Developing Tsunami Damage Estimation and Mitigation Technologies

Shunichi Koshimura (Tohoku Univ.)

Tsunami Research Group (G2)

JST/JICA Science and Technology Research Partnership for Sustainable Development
Enhancement of Earthquake and Tsunami Disaster Mitigation Technology in Peru
The 2nd. Workshop at Chiba University (10 March, 2011)

Tsunami Group Member

(8 Japanese, 5 Peruvian)

- Dr. Shunichi Koshimura (Tohoku Univ., Tsunami engineering)
- Dr. Gaku Shoji and Mr. Yusuke Tani, Mr. Yu Hiraki, Mr. Yoshiyuki Ezura (Tsukuba Univ., Structural and earthquake engineering)
- Dr. Yuji Yagi (Tsukuba Univ., Seismology)
- Dr. Yushiro Fujii (BRI, Seimology and Tsunami modeling)
- Dr. Hideaki Yanagisawa (TEPSCO, Tsunami modeling)
- Mr. Erick Mas (Tohoku Univ., Tsunami engineering)
- Mr. Cesar Jimenez (DHN, San Marcos Univ., Seismology and tsunami modeling)
- Mr. Bruno Adriano (CISMID, Tsunami modeling)
- Ms. Sheila Yauri (IGP, Seismology)
- Dr. Miguel Estrada (CISMID, Earthquake engineering)

Objectives and Goals

- To assess the potential tsunami disaster and its impact to the Peruvian coast
- To develop practical technologies to mitigate tsunami risks in Peru
- Implementation to the strategic plans for disaster mitigation of Peruvian government
- Contributions to Pacific tsunami disaster mitigation strategies

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Tsunami modeling technology

- Tsunami Modeling techniques (Tsunami-code to simulate tsunami generation, off-shore/near-shore propagation and coastal inundation)

Research Plan (Scientific phase)

- Assessing historical tsunami events and its impact in Peru
  - Tsunami sources
  - Tsunami hazard (Tsunami generation, near-shore propagation and coastal inundation)
  - Damage (Casualties, Structural damage)
- Indentifying potential tsunamis and the worst case scenarios
  - Tectonic settings and tsunami source scenarios
  - Potential tsunami exposure (Exposed population)
  - Potential impact
- Mapping tsunami hazard and its impact
  - Inundation modeling
  - Damage estimation (Casualties, Structural damage)
  - Hazard maps, Cartography

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Research Plan (Implementation Phase)

- Developing a fundamental procedure for mapping tsunami hazard
  - Training program (Tsunami modeling and mapping)
  - Warning, guidance and public education
- Strategic planning to mitigate tsunami risks and damage
  - Tsunami disaster mitigation program for Peruvian government
  - Tsunami countermeasures
  - Design for tsunami evacuation facilities
  - Tsunami evacuation strategies

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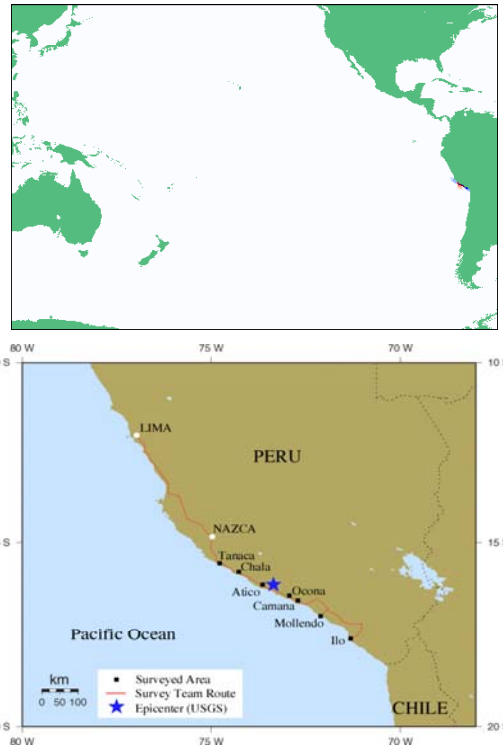
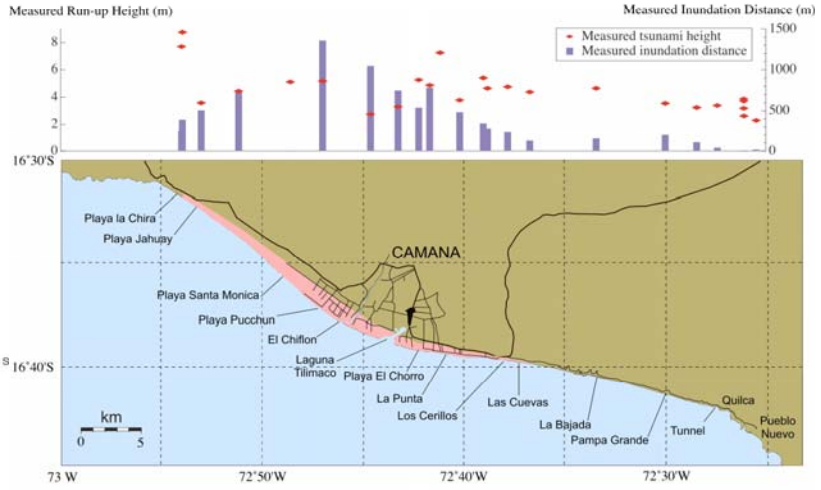
What we have done so far …

- Post-tsunami field survey in Chile
- Tsunami field survey in Camana
- Validation of tsunami numerical model and tsunami source study (2001 Camana tsunami)
- Tsunami risk assessment using PTE (Potential Tsunami Exposure)
- Tsunami risk perception in Callao, Lima

Validation of tsunami numerical model and tsunami source study (The 2001 Camana tsunami)

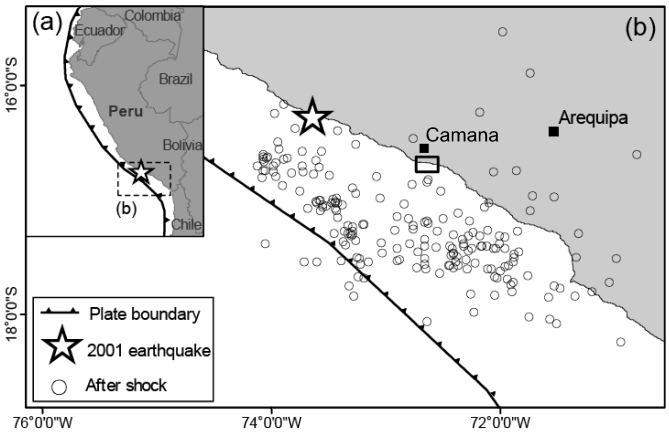




Casualty			House damage	
Dead	Missing	Injury	Major/Minor	Collapsed
24	62	41	760	2915

Field survey of the 2001 tsunami

- Survey area : Camana
- Periods : 21-22 Dec. 2009, 17-19 Mar. 2010, [August, 2001]
- Measurement: Flow depth, Run-up/inundation height



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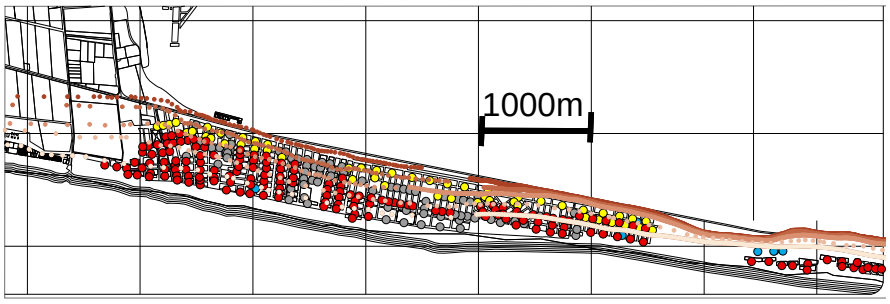
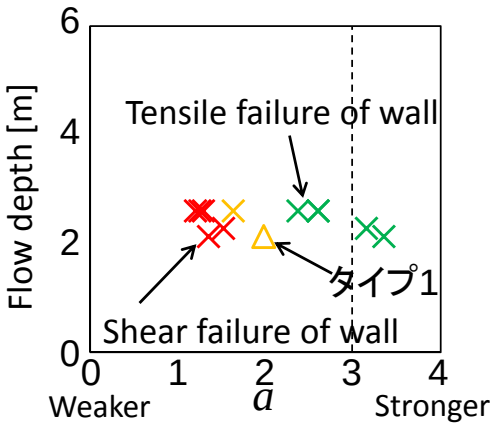
Field survey of the 2001 tsunami



Elevation (m)
- 1m
- 2m
- 3m
- 4m
- 5m-6m

Damage class
- Destroyed
- Major
- Middle - Minor
- Houses for survey

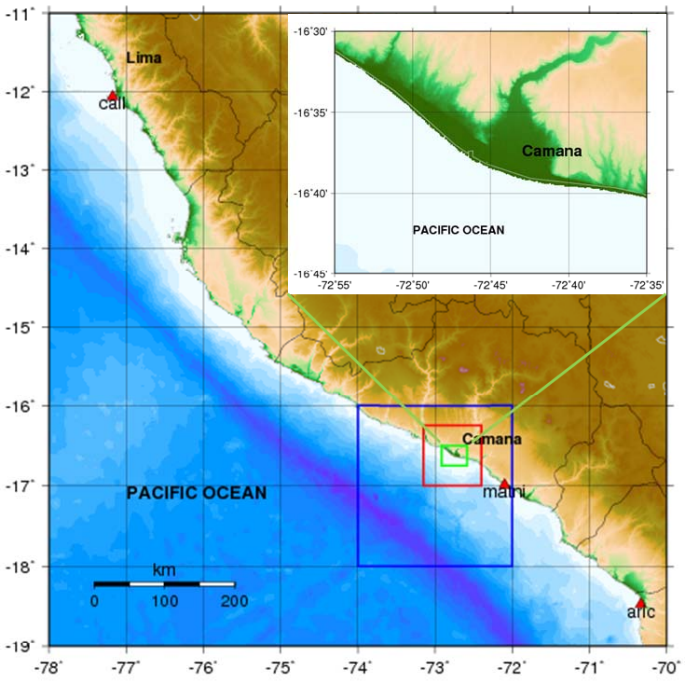


Preparing bathymetry/topography grid

	Longitude		Latitude		Resolution
#D	Mim	Max	Mim	Max	arc-second
1	-78.00	-70.00	-19.00	-11.00	27
2	-74.00	-72.00	-18.00	-16.00	9
3	-73.15	-72.40	-17.00	-16.25	3
4	-72.92	-72.58	-16.75	-16.50	1

Domain	Bathymetry	Topography
1	GEBCO 30	GEBCO 30
2	GEBCO 30	GEBCO 30
3	GEBCO 30	STRM
4	DHN	ASTER GDEM

GEBCO : http://www.gebco.net/
STRM : http://srtm.csi.cgiar.org/
ASTER : http://www.gdem.aster.ersdac.or.jp/index.jsp/



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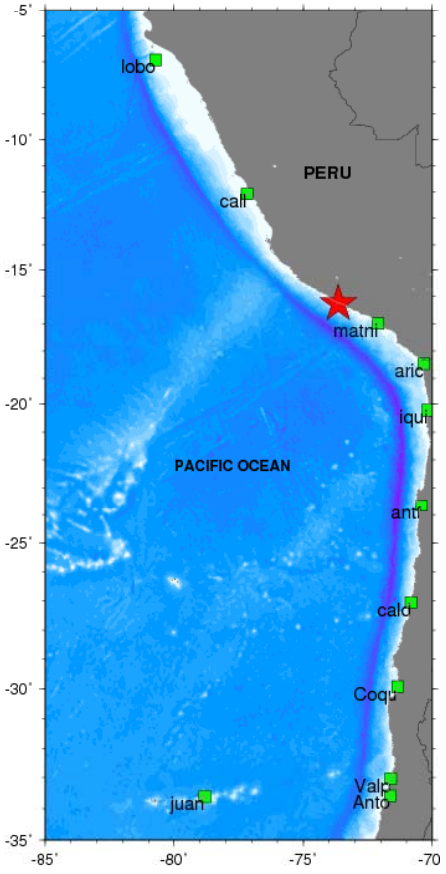
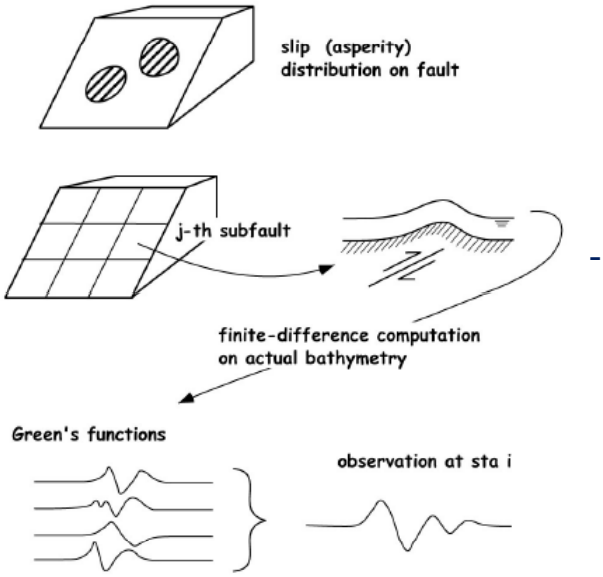
Tide gauge stations for tsunami waveform inversion

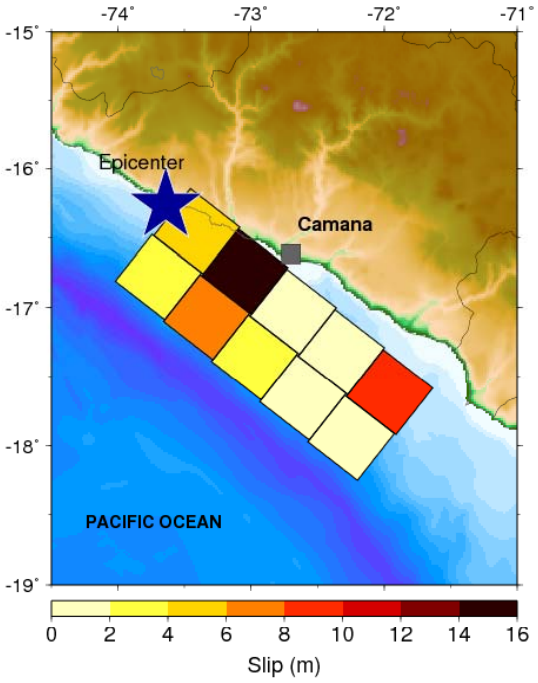
NOAA/PMEL/Center for Tsunami Research

No.	Code	Station name	Latitude	Longitude
1	antf	Antofagasta, Chile	23.65° S	70.42° W
2	aric	Arica, Chile	18.47° S	70.34° W
3	cald	Caldera, Chile	27.06° S	70.83° W
4	call	Callao, Peru	12.07° S	77.17° W
5	coqu	Coquimbo, Chile	29.93° S	71.35° W
6	iqui	Iquique, Chile	20.22° S	70.17° W
7	juan	Juan Fernandez, Chile	33.62° S	78.83° W
8	lobo	Lobos de Afuera, Peru	6.94° S	80.72° W
9	matni	Matarani, Peru	16.99° S	72.10° W
10	anto	San Antonio, Chile	33.58° S	71.63° W
11	valp	Valparaiso, Chile	33.03° S	71.62° W



Tsunami waveform inversion (Satake, 1987)





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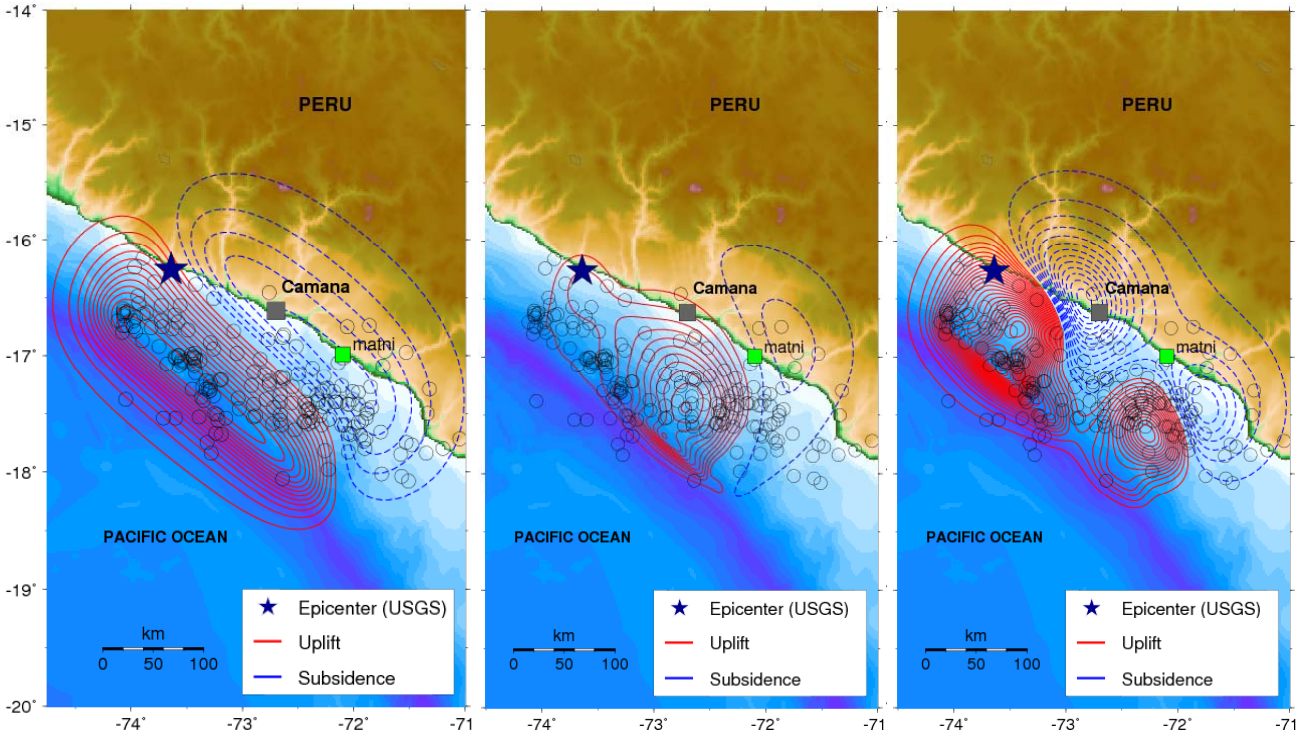
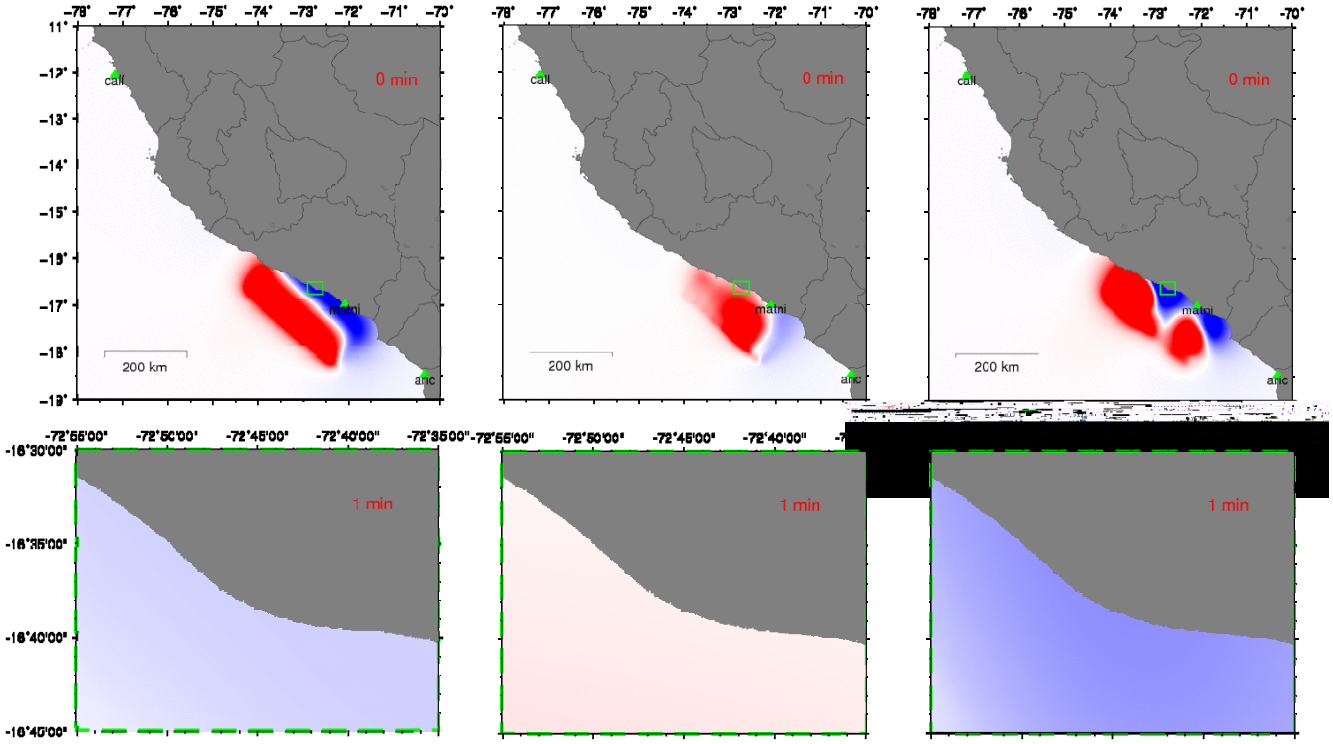
Uniform slip

Heterogeneous slip
(Kikuchi & Yamanaka, 2001)

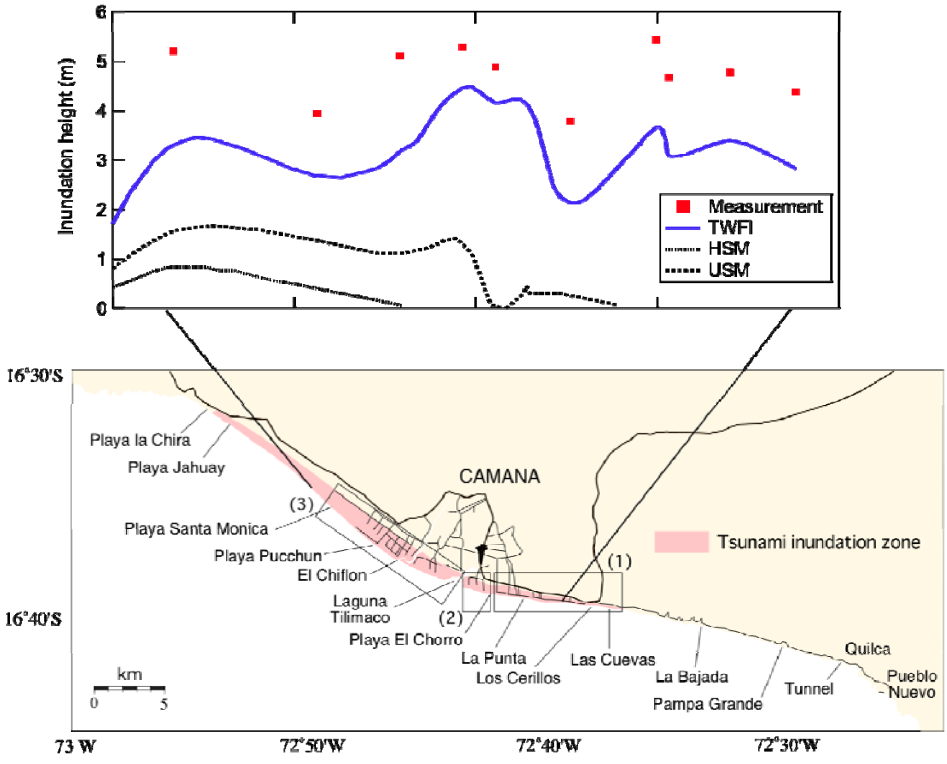
Tsunami waveform inversion



Uniform Slip Model | Heterogeneous Slip Model | Tsunami Waveform Inversion Model



Tsunami run-up height



Tsunami vulnerability assessment

Earthquake scenarios

- *Mw* 8.0, 8.2, 8.4, 8.6, 8.8 along the plate boundary
- Source parameters similar with the 2001 event

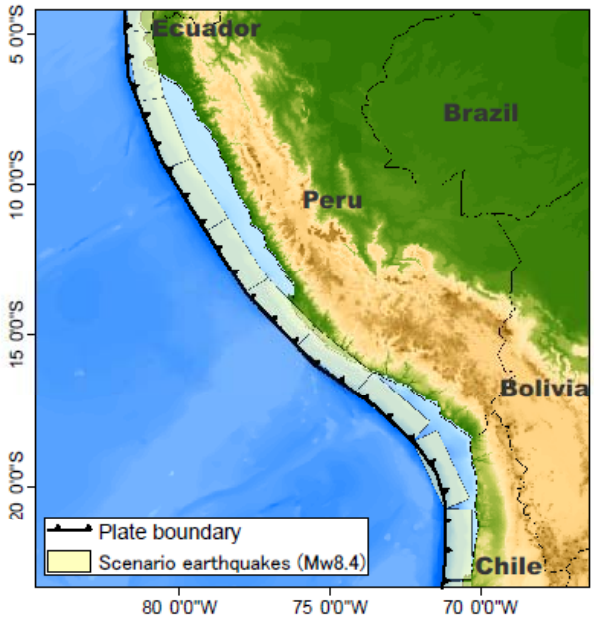
Tsunami propagation model

- Maximum tsunami height

Tsunami fragility curve

- Death ratio
- Population data
- Potential tsunami exposure

Potential tsunami exposure



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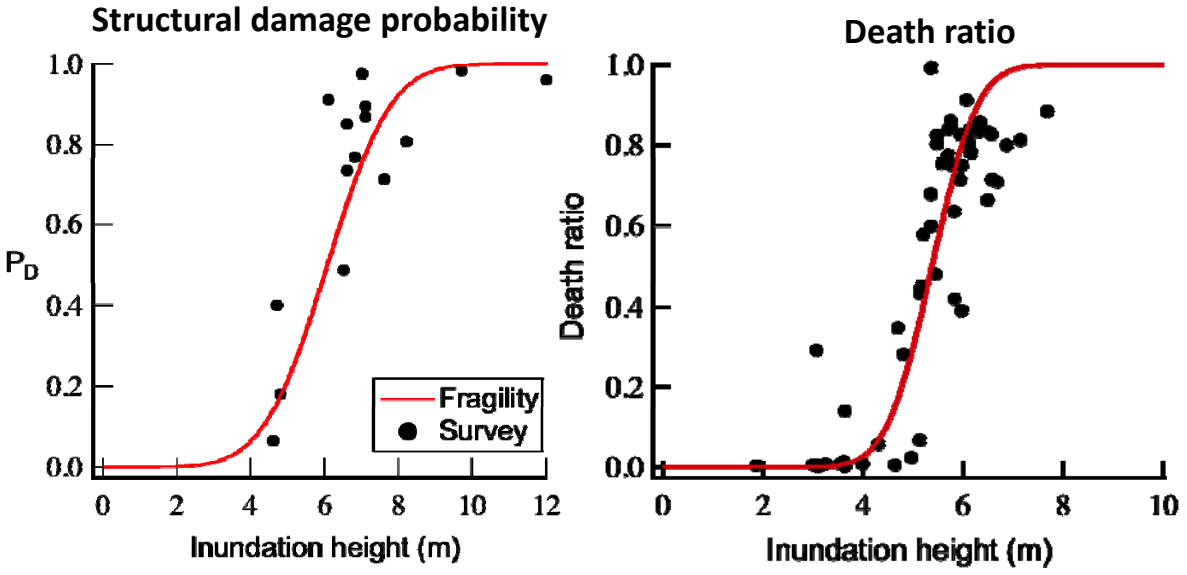
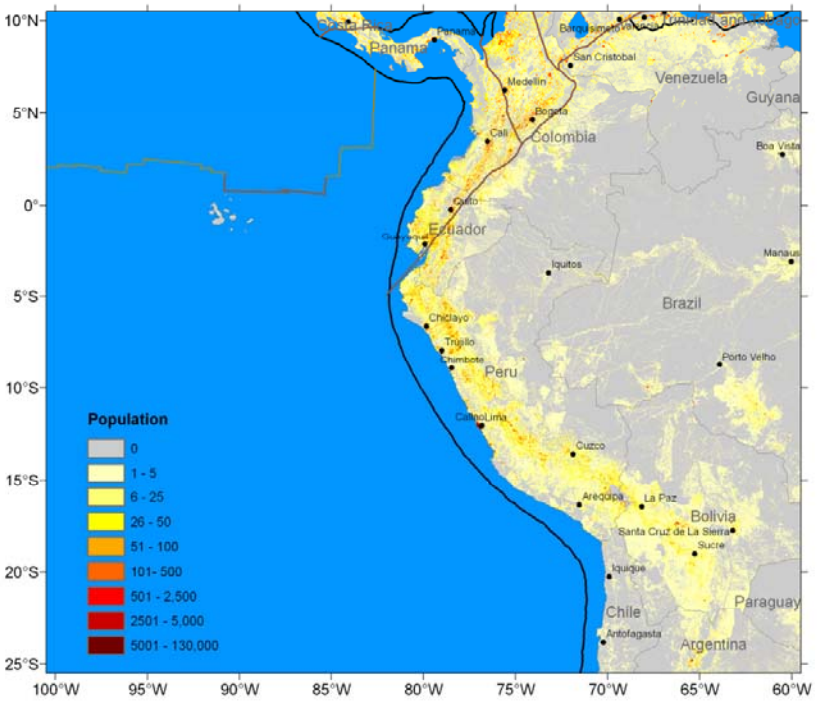
Tsunami fragility curves from the 2004 event



Potential tsunami exposure (PTE) LandScan 2008



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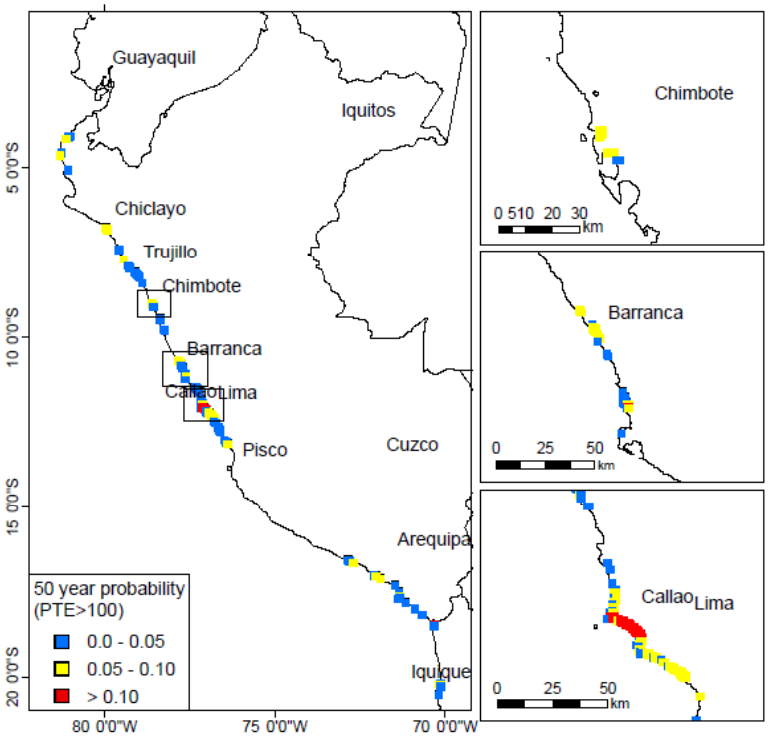
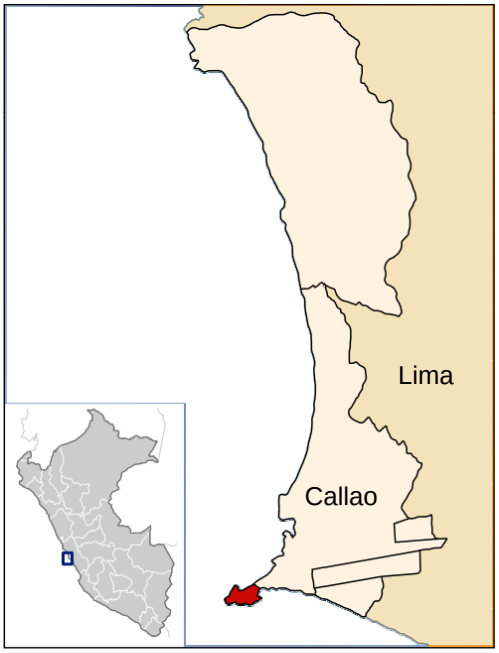
Where is at-risk area ?



How people perceive tsunami risks ? Questionnaire survey in Callao, Lima

I. General Information
II. Tsunami Evacuation Experience and Knowledge
III. Risk Perception and Start Evacuation Decision
IV. Tsunami Warning and Evacuation Decision
V. Earthquake Scenarios and Decision-making
VI. Where and how to evacuate



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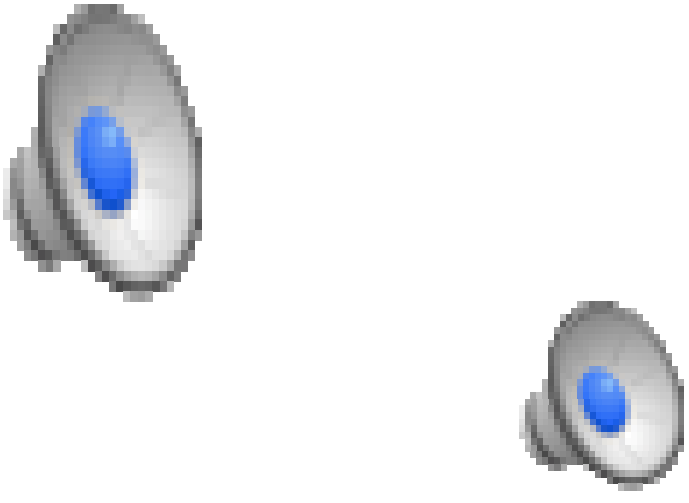
Multi Agent Simulation



So far so good ...
Moving on to the next phase

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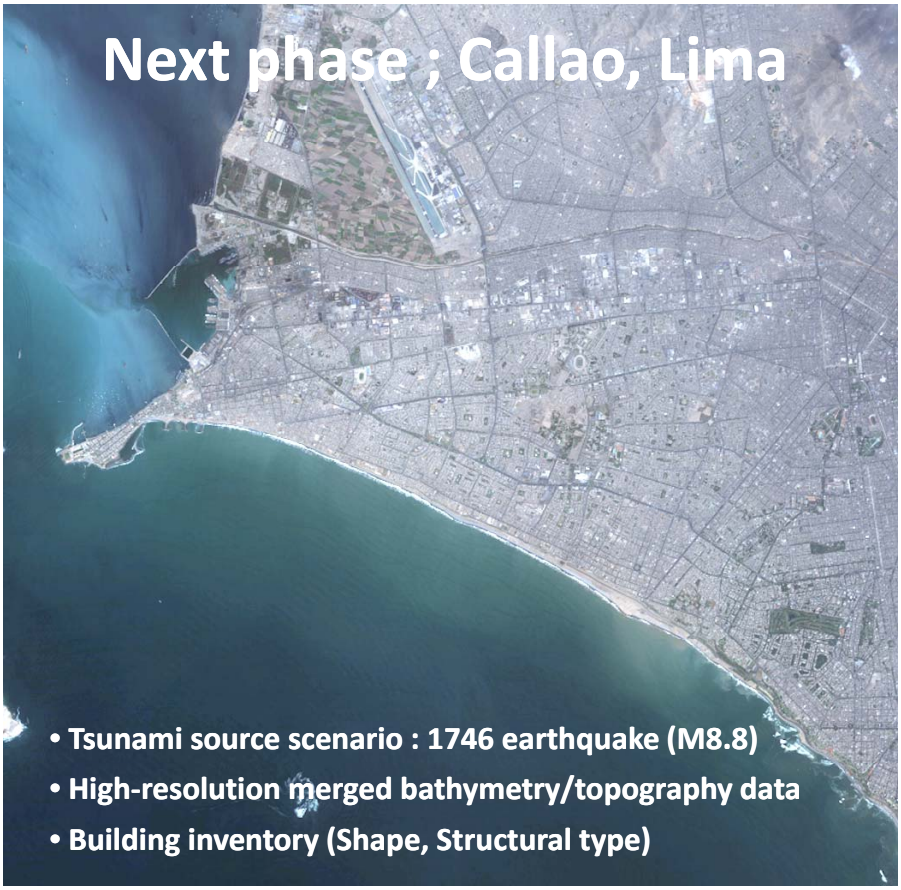
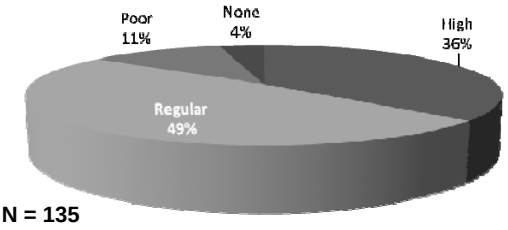


Tsunami Evacuation Experience and Knowledge

KNOWLEDGE



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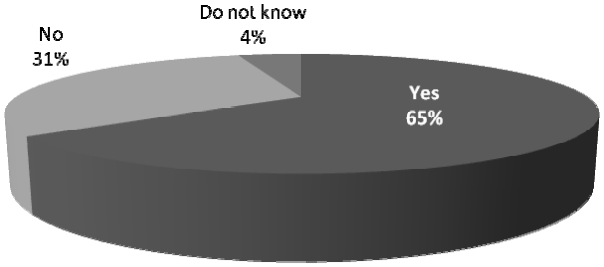
HAZARD MAP?



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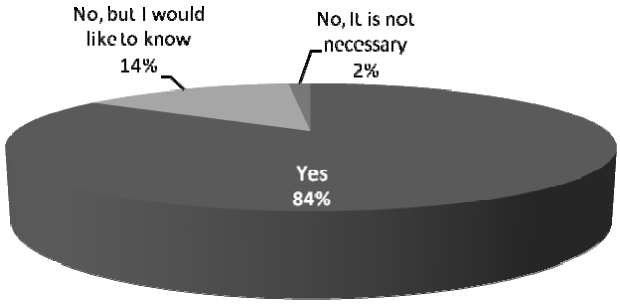
SAFE AREAS?



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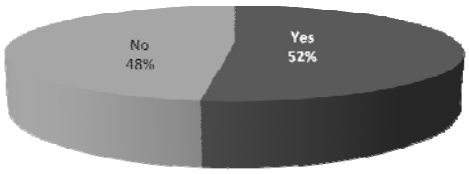
EVACUATION EXPERIENCE?



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Most stated evacuation experiences were for tsunamis of: Pisco (2007), Camana (2001), Chile (2010), Lima (1974).

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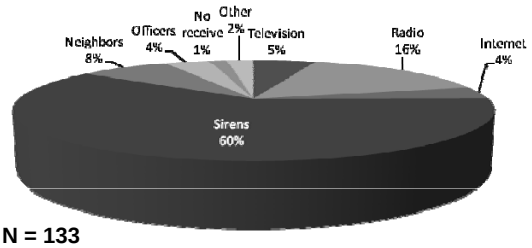
Tsunami Warning and Evacuation Decision

EXPECTED SOURCE OF WARNING



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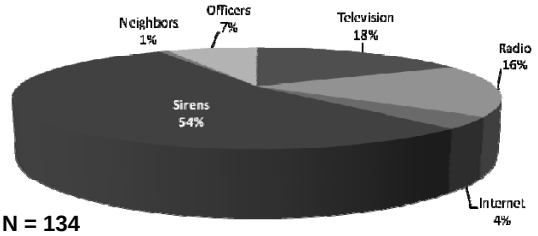
SOURCE RELIABILITY



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EXPECTED TIMES

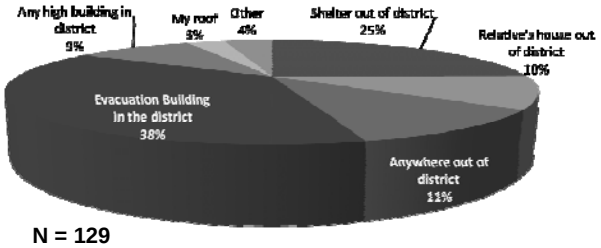
Warning		Preparation		Evacuation	
0-5 min	47.0%	0-2 min	16.4%	0-5 min	19.9%
5-15 min	31.1%	2-5 min	30.5%	5-15 min	39.7%
15-30 min	19.7%	5-10 min	27.3%	15-30 min	32.8%
30-45 min	1.5%	10-15 min	17.2%	30-45 min	4.6%
45 min-1h	0.0%	15-30 min	6.3%	45 min-1h	1.5%
more than 1 hr	0.8%	more than 30min	2.3%	more than 1 hr	1.5%
Total (N=132)	100%	Total (N=128)	100%	Total (N=131)	100%

Warning time: 9.8 min
Preparation time: 7.5 min
Evacuation time: 15.3 min

Total time: 32.6 min

Where and how to evacuate

Where ?



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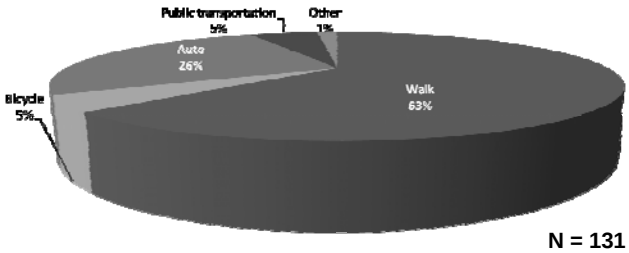
How ?



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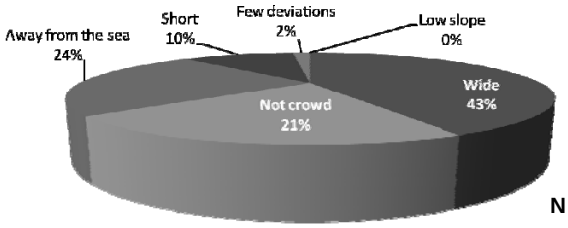
ROUTE PREFERENCE



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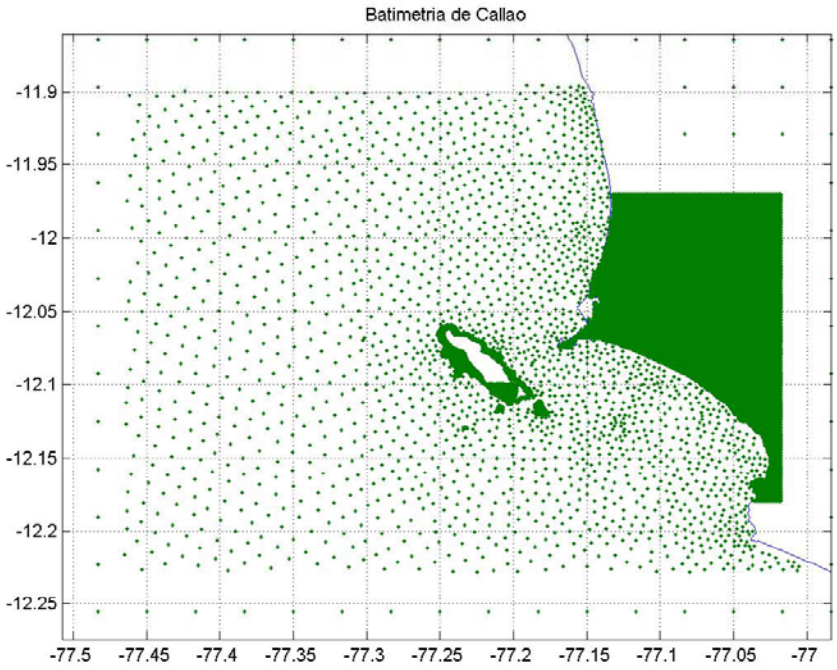
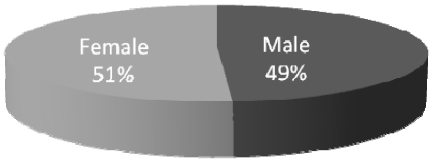
Bathymetry measuring points at Callao by DHN



GENDER



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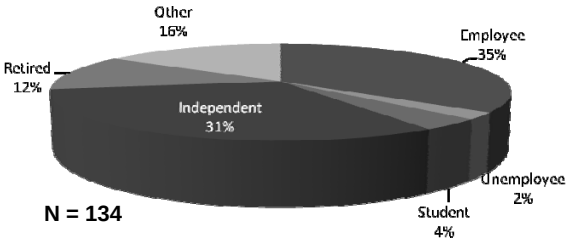
OCCUPATION



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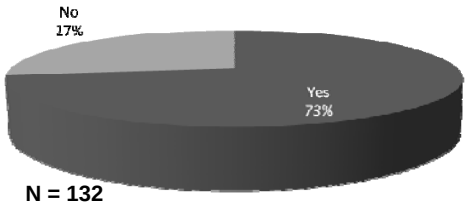

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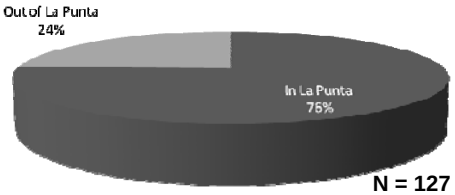
RESIDENT?



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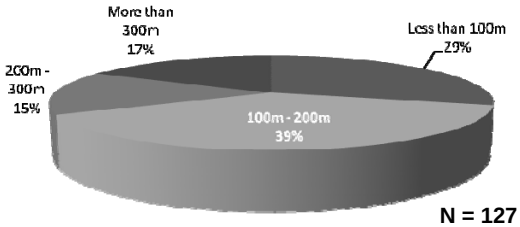
WORKPLACE



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HOME DISTANCE

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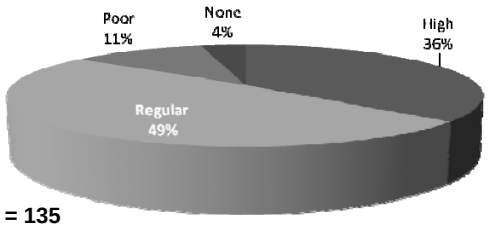
KNOWLEDGE



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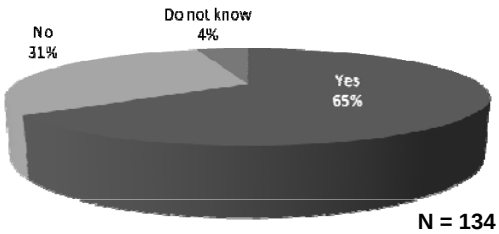
HAZARD MAP?



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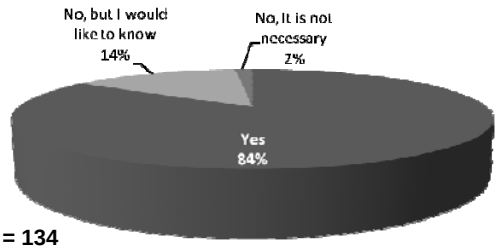

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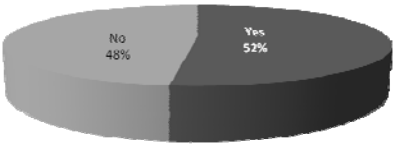
SAFE AREAS?

EVACUATION EXPERIENCE?



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