Earthquake – Tsunami Hazard Assessment and Risk Mitigation in Vietnam using GIS

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INTRODUCTION

- This presentation shows some examples of applying GIS to seismic hazards and risk assessment in Vietnam. The results are obtained in terms of forecasts of damage and human impacts that may result from future earthquakes. Three showcases are presented here focusing on:
- 1) Seismic hazard assessment at regional scale
- 2) Seismic hazard assessment and loss estimation at urban scale
- Extension case of tsunami hazard assessment is discussed emphasizing on the needs of using high-performance computing facility to develop a database of pre-calculated earthquake/tsunami scenarios for warning purpose in Vietnam.

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OUTLINE

- Introduction
- Fault Source Model and Earthquake Scenarios
- GIS tools: a DSS
- Hazard assessment at regional scale
- Risk assessment at urban scale: the Megacities
- Extension case: Tsunami Risk
- Conclusion

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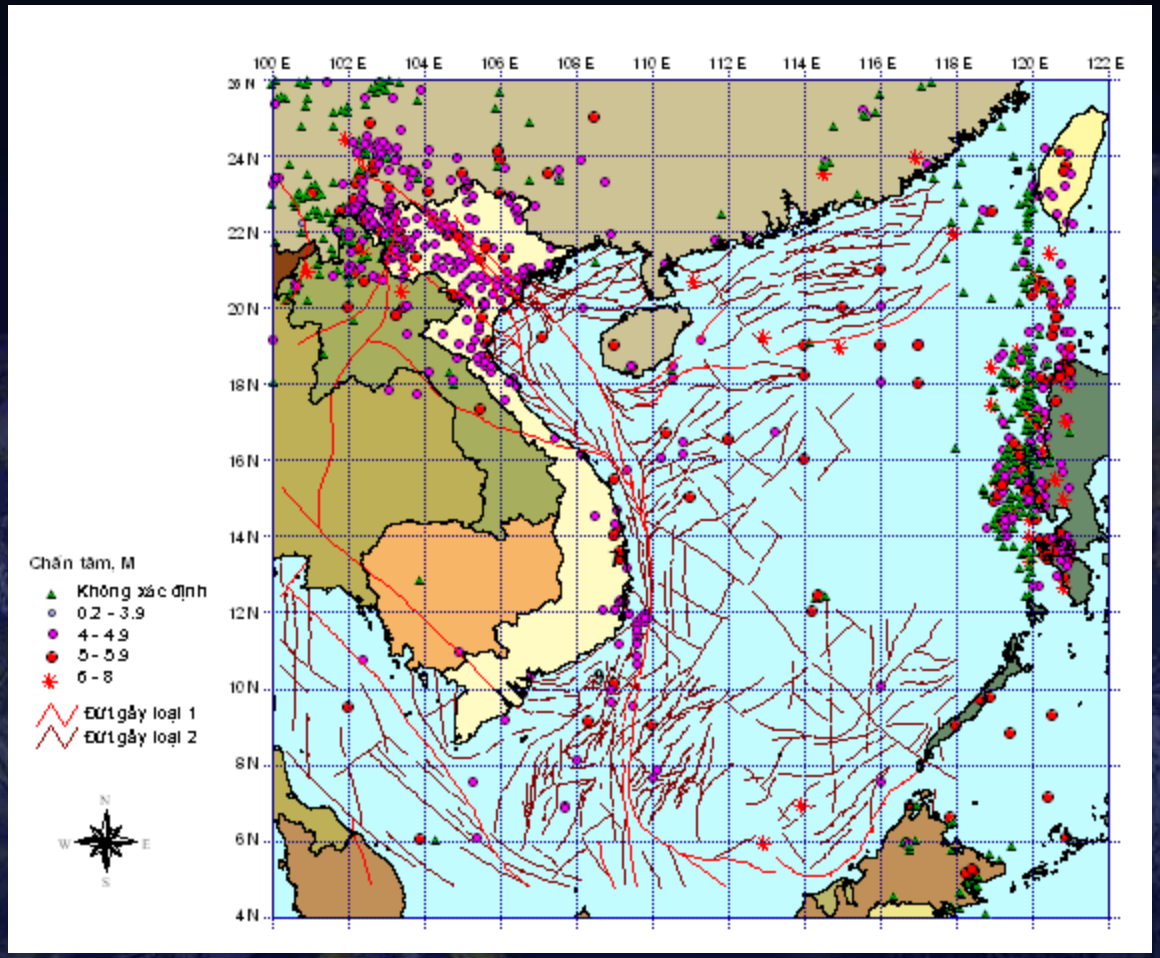
Earthquake hazards in Vietnam



eismotectonic map of Vietnam and adjacent sea areas

- The largest earthquakes in country: 3
  -1 historical (in the 14th century)
  - 2 recorded:
  -Dien Bien 1935 (M=6.7) and Tuan Giao 1983 (M=6.7)
- Offshore volcanic earthquake 1923 (M=6.1).
- No records of historical tsunami s, no official data on damage and casualties

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DEVELOPMENT OF A FAULT SOURCE MODEL

BACKGROUND

A fault-source model of Vietnam was developed, using the relationship of Wells and Coppersmith (1994) given below:

$$Log_{10}(L) = a + b.\ M$$

where *L* is the rupture length (km) and *M* is the moment magnitude of the earthquake; *a* and *b* are regression coefficient, determined for different types of faults.

Regression Coefficients of Fault Rupture Relationship of Wells and Coppersmith (1994)

Rupture Type	Fault Type	a	b
Surface	Strike Slip	-3.55	0.74
	Reverse	-2.86	0.63
	All	-3.22	0.69
Subsurface	Strike Slip	-2.57	0.62
	Reverse	-2.42	0.58
	All	-2.44	0.59

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DEVELOPMENT OF A FAULT SOURCE MODEL

BACKGROUND

Relationship between ground motion parameters *Y*, the earthquake magnitude *M* and the focal distance *R*, also known as the attenuation equation, can be express as follows:

$$Y = c_1 \exp(c_2 M) R C_3$$

where *Y* is one of the peak ground motion values (acceleration, velocity, or displacement). c_1, c_2 and c_3 are spatial dependent constants.

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DEVELOPMENT OF A FAULT SOURCE MODEL

BACKGROUND

For the PGA values, many attenuation equations have been defined by various investigators for regions of the World with different geological and geo-dynamical conditions. The table below lists 10 most characteristic attenuation equations used for the application of fault-source model of Vietnam.

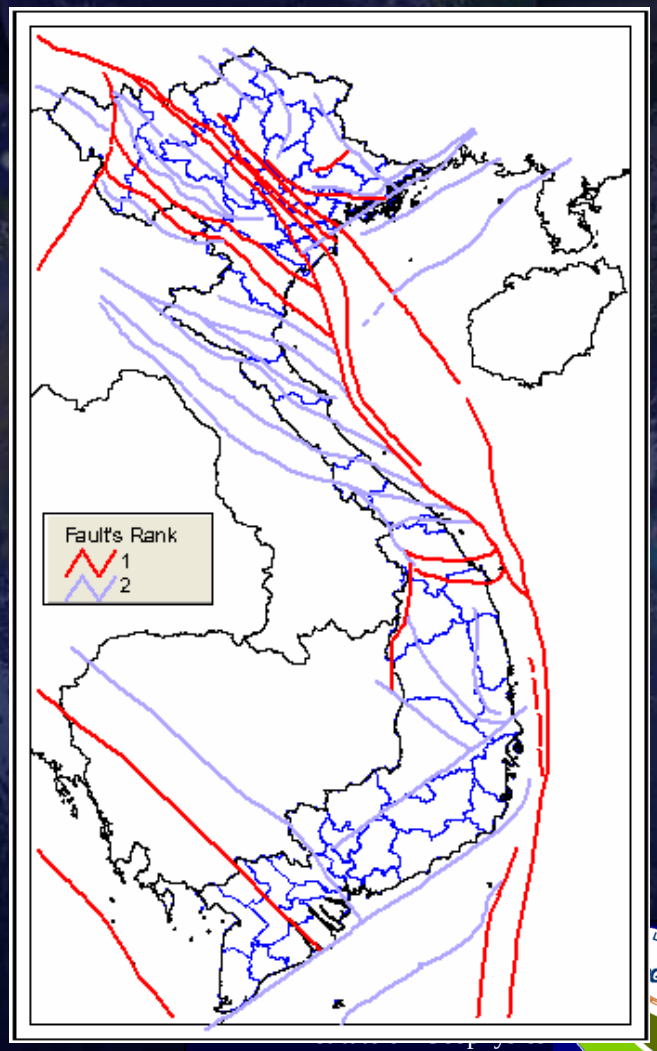
Table 2. The attenuation equations used for the fault-source model of Vietnam

No	Reference	Purpose
1	Nguyen Dinh Xuyen and Tran Thi My Thanh (1999)	Vietnam earthquakes.
2	Xiang Jianguang and Gao Dong (1998)	Yunnan earthquakes (PGA only).
3	Boore, Joyner & Fumal (1993, 1994a, 1994b)	Shallow crustal earthquakes.
4	Sadigh, Chang, Abrahamson, Chiou, and Power (1993)	Shallow crustal earthquakes.
5	Campbell and Bozorgnia (1994)	Shallow crustal earthquakes (PGA only).
6	Munson and Thurber (1997)	Hawaiian earthquakes (PGA only).
7	Youngs, Chiou, Silva and Humphrey (1997)	Deep and subduction zone earthquakes.
8	Frankel et al. (1996)	The central and Eastern U.S.
9	Toro, Abrahamson and Schneider (1997)	The central and Eastern U.S.
10	Lawrence Livermore National Laboratory (Sayv, 1998)	The central and Eastern U.S.

DEVELOPMENT OF A FAULT SOURCE MODEL

DATABASE

- A database of 46 seismically active faults systems in the territory and continental shelf of Vietnam was created.
- The faults systems are grouped in two ranks, depending on their depth of active layers and magnitude thresholds.
- The faults systems are simplified and digitized as single polylines in a GIS environment, and linked with their attribute data.
- There are two types of faults attribute data stored in the database. The first type is the descriptive information, including fault name, fault rank, type of faulting, main direction, total length, etc... More important attribute type is the fault parameters, which can be used directly to the hazard calculation as maximum moment magnitude, surface and subsurface rupture sizes, dip angle, etc…



SCENARIO-BASED HAZARD ASSESSMENT

Fault-source model was applied to define scenario earthquakes to be used in seismic hazard and risk assessment procedures in Vietnam at two levels: regional and urban.

A scenario earthquake is assumed the event, predicted (most likely) to occur in the study area, with predefined parameters. In another words, scenario earthquake is a simulation of an event in the past for predicting the effects of a future event.

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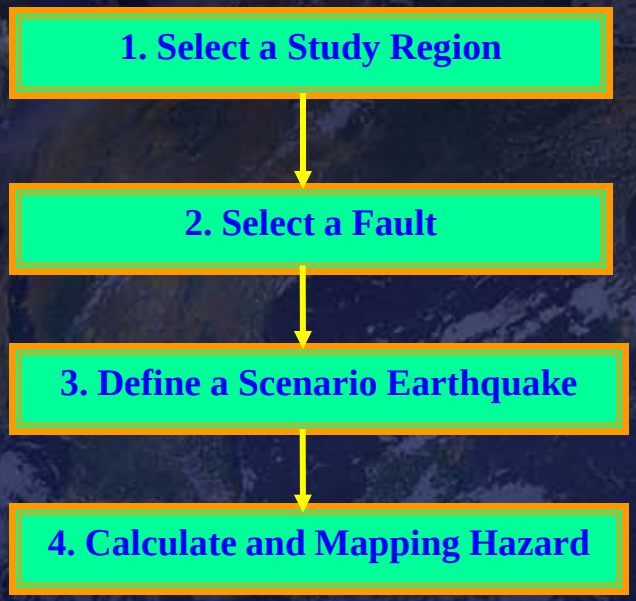
GIS TOOLS FOR SCENARIO-BASED HAZARD AND RISK ASSESSMENT

REGIONAL SCALE

- Name : F-Hazard
- Environment: ArcView GIS
- Programming language: Avenue



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EXAMPLE 1

- Program *F-Hazard* was used to simulate the Tuan Giao earthquake of June 24th, 1983, the one of the largest events ever observed and instrumentally recorded in the territory of Vietnam. With the assumption of the earthquake origination on Son La fault, the parameters of scenario earthquake were defined as follows:
- The fault-source is stretching in NW-SE direction, with a normal, right-lateral strike slip mechanism. The fault surface plunged north-eastward with a dip angle of γ=750;
- Epicentre coordinates are φ= 103.43; λ= 21.71;
- M_W = 6.77 (converted from M_S = 6.7);
- Focal depth H = 23 km

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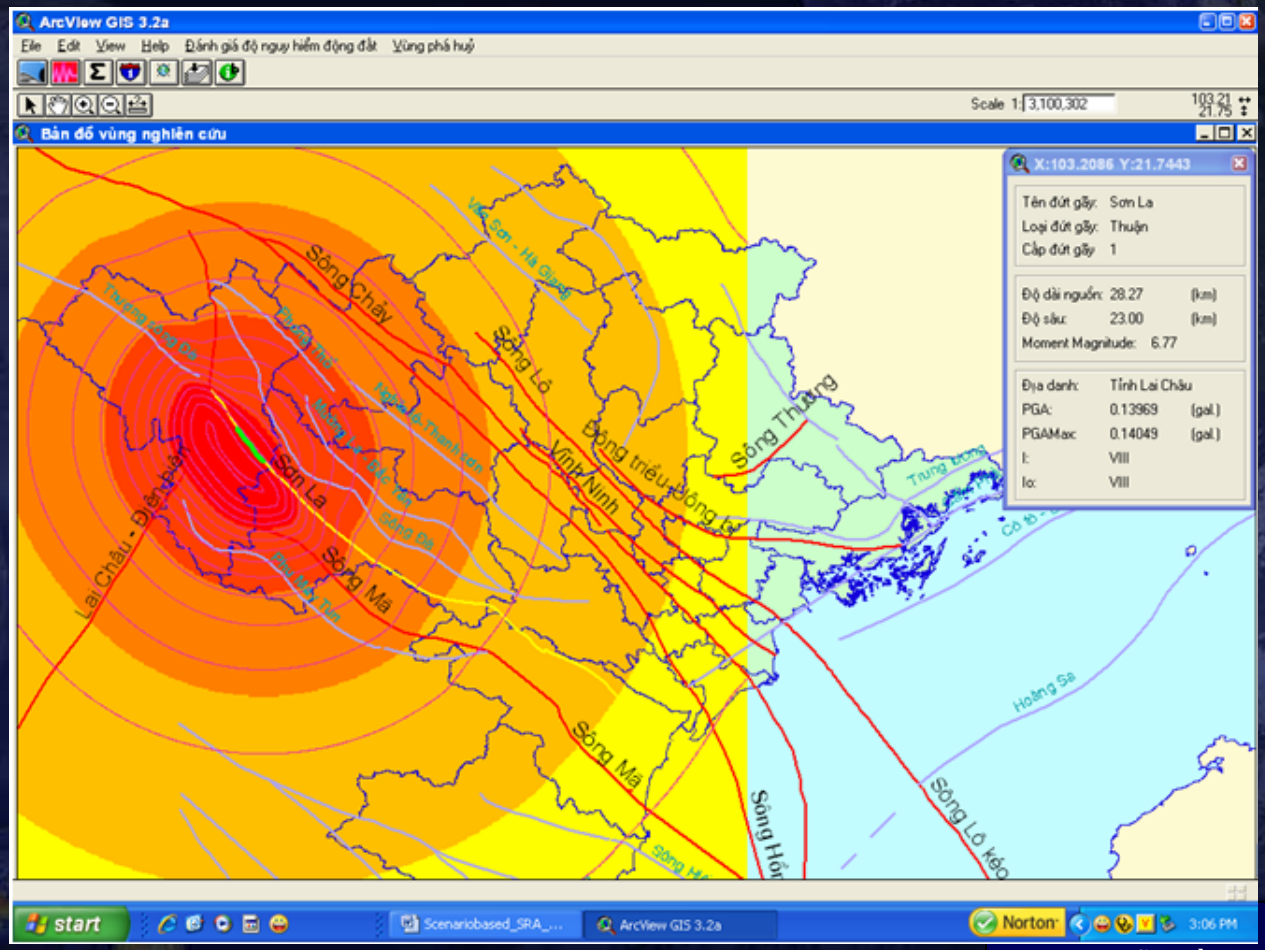
EXAMPLE 1

EXAMPLE 1

SEISMIC HAZARD ASSESSMENT AT REGIONAL SCALE



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NOTES ON THE REGIONAL CASE

- On-fly calculation
- Producing Shake Maps
- Rapid Assessment

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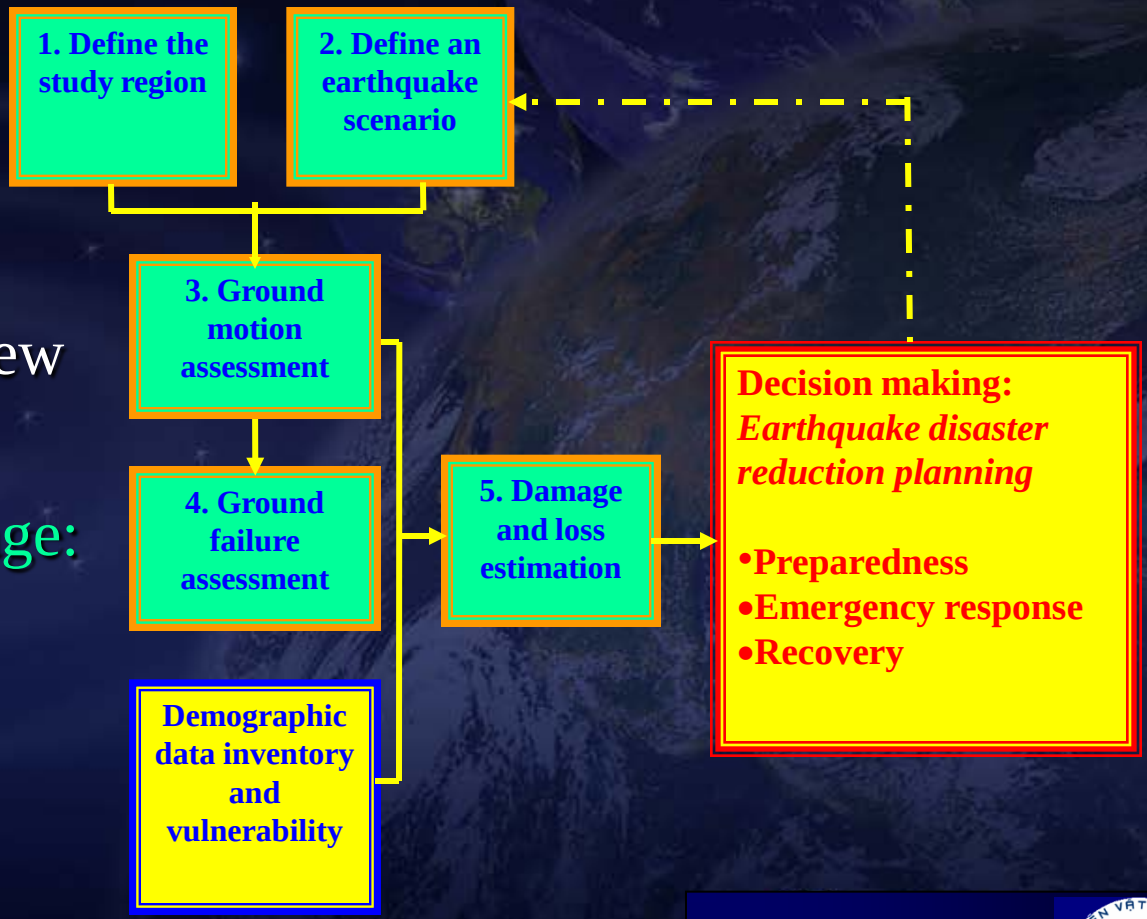
GIS TOOLS FOR SCENARIO-BASED HAZARD AND RISK ASSESSMENT

URBAN SCALE

- Name : ArcRisk
- Environment: ArcView GIS
- Programming language: Avenue



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EXAMPLE 2

SEISMIC HAZARD ASSESSMENT FOR MEGACITIES OF VIETNAM

- *ArcRisk* has been used to estimate building damage and casualties for urban areas of some megacities of Vietnam.
- An example of Hanoi city is presented here. The scenario earthquakes were created with the assumption that they are originated on one of the seismically active faults, crossing or passing nearby the city territory.

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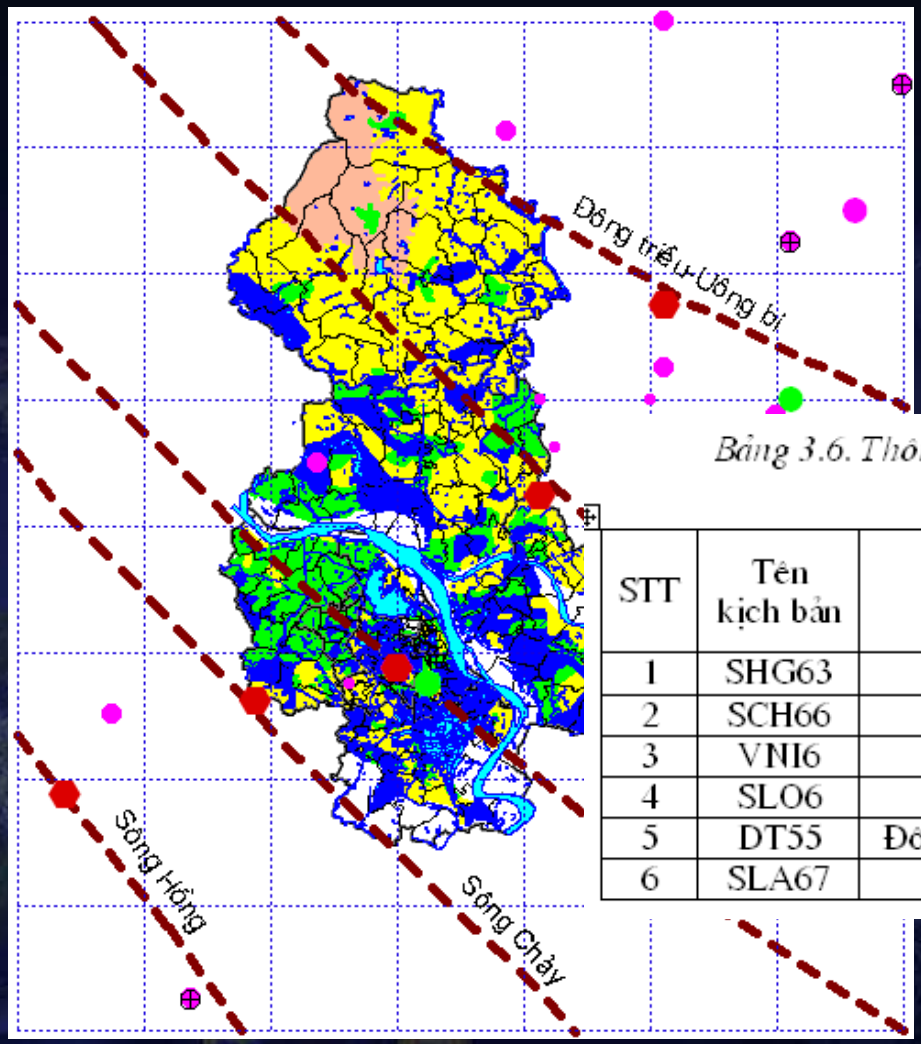
THE HANOI CASE STUDY



Earthquake Scenarios (red dots)

Bảng 3.6. Thông số của các động đất kịch bản sử dụng trong tính toán rủi ro cho thành phố Hà nội

STT	Tên kịch bản	Tên đứt gãy	M_w	Toạ độ chấn tâm		Độ sâu chấn tiêu, km
				Kinh	Vĩ	
1	SHG63	Sông Hồng	6,3	105,62	20,93	18
2	SCH66	Sông Chảy	6,6	105,74	20,99	15
3	VNI6	Vĩnh Ninh	6,0	105,83	21,01	10
4	SLO6	Sông Lô	6,0	105,92	21,12	15
5	DT55	Đông Triều-Uông Bi	5,5	106,00	21,24	15
6	SLA67	Sơn La	6,7	104,93	20,66	23

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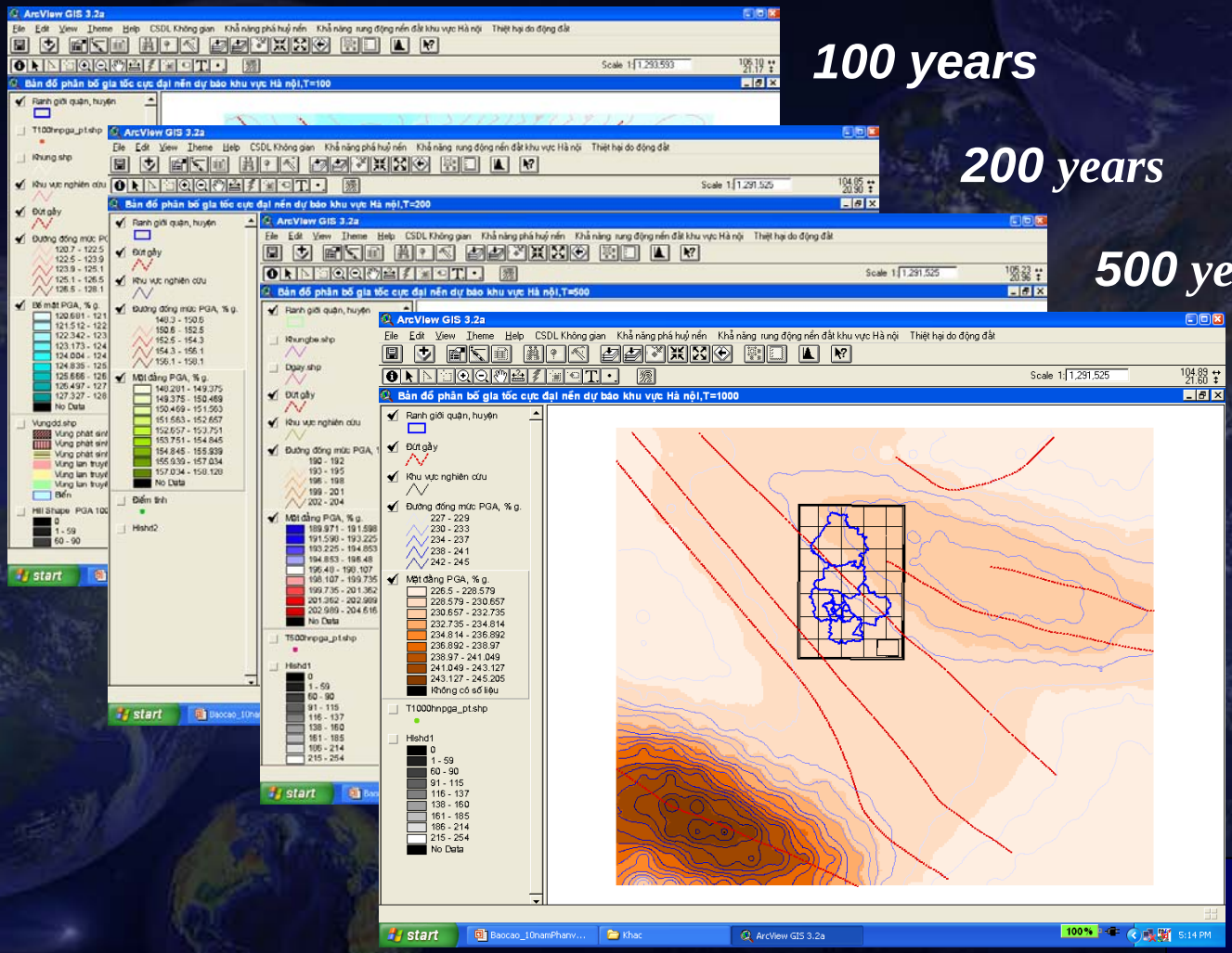
THE HANOI CASE STUDY

GROUND SHAKING ASSESSMENT



100 years

200 years

500 years

1000 years

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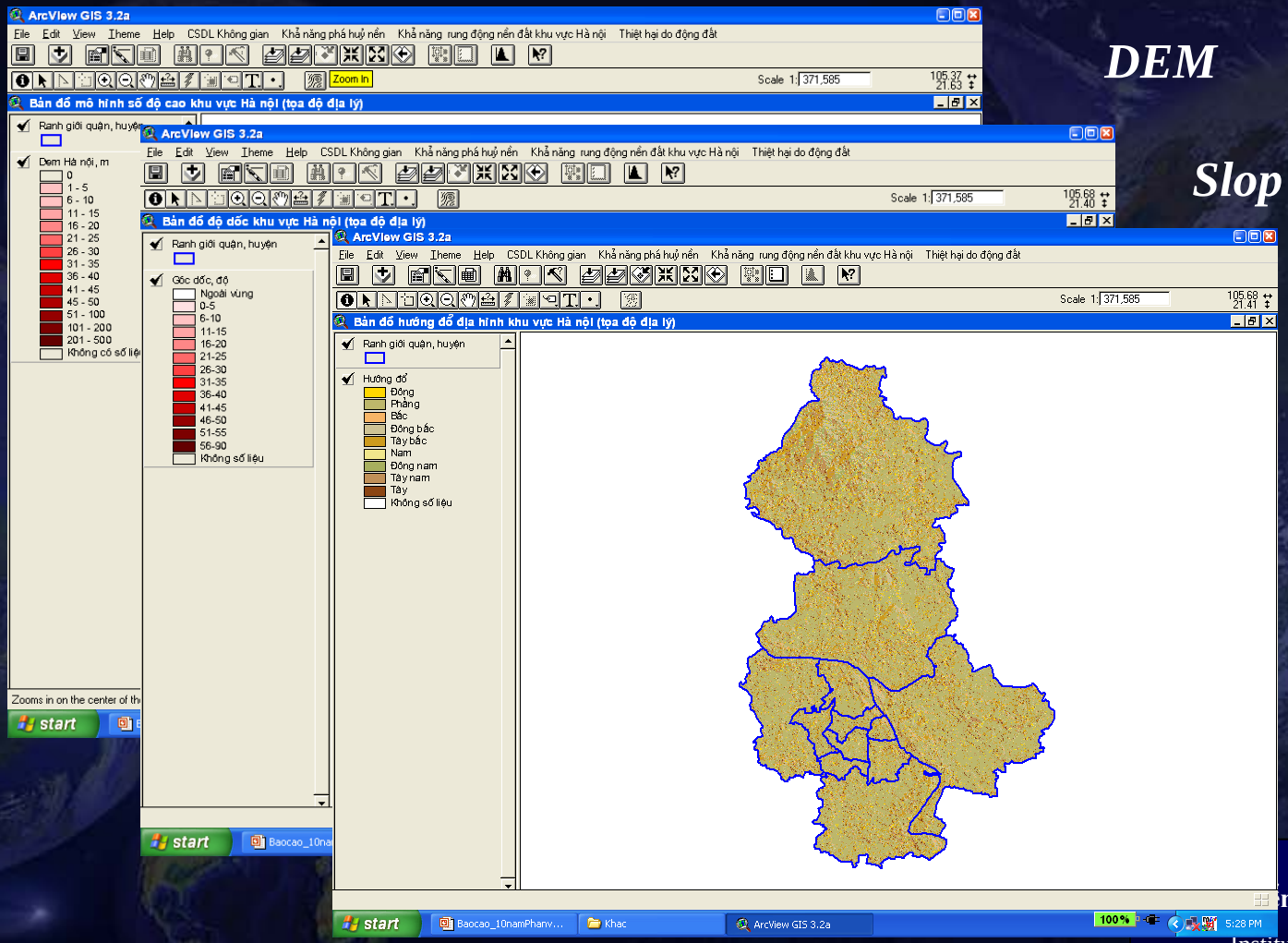
THE HANOI CASE STUDY

GROUND FAILURE ASSESSMENT



DEM

Slop map

Aspect map

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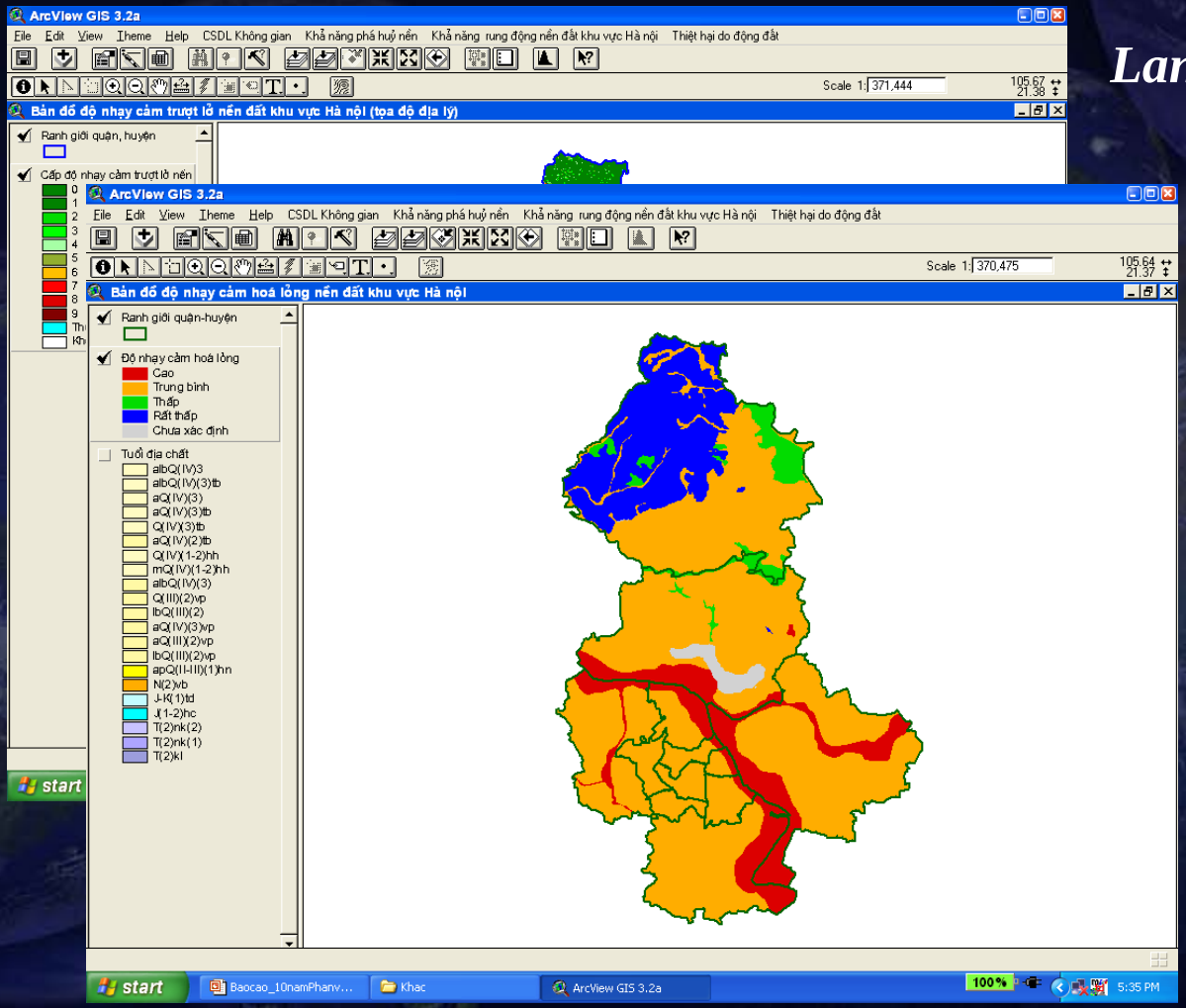
THE HANOI CASE STUDY

GROUND FAILURE ASSESSMENT



Landslide susceptibility

Liquefaction susceptibility

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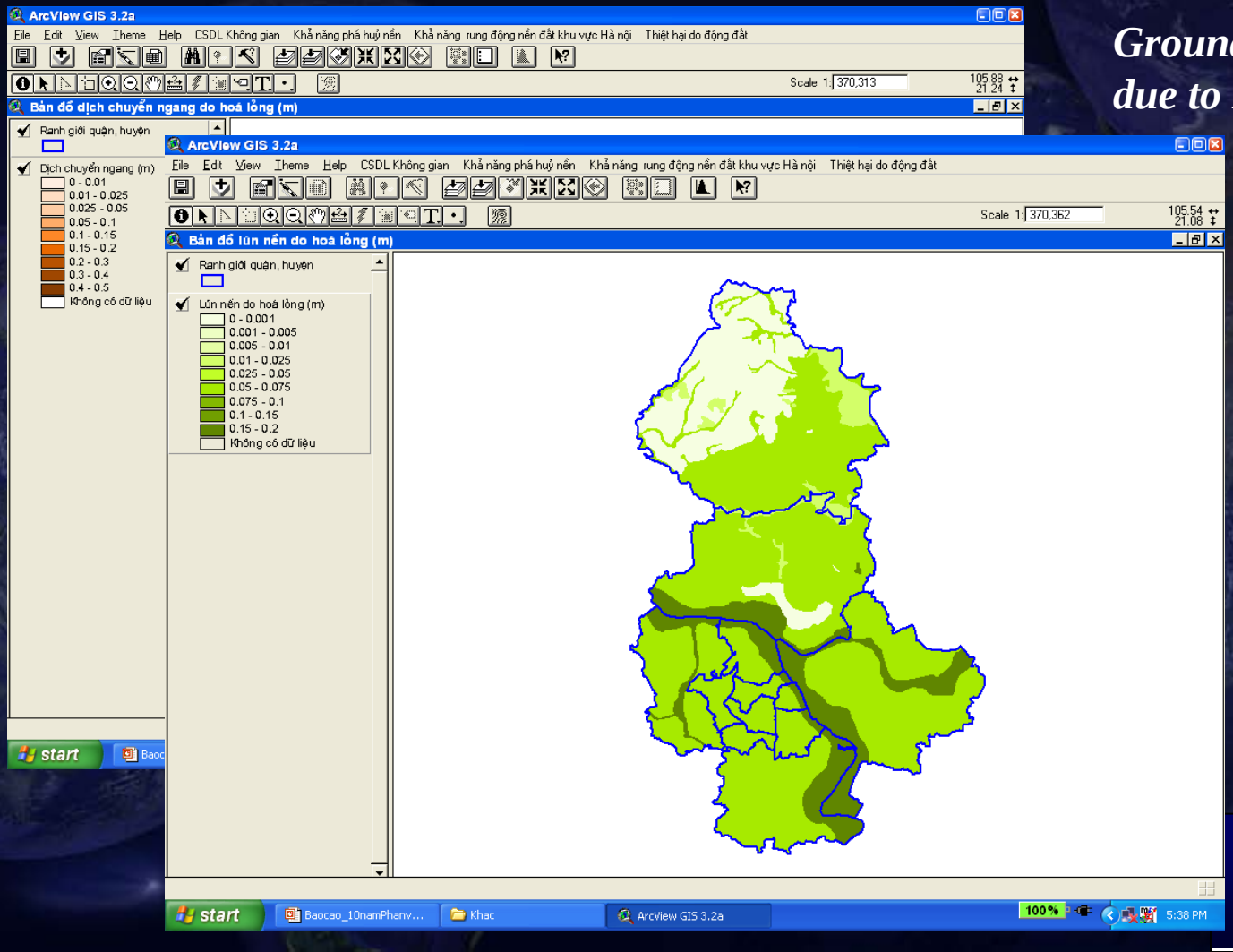
GROUND FAILURE ASSESSMENT



Ground lateral spreading due to Liquefaction

Ground settlement due to Liquefaction

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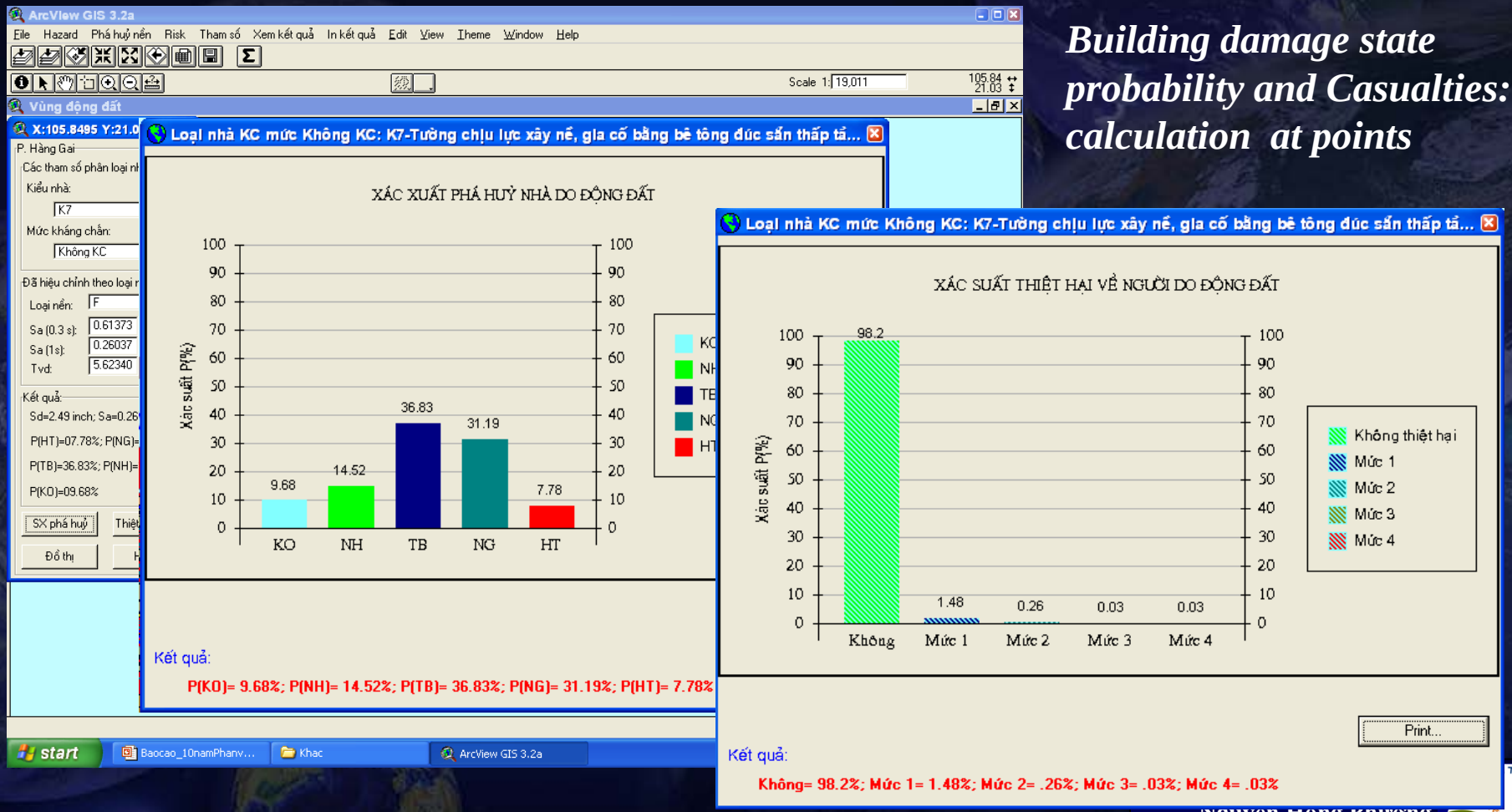
THE HANOI CASE STUDY

EARTHQUAKE LOSS ESTIMATION: HOAN KIEM DISTRICT



Building damage state probability and Casualties: calculation at points

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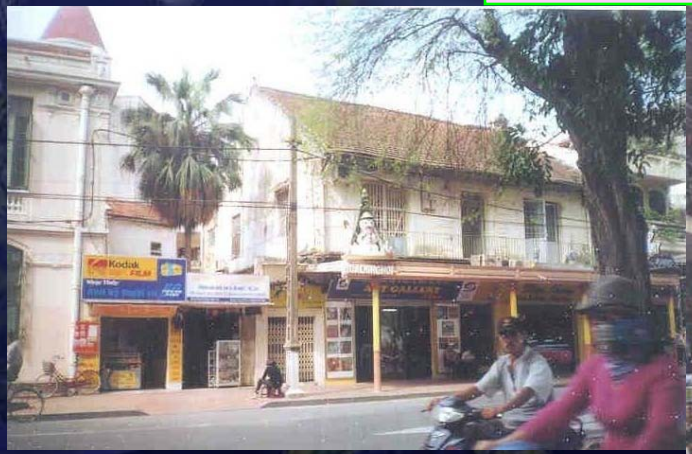
DATA/INVENTORY

BUILDINGS IN HANOI: THE C TYPE

BUILDINGS IN HANOI: THE M TYPE



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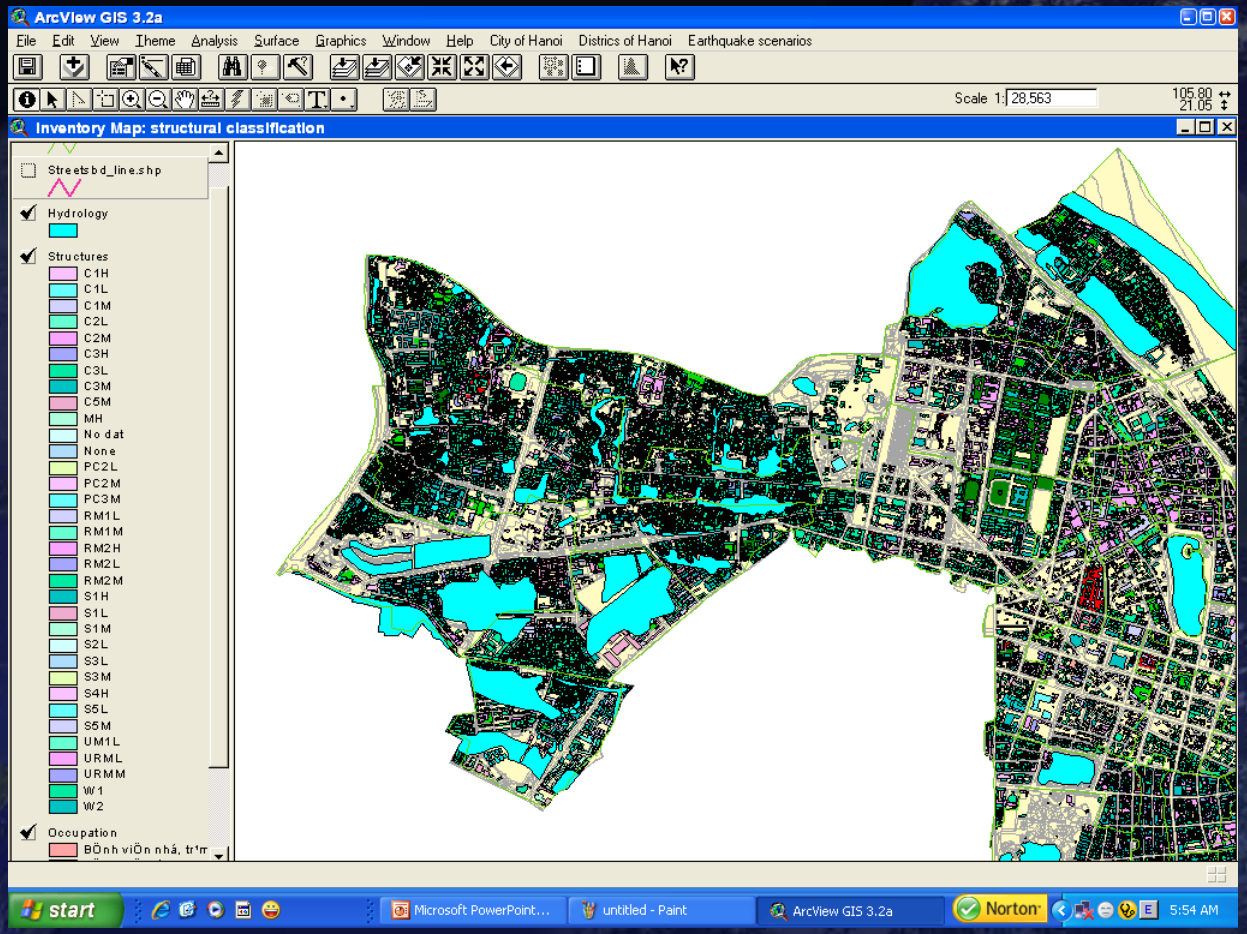
DATA/INVENTORY



Building stocks: structural classification

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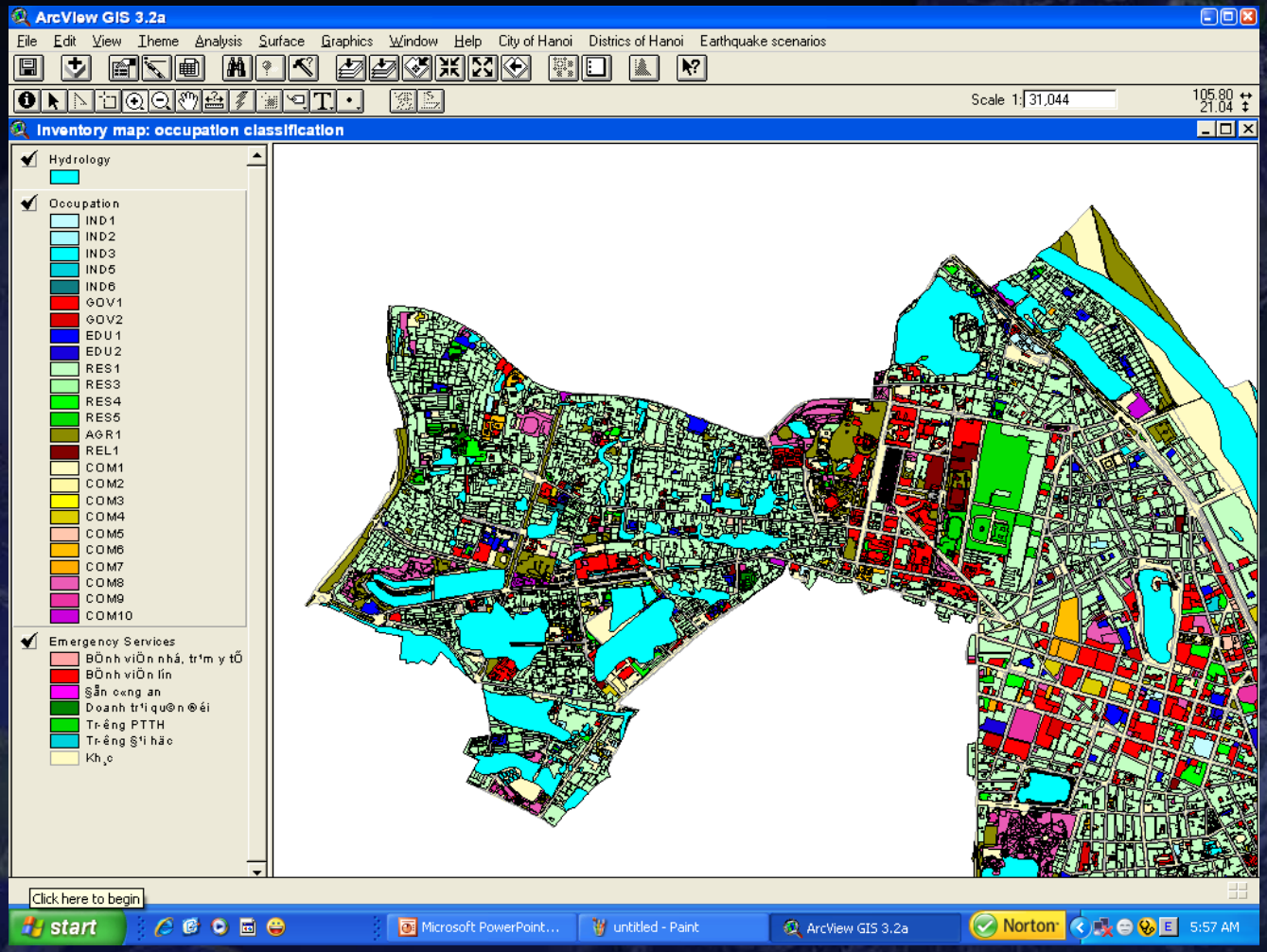
DATA/INVENTORY



Building stocks: occupancy classification

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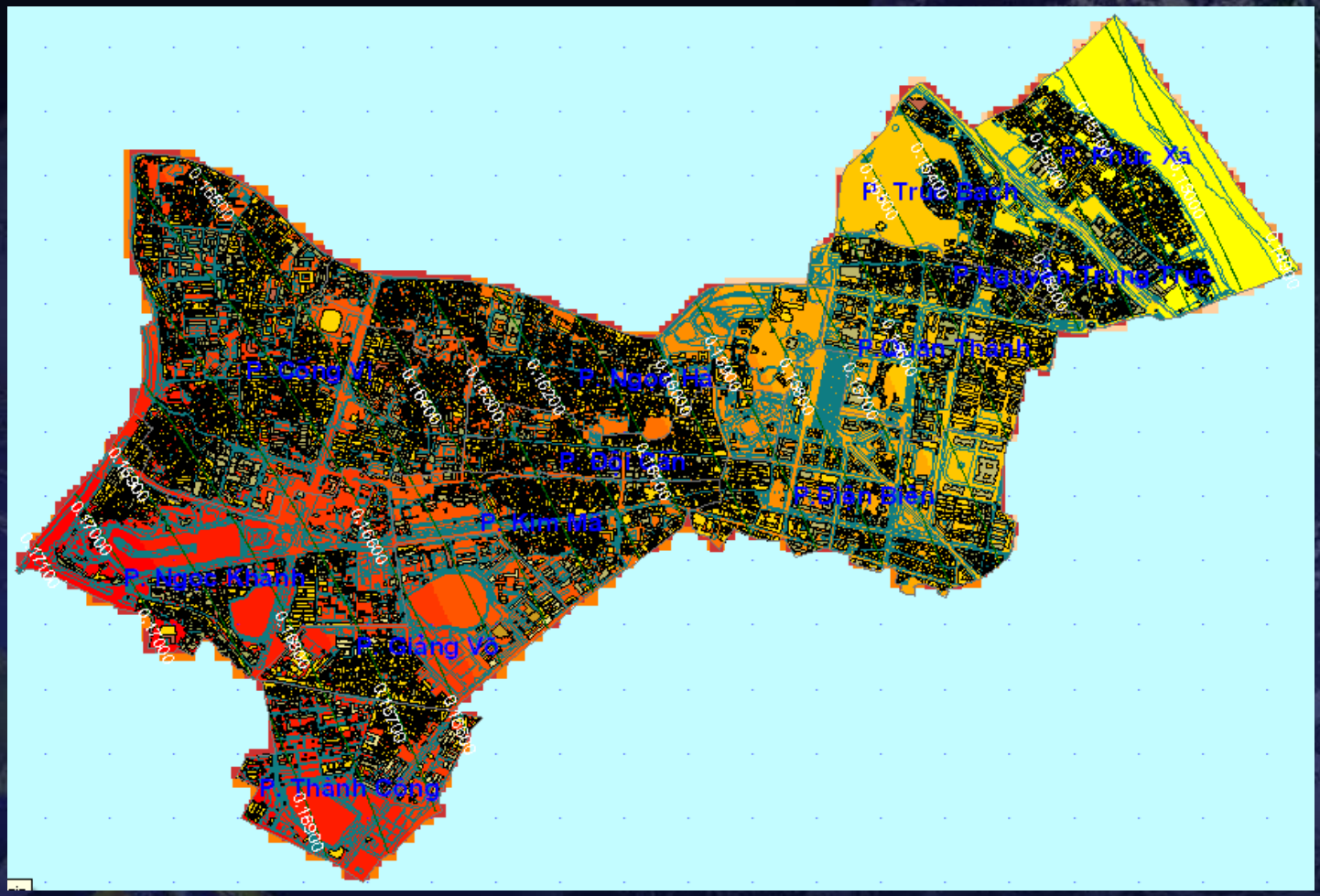
HAZARD ASSESSMENT



Shaking map: Peak Ground Acceleration

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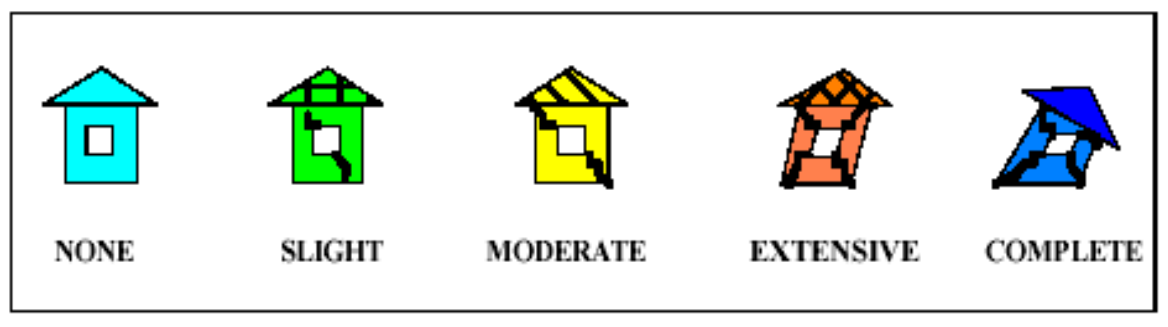
LOSS ESTIMATION: BUILDINGS

- Elements at Risk : 1) Buildings
- Building damage: 5 states (None, Slight, Moderate, Extensive and Complete)



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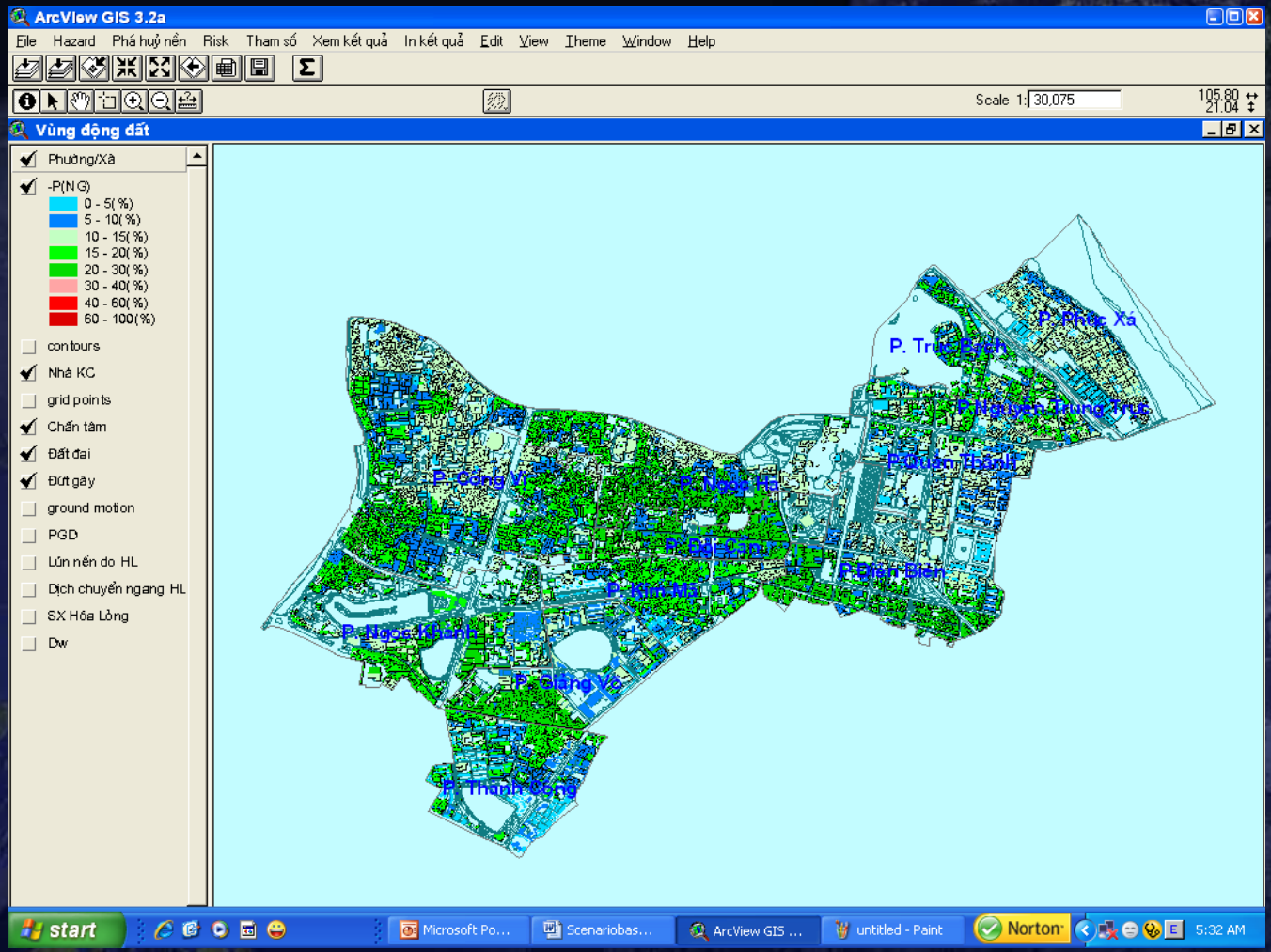
LOSS ESTIMATION: BUILDINGS

MAPS



Probability of building damage: Extensive state

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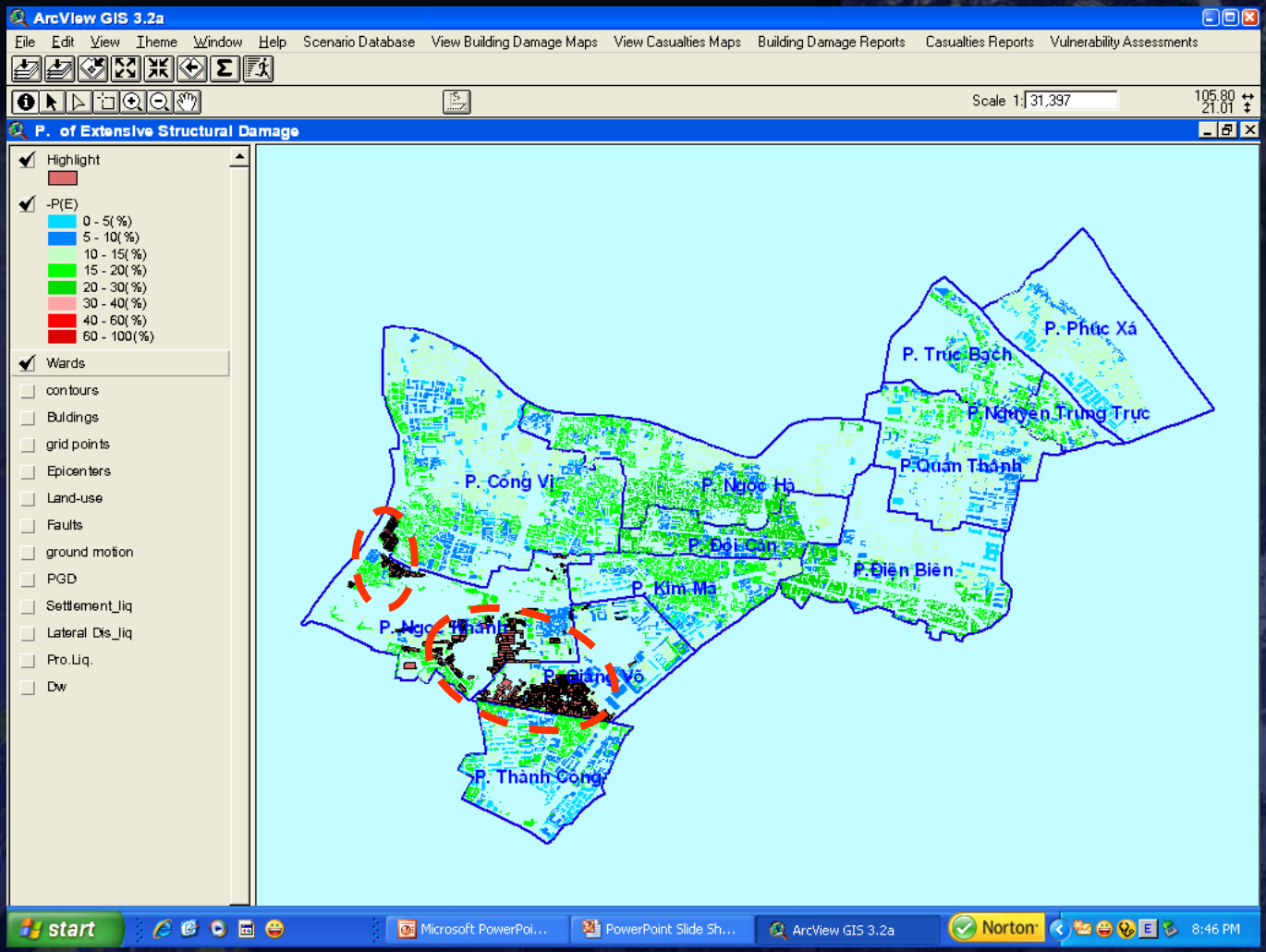
LOSS ESTIMATION: BUILDINGS

MAPS



Probability of building damage: Extensive state

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LOSS ESTIMATION: BUILDINGS

REPORTS

STRUCTURAL BUILDING DAMAGE

DISTRICT: QUẬN BA ĐÌNH

SCENARIO: SCH66_BD FAULT: SÔNG CHẢY MW: 6.6 LONG: 105.74 LAT: 20.99 DEPTH: 15

STRUCTURAL BUILDING	AREA, M2	STATE DAMAGE, %				
		NONE	SLIGHT	MEDIUM	HEAVY	COMPLETE
W1	25248.43	40.33	31.70	21.82	5.42	0.76
W2	12258.33	40.42	34.65	22.57	2.03	0.34
S1L	100610.37	45.76	21.21	24.53	6.78	1.80
S1M	34754.25	47.60	23.58	21.16	5.77	1.77
S1H	23006.08	38.79	25.31	23.75	9.93	2.11
S5L	29575.27	28.79	21.68	29.70	16.64	3.31
S5M	70121.74	32.27	31.61	26.10	8.20	2.00
C1L	18835.62	36.18	18.74	32.34	10.67	2.40
C1M	1695.49	33.00	24.76	32.47	7.82	2.17
C1H	19434.42	30.00	23.59	31.19	12.00	3.24
C2L	487.60	32.00	22.42	29.91	14.49	1.62
C2M	18868.82	47.18	28.24	21.59	2.37	0.66

Probability of building damage: Extensive state

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LOSS ESTIMATION: CASUALTIES

- Elements at Risk: 2) People
- Casualties: 4 severity levels, at 2 am, 2 pm and 5 pm

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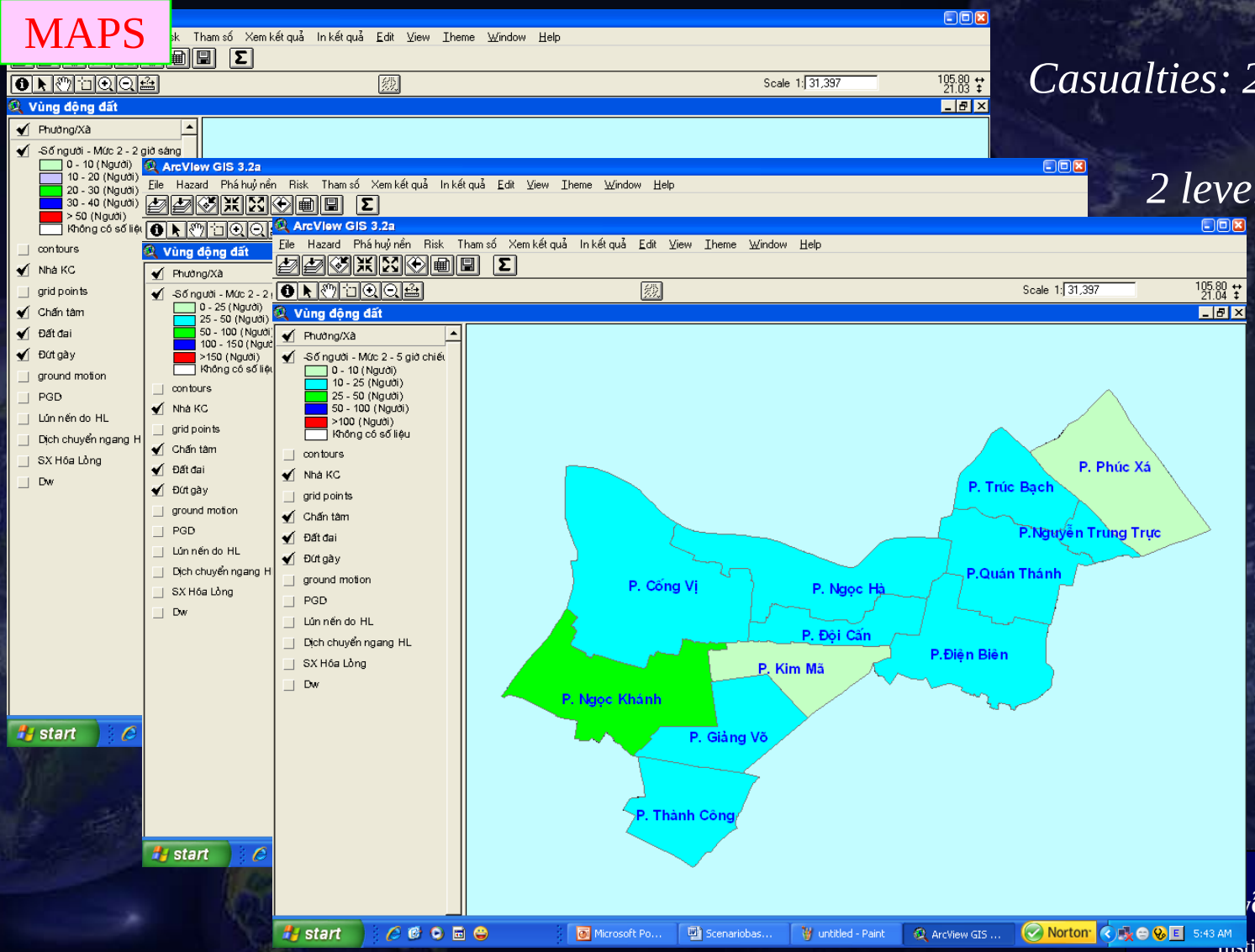
LOSS ESTIMATION: CASUALTIES

MAPS



Casualties: 2 level, at 2 am

2 level, at 2 pm

2 level, at 5 pm

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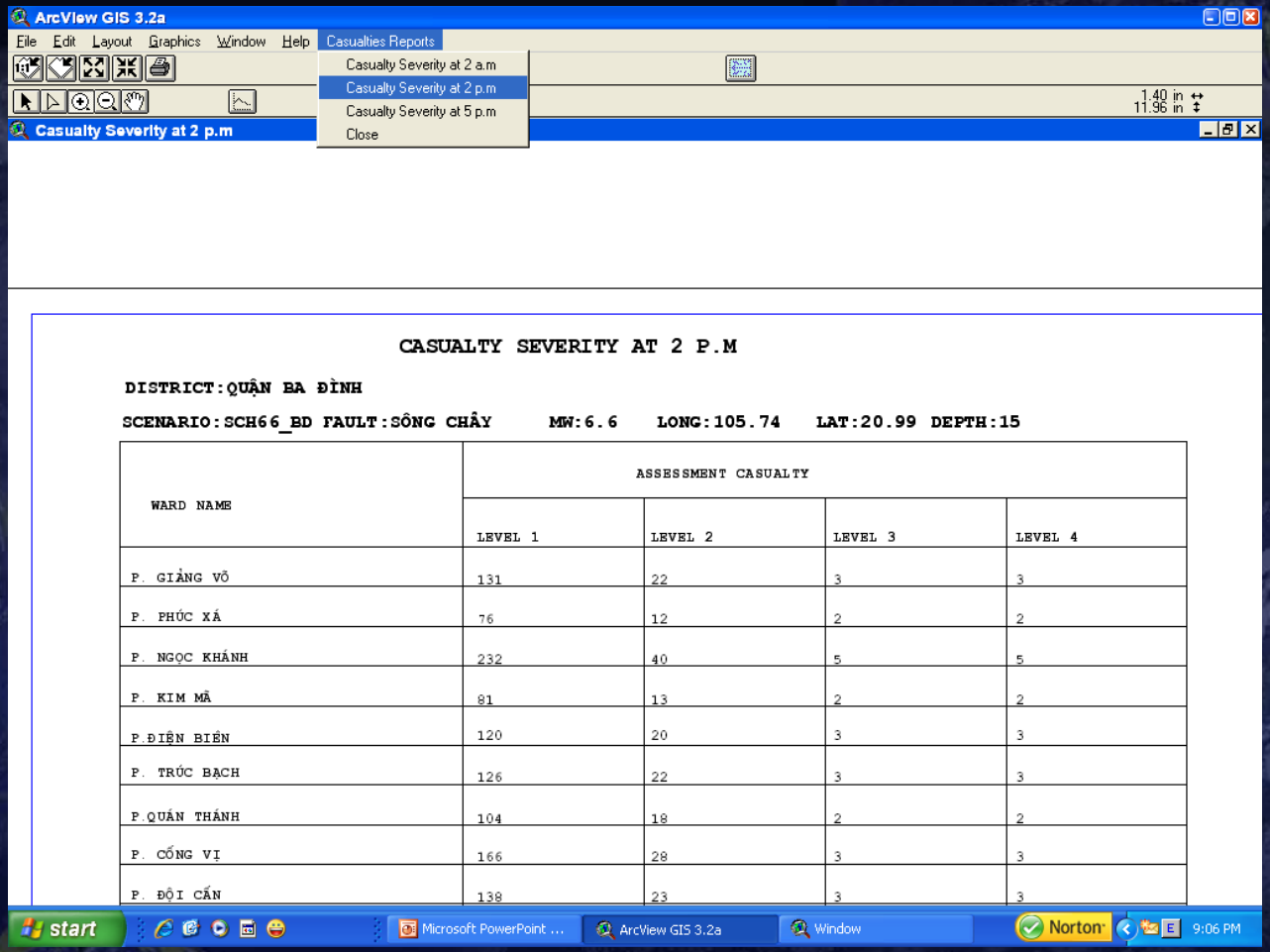
LOSS ESTIMATION: CASUALTIES

REPORTS



CASUALTY SEVERITY AT 2 P.M

DISTRICT:QUẬN BA ĐÌNH

SCENARIO:SCH66_BD FAULT:SÔNG CHẢY MW:6.6 LONG:105.74 LAT:20.99 DEPTH:15

WARD NAME	ASSESSMENT CASUALTY			
	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
P. GIẢNG VÕ	131	22	3	3
P. PHÚC XÁ	76	12	2	2
P. NGỌC KHÁNH	232	40	5	5
P. KIM MÃ	81	13	2	2
P.ĐIỆN BIÊN	120	20	3	3
P. TRÚC BẠCH	126	22	3	3
P.QUÁN THÁNH	104	18	2	2
P. CỐNG VỊ	166	28	3	3
P. ĐỘI CẤN	138	23	3	3

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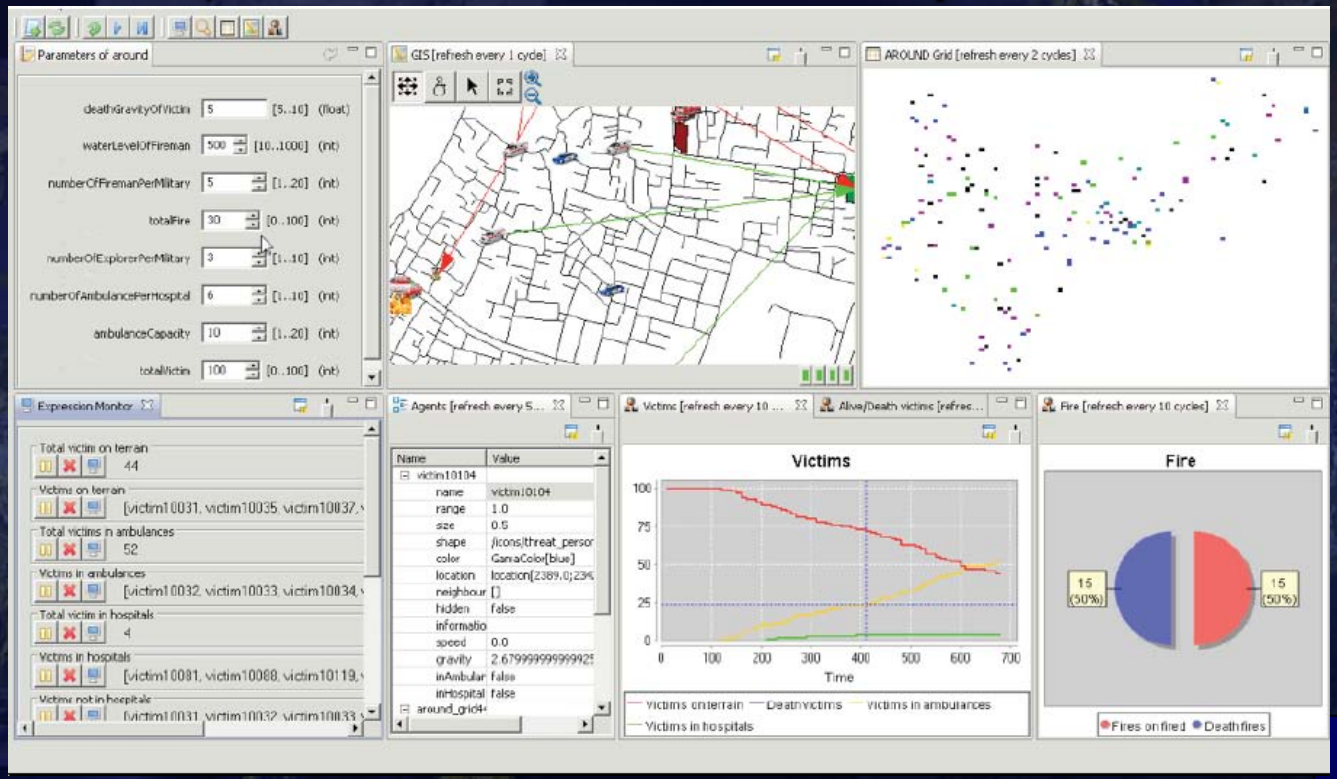
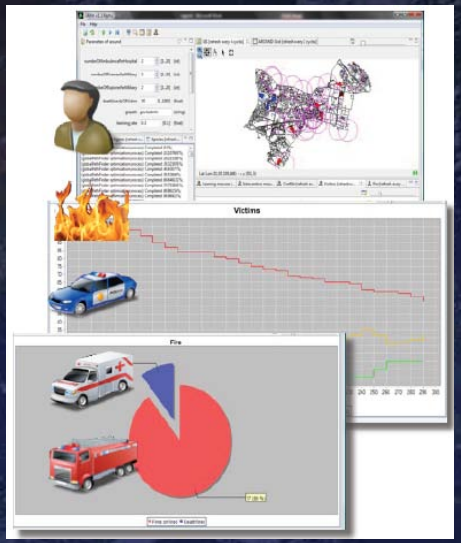
EMERGENCY RESPONSE

- Coupling GIS and simulation: ArcRisk and GAMA (Gis & Agent-based Modeling Architecture)
- Search and Rescue Tools in a DSS
- A product of a Scientific Joint Project between IGP and IRD/IFI





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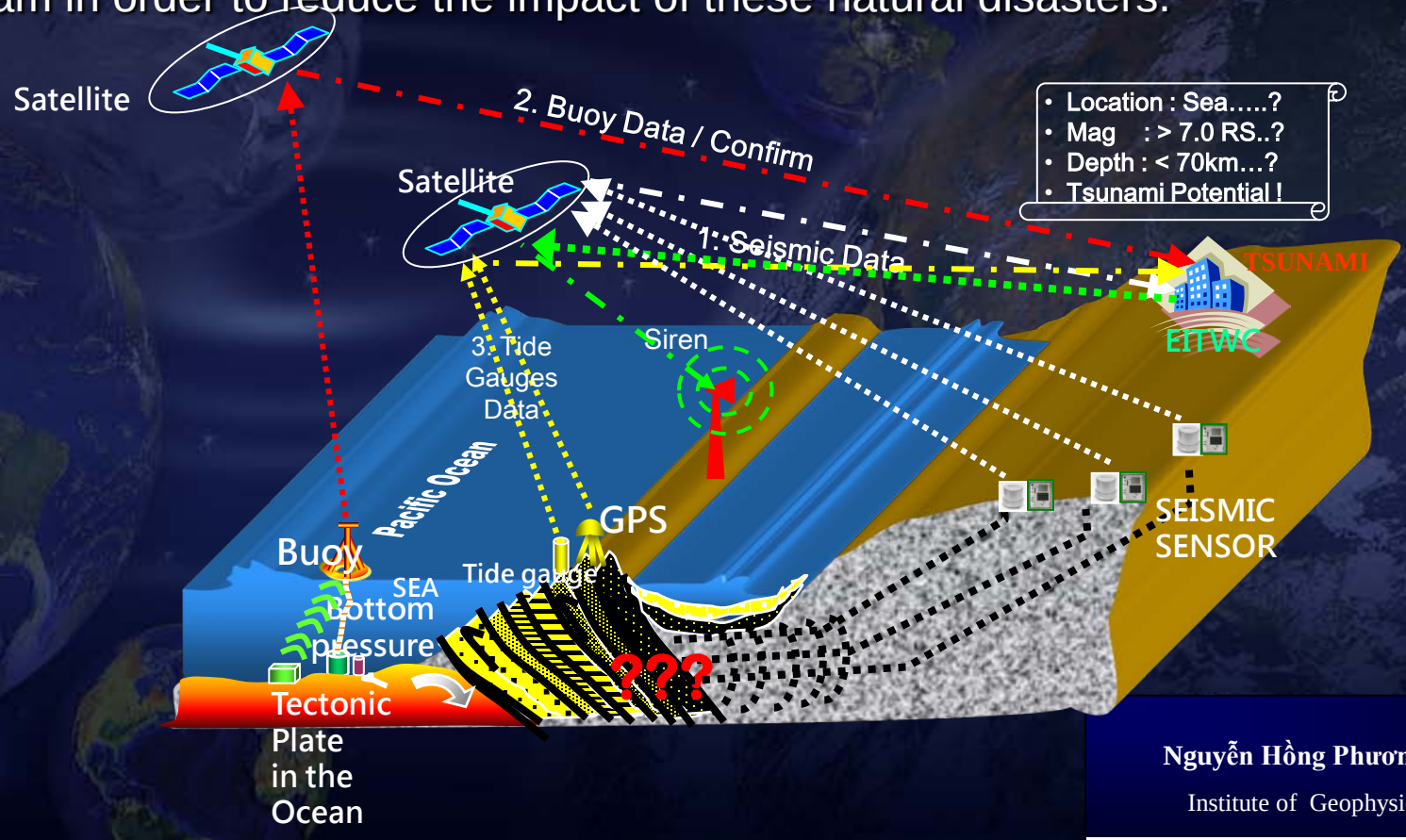
EARLY WARNING SYSTEM

The Earthquake Information and Tsunami Warning Centre (EITWC) within the Vietnam Academy of Science and Technology (VAST) has been given the responsibility for issuing earthquake information and tsunami warnings for Vietnam in order to reduce the impact of these natural disasters.



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NOTES ON THE URBAN CASE

1) Need Pre-calculation
2) Problems of Data Storage and Retrieval

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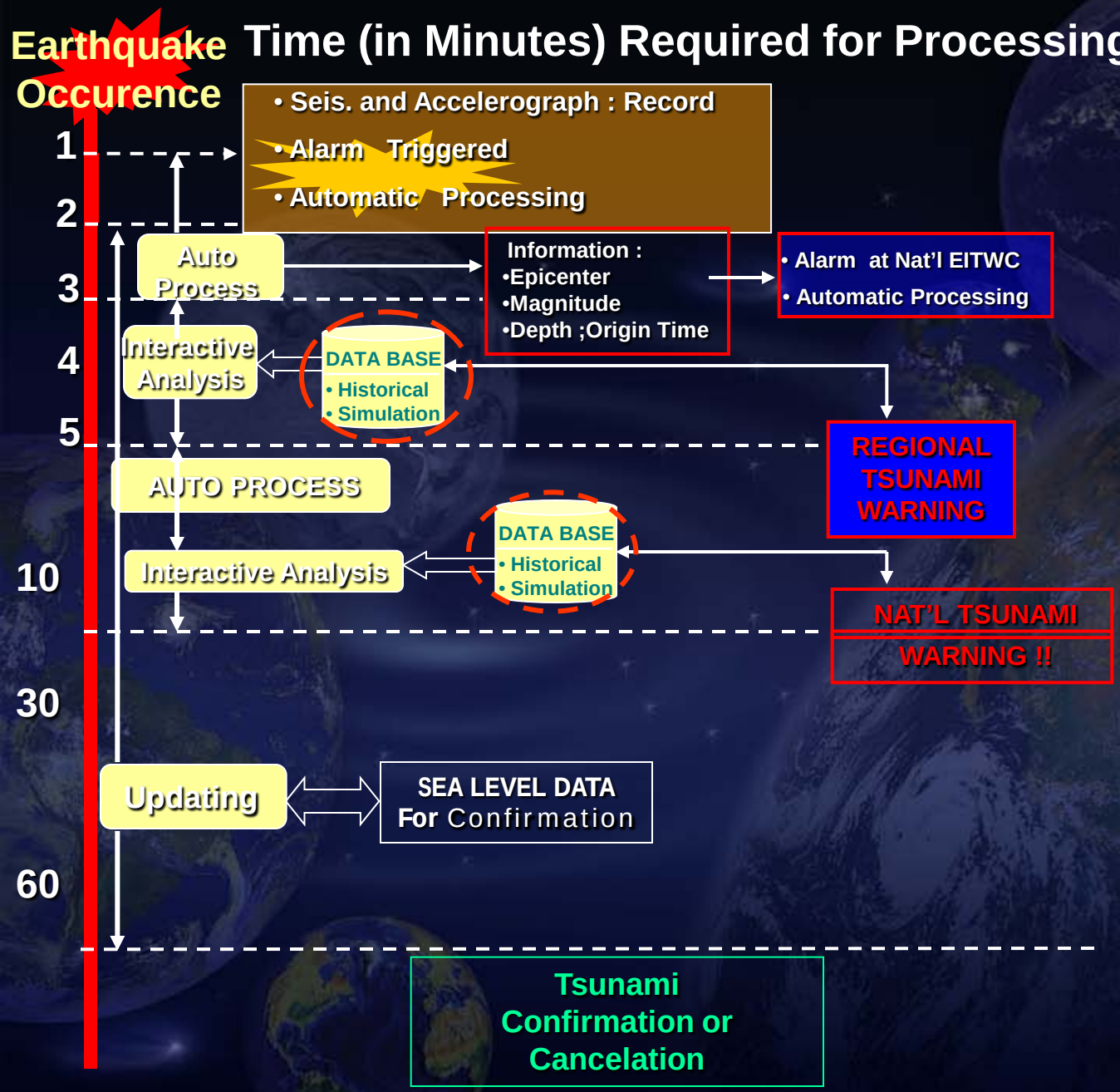
Time (in Minutes) Required for Processing Warning Information



Processing Time Frame (Minute 1 – Minute 10)

Minute 1: Signal recorded at ≥ 5 Stations

Minute 2: Processing

Minute 3: EQ Parameters (Origin Time; Epicenter; Depth; Magnitude)

Minute 4: - Database is activated
- Interactive Analysis

Minute 5: Warning !!

Minute 10: Warning From Nat'l Center to Wider Region/ International

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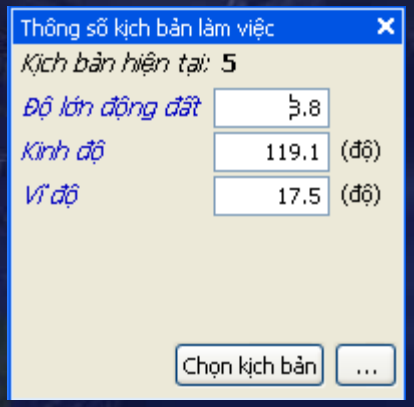
EXTENSION CASE: TSUNAMI

1) Development of a pre-calculated tsunami scenario database: Vu Thanh Ca et al (2008)



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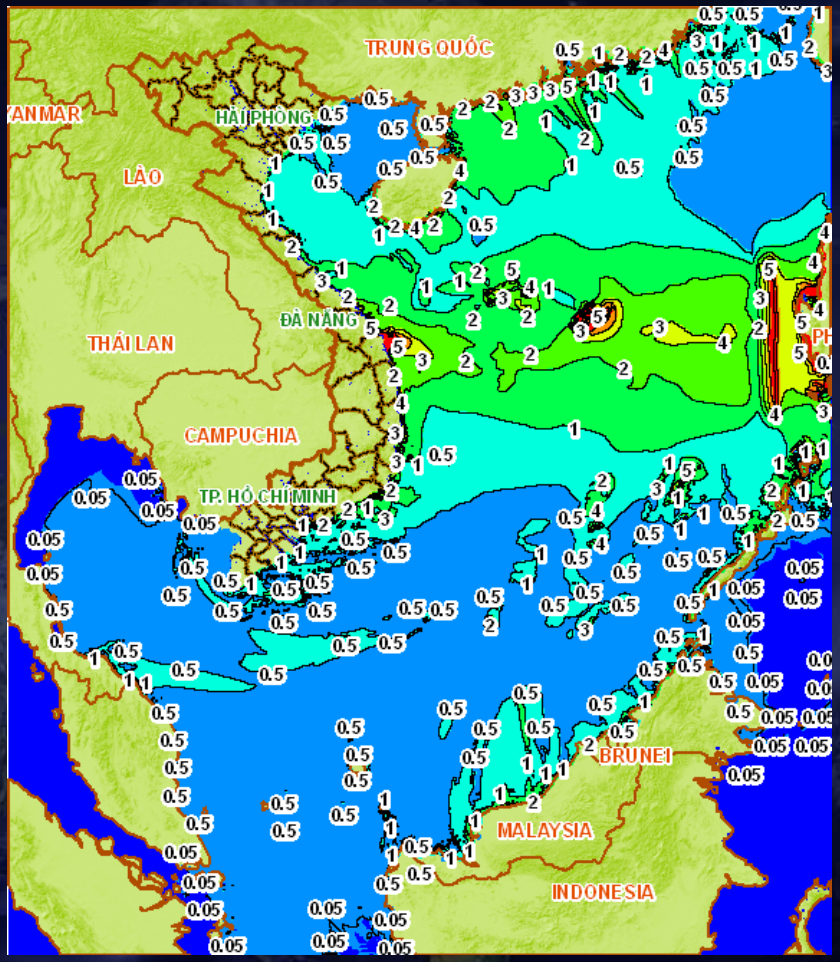
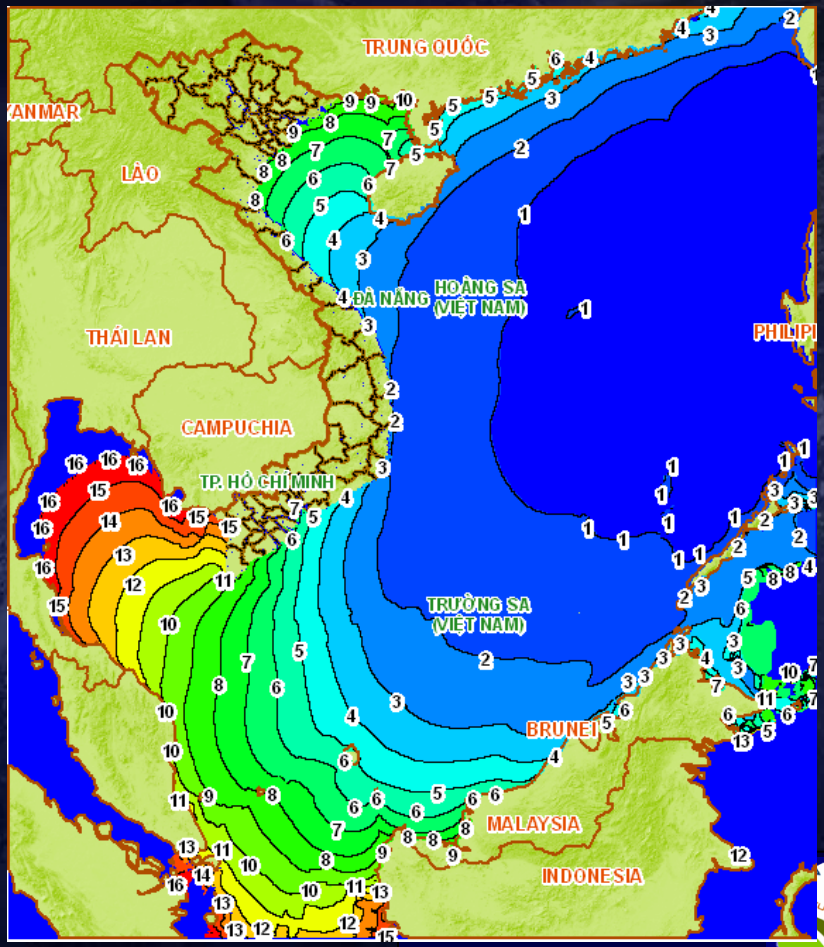
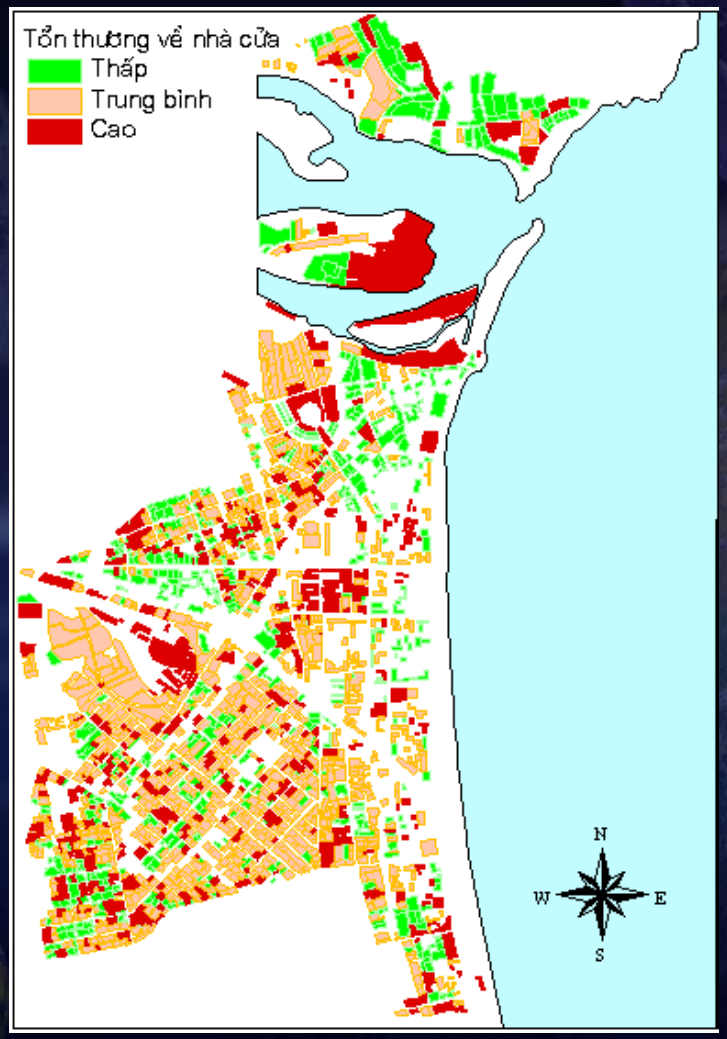
1) Development of a pre-calculated tsunami scenario database: Vu Thanh Ca et al (2008)





EXTENSION CASE: TSUNAMI

2) Tsunami vulnerability mapping: Nguyen Hong Phuong et al (2009)



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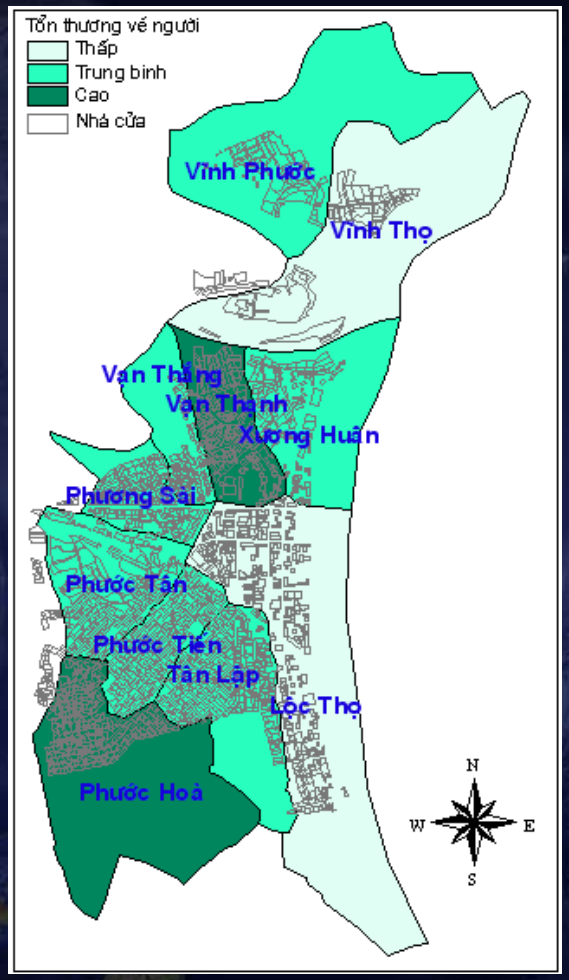
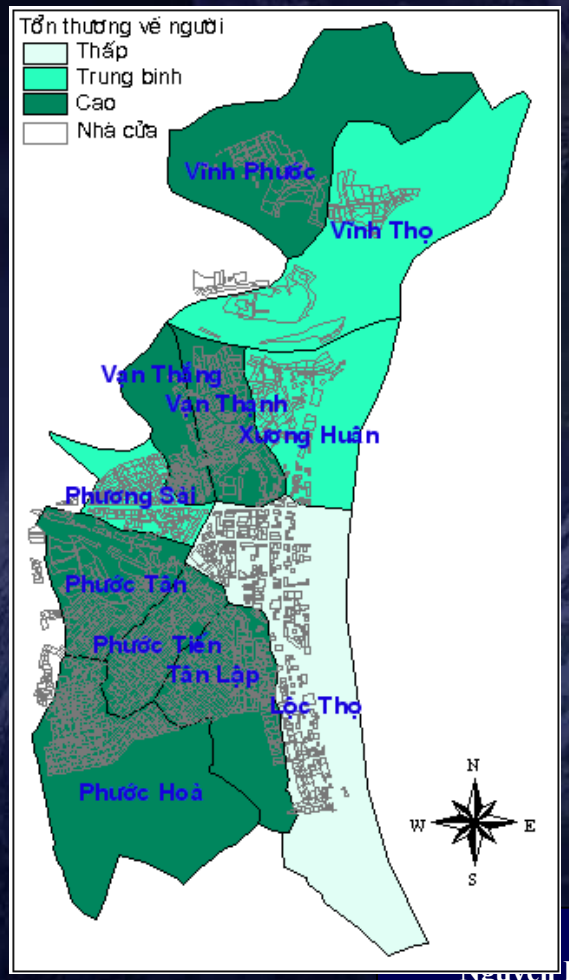
EXTENSION CASE: TSUNAMI

2) Tsunami vulnerability mapping: Nguyen Hong Phuong et al (2009)





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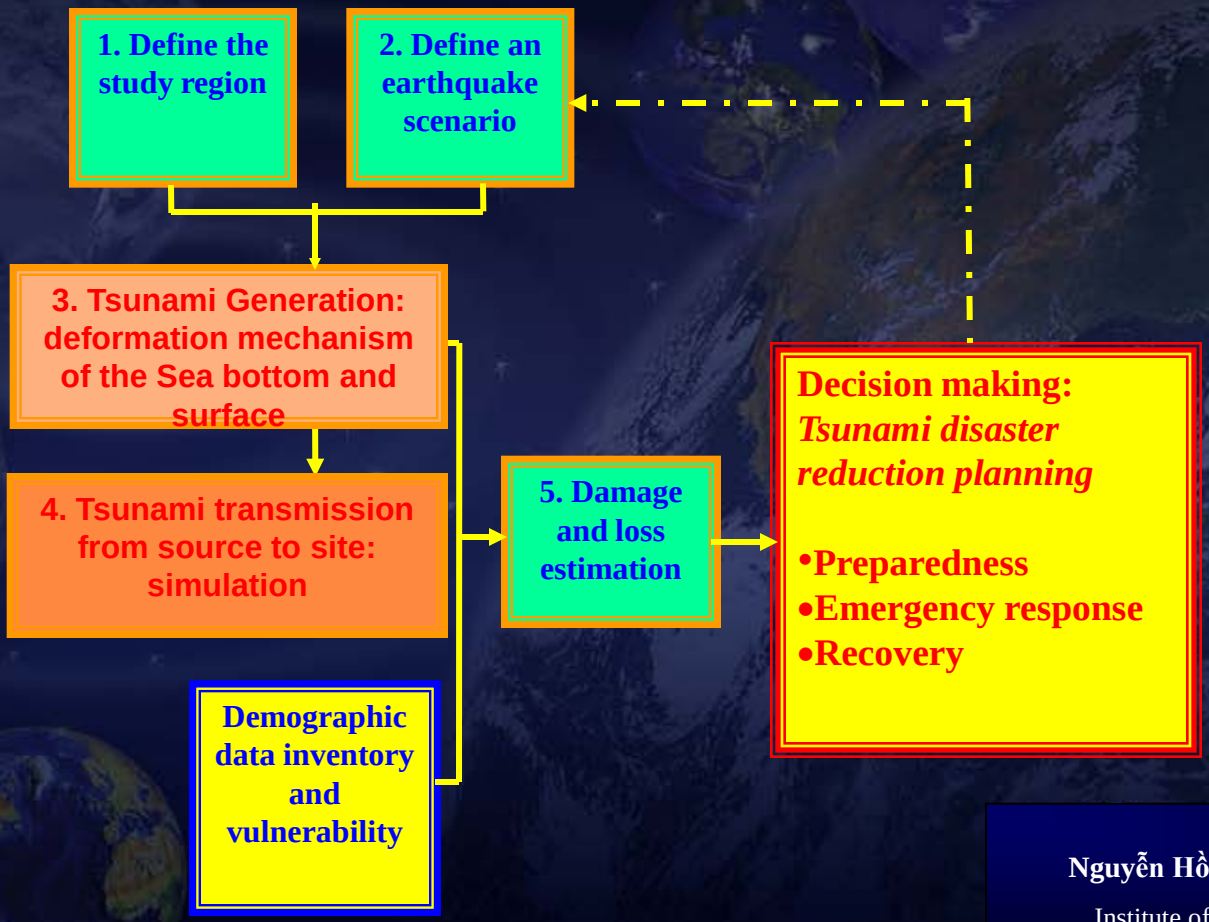
3) A DSS tool for Scenario-based deterministic tsunami risk analysis as extension of the ArcRisk



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NOTES ON THE TSUNAMI CASE

1) 25 tsunami scenarios for Vietnam versus 100 000 ones for Japan; 7 000 for Indonesia, …
2) Far not enough for warning purpose in Vietnam
3) Problems of Data Storage and Retrieval

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Conclusion

1) Based on a simple fault-source model, GIS-based tools were created, allowing for seismic risk analysis in Vietnam at various scales, from regional to urban. The extent and level of risk due to scenario earthquake are depicted in a variety of GIS maps, automatically generated in a GIS environment. Scenario-based deterministic seismic risk analysis can be extended for the case of tsunami hazard and risk assessment.

2) Pre-calculated earthquake/tsunami scenarios can provide authorities with useful response information, including data on the distribution of shaking, building damage and casualties immediately after major earthquakes.

3) All results presented here show the need for High Performance Computing in earthquake/tsunami hazard and risk assessment in Vietnam. GRIDS AND CLOUDS NOW!

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Earthquake – Tsunami Hazard Assessment and Risk Mitigation in Vietnam using GIS

Nguyen Hong Phuong
Earthquake Information and Tsunami Warning Centre
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THANK YOU !

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