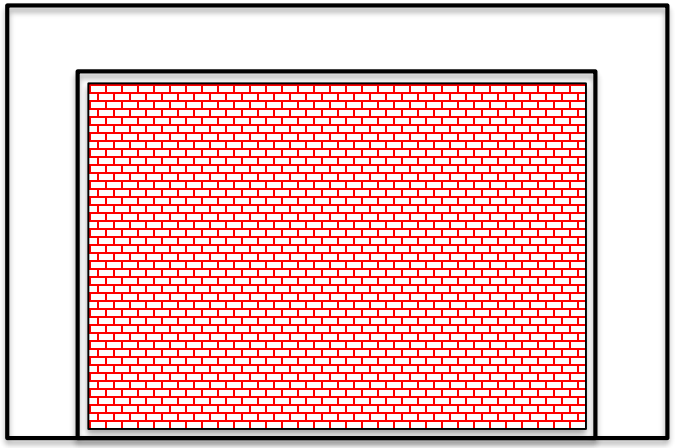
MIDUVI - COE 3

Prohibido Remover, Alterar o Cubrir esta Pancarta sin la debida autorización de las Autoridades Gubernamentales

Photo by E. Miranda

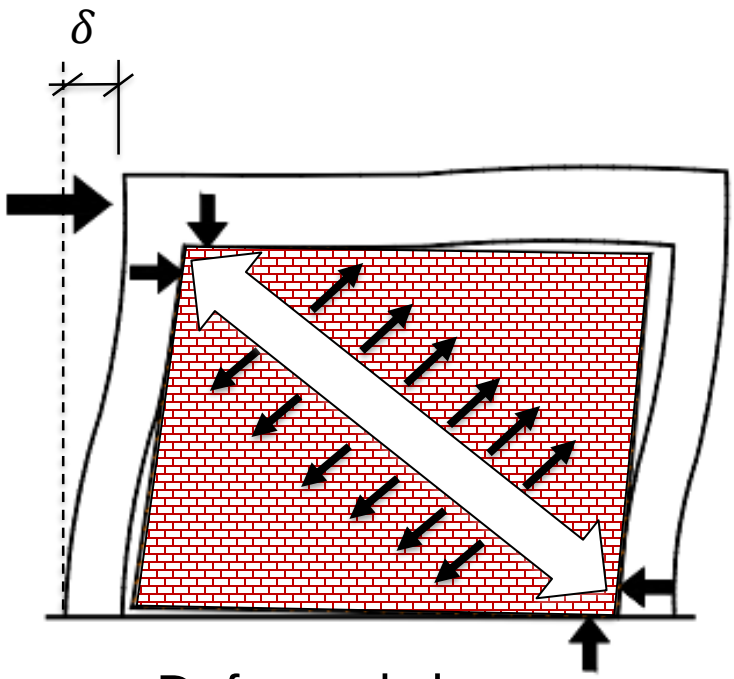
Occupancy allowed! Inspection date: 3 days after EQ.

Infill wall behavior



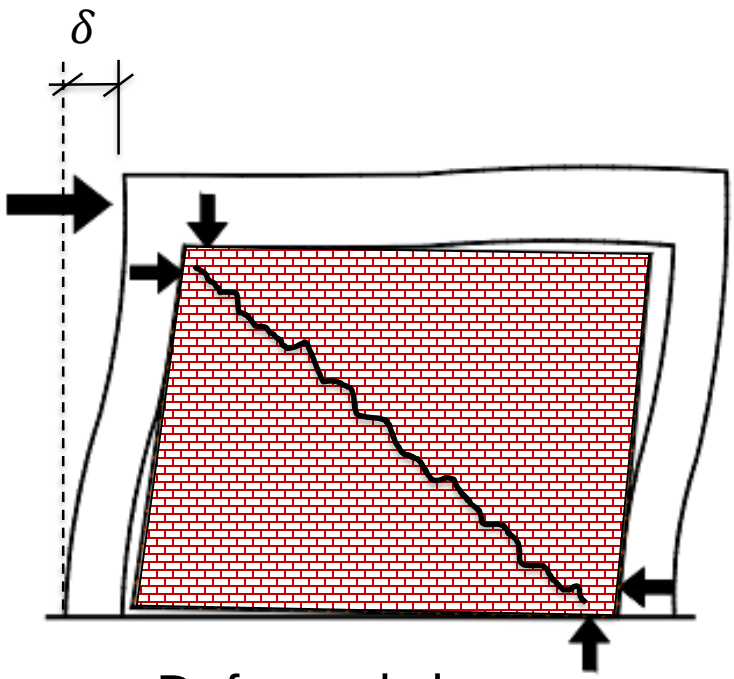
Undeformed shape

Infill wall behavior



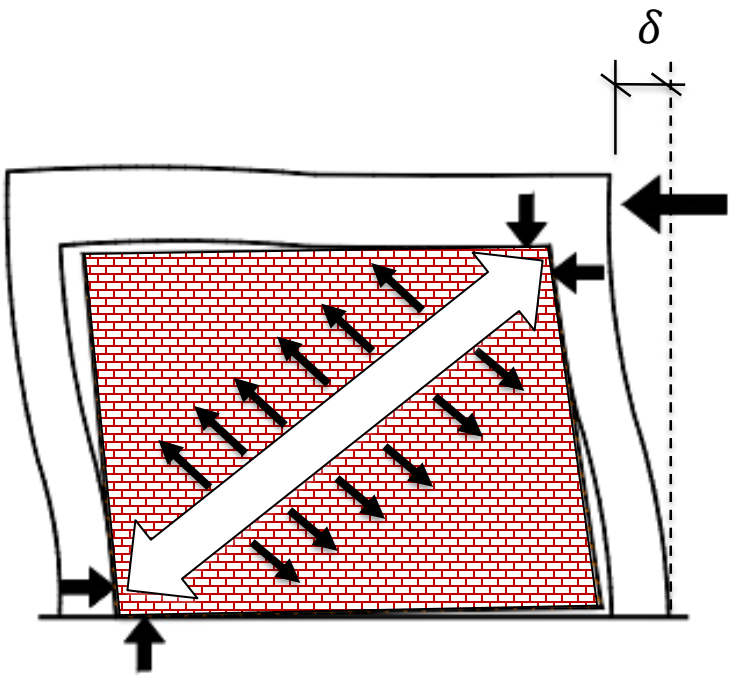
Deformed shape

Infill wall behavior



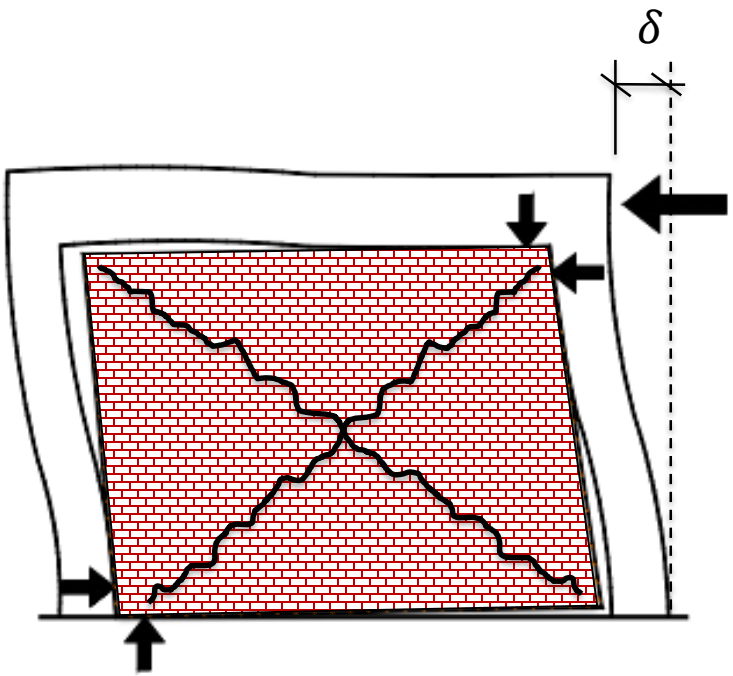
Deformed shape

Infill wall behavior



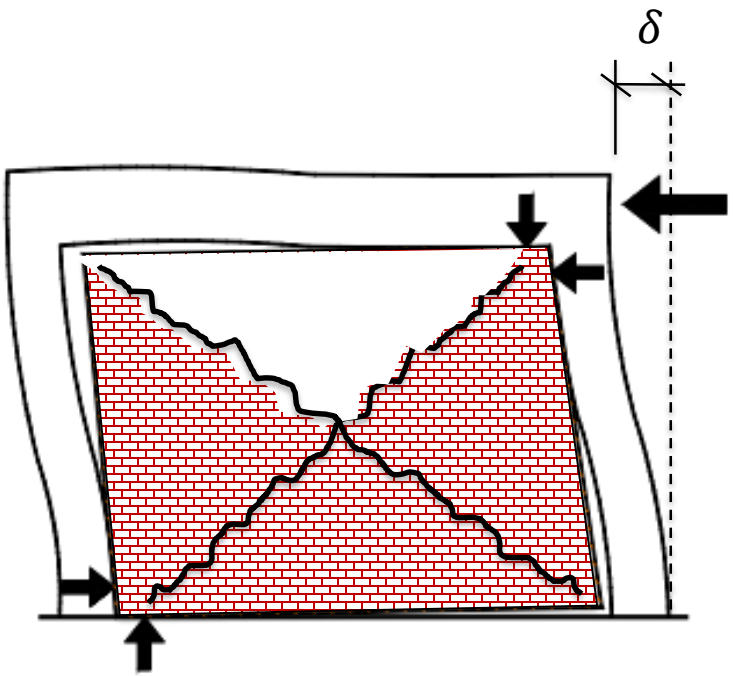
Deformed shape

Infill wall behavior



Deformed shape

Infill wall behavior



Deformed shape

Out-of-plane failure

Luis Ceferino

Out-of-plane failure

Luis Ceferino

Pedernales

Collapse of small hotel

Photo by E. Miranda

Pedernales

School "Atahualpa"

Photo by E. Miranda

Pedernales

School "Atahualpa". Side View

Photo by E. Miranda

Pedernales

School "Atahualpa". Side View

Photo by E. Miranda

Pedernales

School "Atahualpa"

Photo by E. Miranda

School "Atahualpa". Column rebars

Photo by E. Miranda

Pedernales

School "Atahualpa". Side View

Photo by E. Miranda

Pedernales

School "Atahualpa"

Photo by E. Miranda

Pedernales

School "Atahualpa". Interior view

Photo by E. Miranda

Pedernales

School "Atahualpa". Interior view

Photo by E. Miranda

Pedernales

Collapse mechanism

Luis Ceferino

Pedernales

Collapse mechanism

Photo by E. Miranda

Pedernales

Collapse mechanism

Jama

6k inhabitants

Source: Google Earth

Jama

School "Josefina Zambrano"

Jama

School "Josefina Zambrano". Partial collapse

Luis Ceferino

Jama

No collapse of wooden house

Photo by E. Miranda

Jama

Collapse of wooden house

Photo by E. Miranda

Bahia de Caráquez

21k inhabitants

Source: Google Earth

Bahia de Caráquez

Bahia de Caráquez

Museum

Bahia de Caráquez

Museum

Bahia de Caráquez

Museum

Bahia de Caráquez

Museum

Eduardo Miranda

Bahia de Caráquez

Fire Station

Eduardo Miranda

Bahia de Caráquez

Fire Station

Bahia de Caráquez

Fire Station

Bahia de Caráquez

Fire Station

Bahia de Caráquez

Fire Station

Bahia de Caráquez

Bahia de Caráquez

Coupling Girder Failure

Eduardo Miranda

April 16, 2016
Ecuador

Vitelmo Bertero

March 27, 1964
Alaska

Bahia de Caráquez

Bahia de Caráquez

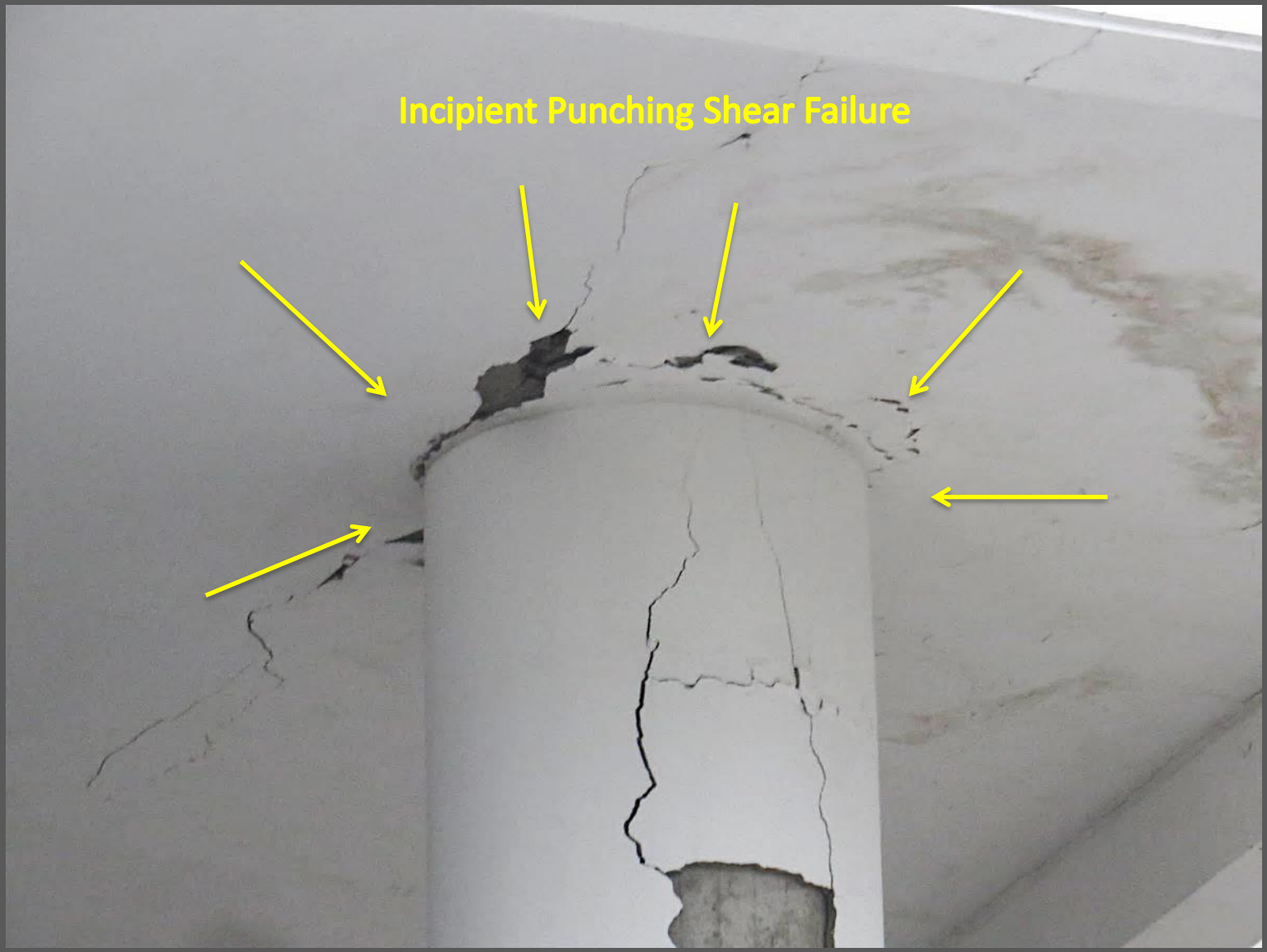
Bahia de Caráquez

Bahia de Caráquez

Bahia de Caráquez

Bahia de Caráquez

Bahia de Caráquez



Bahia de Caráquez

Portoviejo

280k inhabitants

Source: Google Earth

Portoviejo

Universidad Tecnica de Manabi

Portoviejo

Universidad Tecnica de Manabi

Portoviejo

Universidad Tecnica de Manabi

Andres Acosta Vera

Portoviejo

Universidad Tecnica de Manabi

Photo by E. Miranda

Portoviejo

Portoviejo

Portoviejo

Universidad Tecnica de Manabi

Portoviejo

Downtown Portoviejo

Before

Source: Google Maps

After

Source: facebook.com

Portoviejo

Portoviejo

Portoviejo

Portoviejo

Portoviejo

Photo by E. Miranda

Portoviejo

Downtown Portoviejo

Before

Source: Google Maps

After

Source: facebook.com

Portoviejo

Downtown Portoviejo

Portoviejo

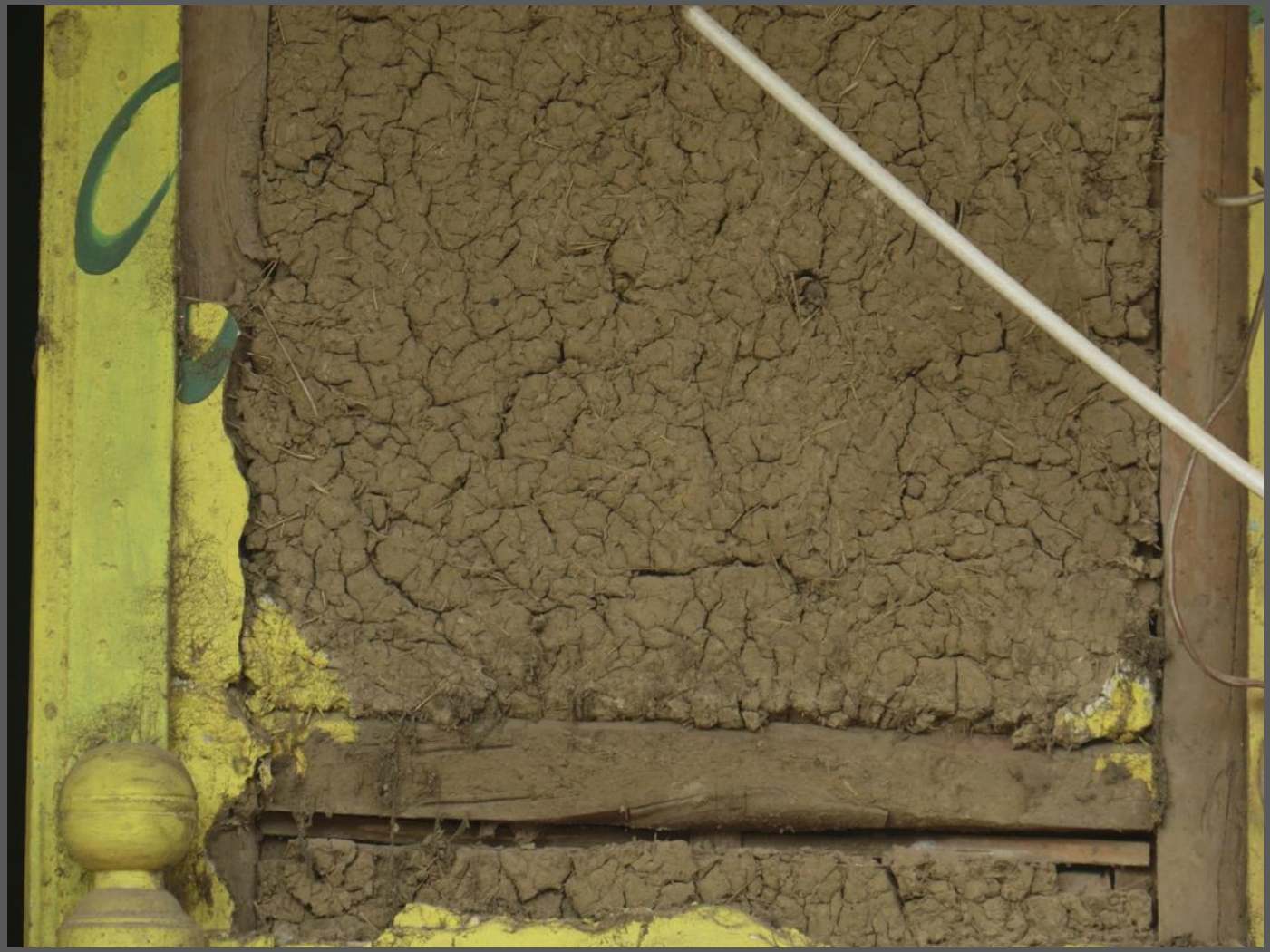
Downtown Portoviejo

Portoviejo

Downtown Portoviejo

Portoviejo

Downtown Portoviejo



Portoviejo

Downtown Portoviejo

Portoviejo

Downtown Portoviejo

Before

Source: Google Maps

After

Source: facebook.com

Portoviejo

Downtown Portoviejo

Before

Source: Google Maps

After

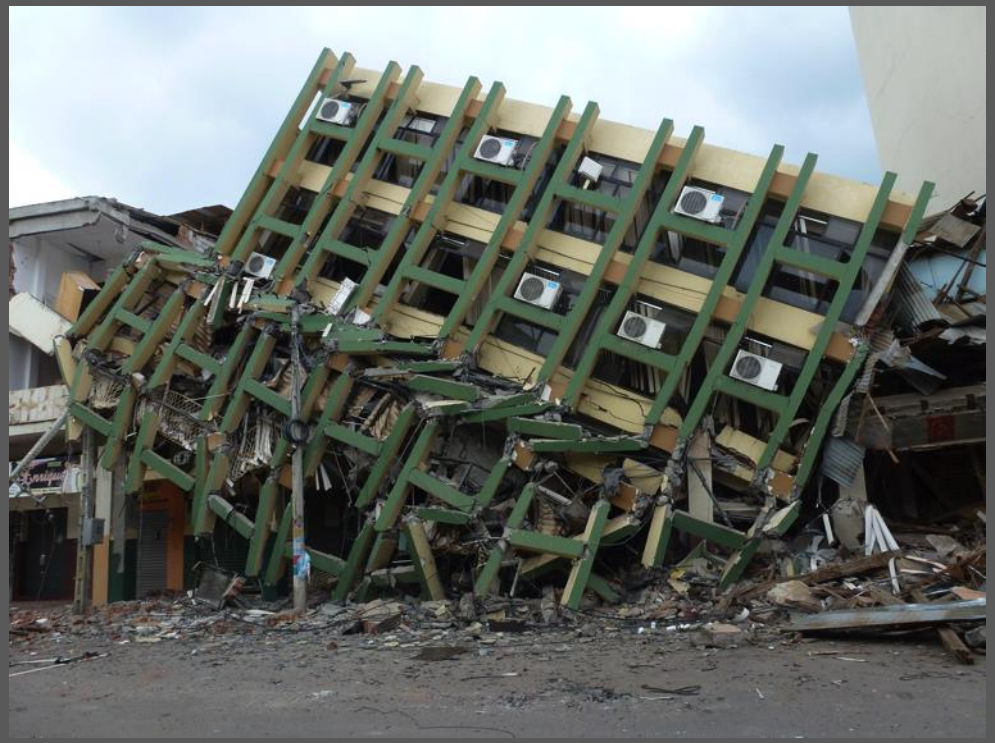
Source: facebook.com

Portoviejo

Downtown Portoviejo

Before

After



Source: Google Maps

Portoviejo

Downtown Portoviejo

Eduardo Miranda

Portoviejo

Downtown Portoviejo

Portoviejo

Downtown Portoviejo

Eduardo Miranda

Manta

227k inhabitants

PGA H= 0.52g
PGA Z = 0.17g

Source: Google Earth

Manta

IESS Hospital

Photo by E. Miranda

Manta

IESS Hospital

Photo by E. Miranda

Manta

IESS Hospital

Photo by E. Miranda

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IESS Hospital

Photo by E. Miranda

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IESS Hospital

Photo by E. Miranda

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Photo by E. Miranda

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Photo by E. Miranda

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IESS Hospital

Photo by E. Miranda

Manta

IESS Hospital

Photo by E. Miranda

Manta

IESS Hospital *Pediatrics*

Photo by E. Miranda

Manta

IESS Hospital *Pediatrics*

Photo by E. Miranda

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Photo by E. Miranda

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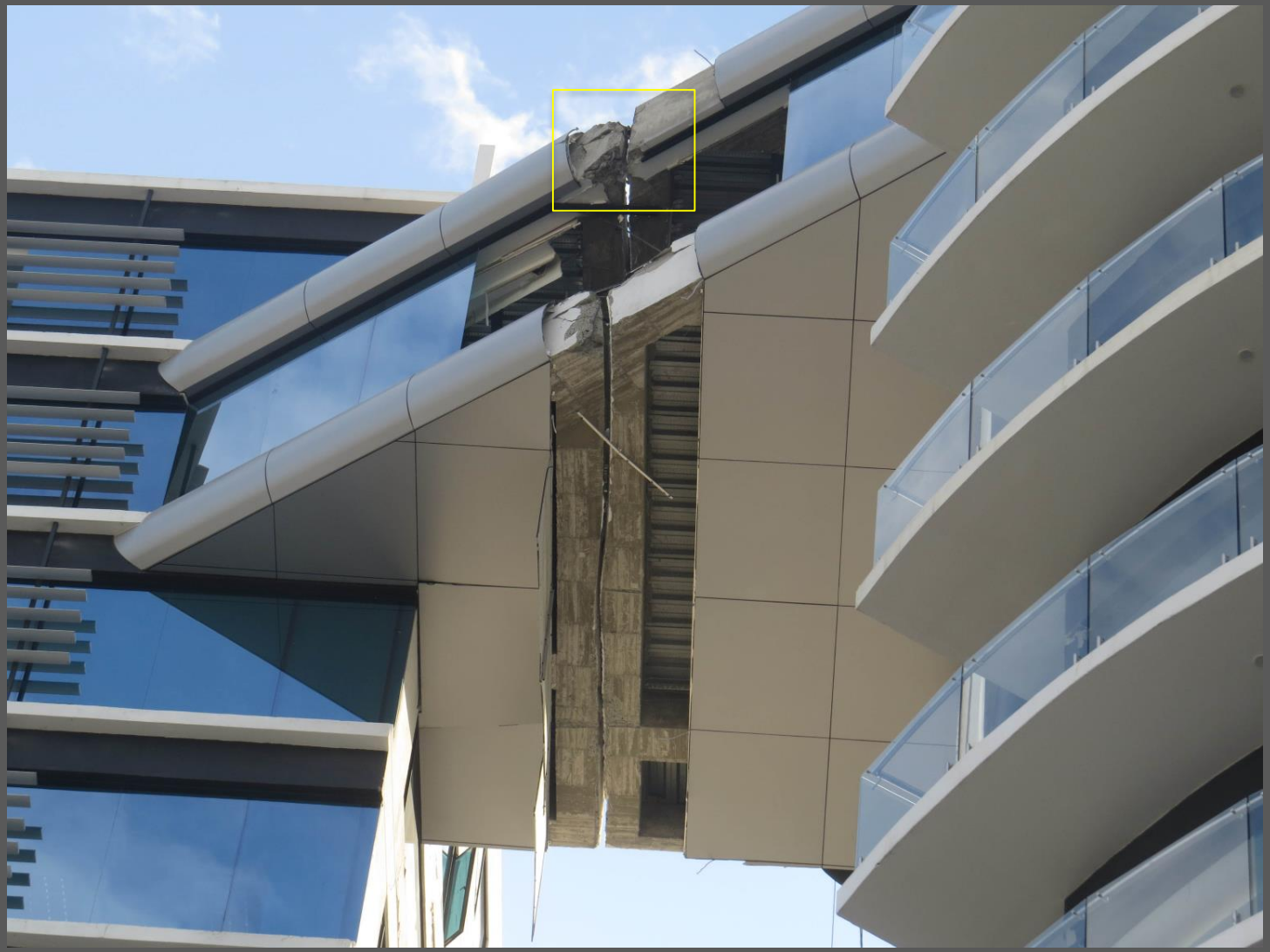

Manta

Photo by E. Miranda

Manta

Do you see something wrong in this picture ?

Photo by E. Miranda

Some brief final thoughts

- Earthquakes continue to teach us that near source ground motions can be significantly more intense that what we often estimate.

- Although we have made great progress over the last 50 years, there are many aspects that we cannot fully understand.

- Many structures did remarkably well considering that in some places like Pedernales spectral ordinates exceeded the design spectral ordinates by more than a factor of 3

- We need to remain humble and recognize that we must continue to learn from earthquakes

Thank you !


Thank you !