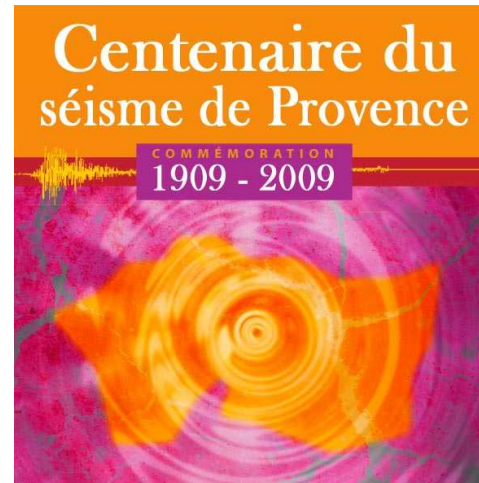


International conference Provence' 2009
Seismic risk in moderate seismicity area: from hazard to vulnerability



Mapping earthquake effects at large scale

A.-M. Duval E. Bertrand J. Régnier
P. Maurin D. Criado J. Quittard
D. Davi C. Thibault

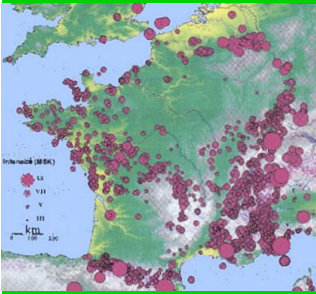
(Earthquake engineering)
(Geotechnical Engineering)
(Structural Engineering)

CETE
Méditerranée

Ministère
de l'Écologie, de l'Énergie,
du Développement durable
et de l'Aménagement
du territoire

The aim of this presentation is to point out:

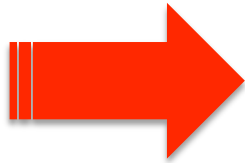
- Common **global principles** experimented by our team when mapping earthquake effect at large scale
- Successive **steps** of resulting operating system
- Tentative of **improvement**
- Requested **evolution** : What is expected from specialist of different domain.



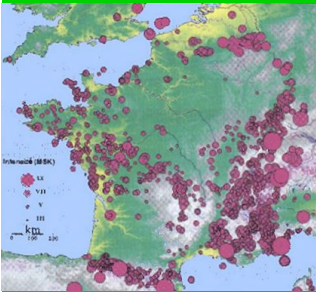
Context and common features of the approaches

- Requested by central directions of Ministries (Planning, Environment)
- Because it is financially impossible to analyze precisely and retrofit the whole elements of road and the whole building stock:
- **Prioritization scheme** are first requested
- **Vulnerability // Importance // seismicity**
- = first estimate of **mecanical** vulnerability or damage
- To plan rescue itinerary or building
- To be applied every where on French territory
- To be applied by non-specialist
- Large scale, economic, rapid: very few field investigation allowed

Major projects: RISKUE, GEM-GEP, SISROUTE, FORESIGHT, several recent test in the context of risk mapping



Bases of proposed approaches :



- The Hazard is mainly represented by **PGA** (peak ground acceleration of the soil)
- Induced phenomena are considered not to occur under a threshold value of PGA
- The response of the structure to the hazard is assessed via parameters that can be easily obtained
- **Object behavior empirical law** are inferred from earthquake effect observation (literature review, numerical simulation)

STEP 1

Homogeneous element identification

Along an itinerary (SISROUTE) :

- ✓ bridge
- ✓ Retaining wall
- ✓ Tunnel
- ✓ Simple element of road

On a territory :

- ✓ urban district
- ✓ area homogeneous vs earth. hazard

STEP 1

Homogeneous element identification along an itinerary (SISROUTE)

Topography

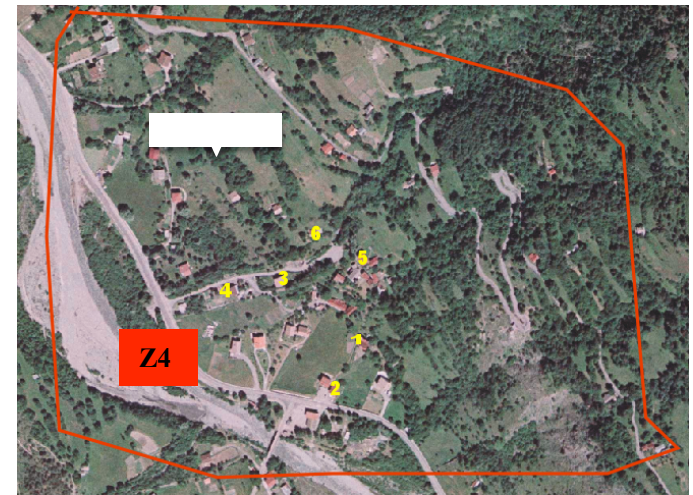
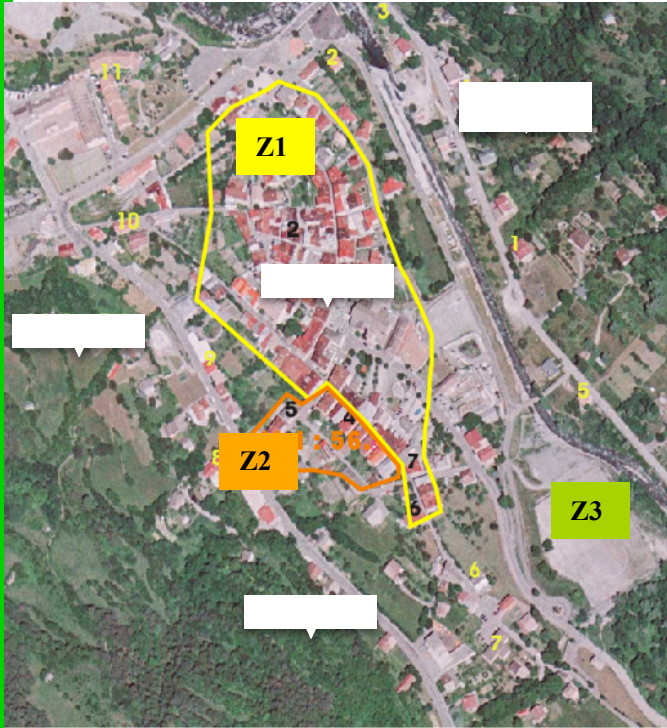
Bridges identification and characteristics

- Bridge
- Retaining wall

Resources, territories, logistics & cooperation
Énergie et climat Développement durable
Prévention des risques Infrastructures, transports et mer

STEP 1

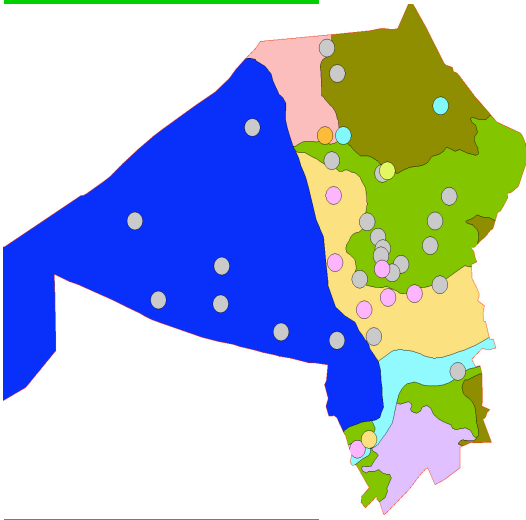
Homogeneous element identification Urban area (ex : Saint Etienne, Alpes)



STEP 2

Local hazard assessment: site effect

Zonation: geology, lithology, topography



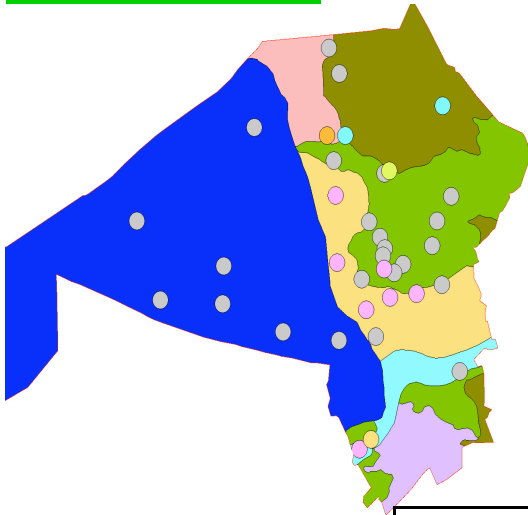
Soil amplification: \times PGA

Soil type		<i>Coeff</i>	<i>Vs</i> (m/s)
Bedrock	Hard bedrock and hard chalk	1	>800
Soil with good to very good geotechnical characteristics	Compact granular soil	1.35	>400
	Soil with good coherence (clay or hard marl)		
Soil with medium geotechnical characteristics	Weathered or fractured rock	1.35	300 to 800
	Granular soil with medium compaction	1.5	150 to 400
	Soil with good coherence and medium consistency + soft chalk		
Soil with weak geotechnical characteristics	Loose granular soil	1.8	<150
	Soft coherent soil (soft clay or mud) and altered chalk		

STEP 2

Hazard parameter assessment:

induced phenomena



Landslide PGA threshold values

Wilson and Keefer (1985)

		Slope Angle (degrees)					
		0°-10°	10°-15°	15°-20°	20°-30°	30°-40°	>40°
Strongly cemented rocks (crystalline rocks and well-cemented sandstone, calcareous)	Wet		0,4	0,25	0,20	0,15	0,15
	Dry			0,6	0,5	0,35	0,25
Weakly cemented rocks and soils (sandy soils and poorly cemented sandstone, rock slide)	Wet	0,30	0,15	0,10	0,10	0,10	0,05
	Dry		0,40	0,35	0,30	0,25	0,20
Argillaceous rocks (shales, clayey soil, existing landslides, slump, poorly compacted fills)	Wet	0,20	0,10	0,05	0,05	0,05	0,05
	Dry	0,30	0,25	0,20	0,10	0,10	0,10

Rock fall PGA threshold values

Active falls (unit volume < 1dm ³)	0.3g
Rock falls, crumbling in mass (unit volume > 1dm ³ or total volume > 100 m ³)	0.4g

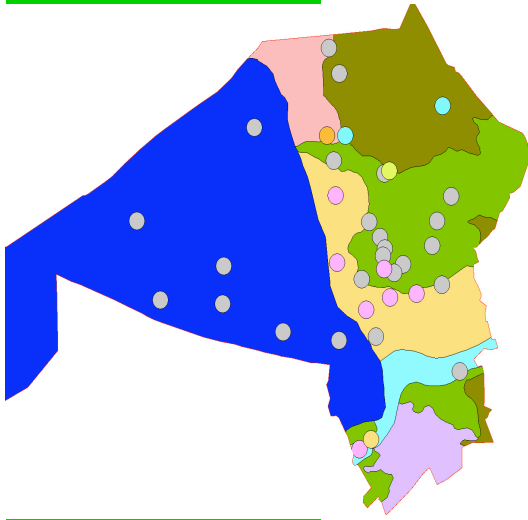
Duval et al (2006)

STEP 2

Hazard parameter assessment:

induced phenomena

Liquefaction PGA threshold values

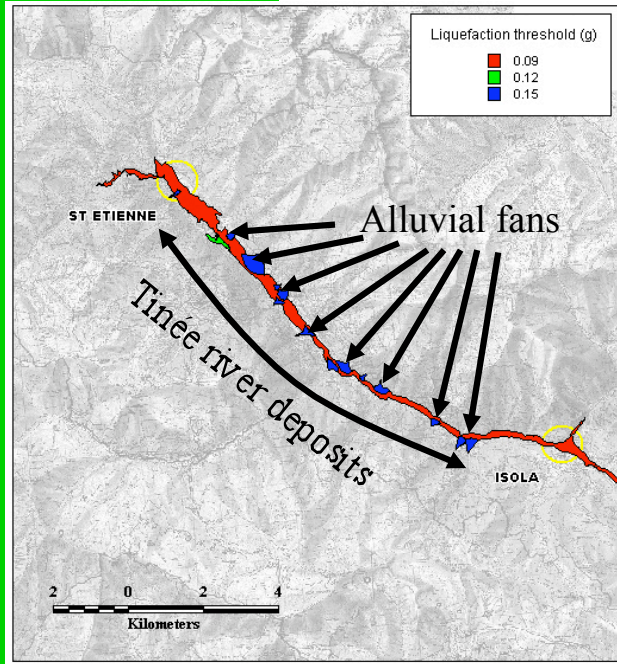


Type of deposit	Proposed T_{liq} by Age of deposit			
	< 500 ya Modern	< 11 Ka Holocene	11 Ka –2 Ma Plesitocene	>2 Ma Pre-pleistocene
Continental deposits				
River channel	0,09	0,12	0,21	0,26
Flood plain	0,12	0,15	0,21	0,26
Alluvial fan and plain	0,15	0,21	0,21	0,26
Marine terrace and plain	-	0,21	0,26	0,26
Delta and fan delta	0,12	0,15	0,21	0,26
Lacustrine	0,12	0,15	0,21	0,26
Colluvium	0,12	0,15	0,21	0,26
Talus	0,21	0,21	0,26	0,26
Dune	0,12	0,15	0,21	0,26
Loess	0,12	0,12	0,12	-
Glacial fill	0,21	0,21	0,26	0,26
Tuff	0,21	0,21	0,26	0,26
Residual soils	0,21	0,21	0,26	0,26
Costal areas				
Delta	0,09	0,12	0,21	0,26
Estuarine	0,12	0,15	0,21	0,26
Beach: High wave enenergy	0,15	0,21	0,26	0,26
Beach: Low wave enenergy	0,12	0,15	0,21	0,26
Lagoon	0,12	0,15	0,21	0,26
Fore shore	0,12	0,15	0,21	0,26
Artificial embakement				
Uncompacted fill	0,09	-	-	-
Compacted fill	0,21	-	-	-

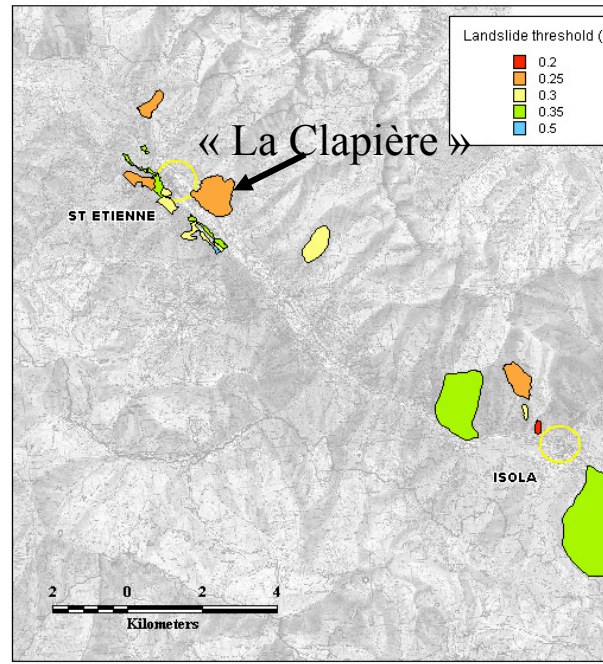
After Youd and Perkins (1978) and Hazus99

STEP 2

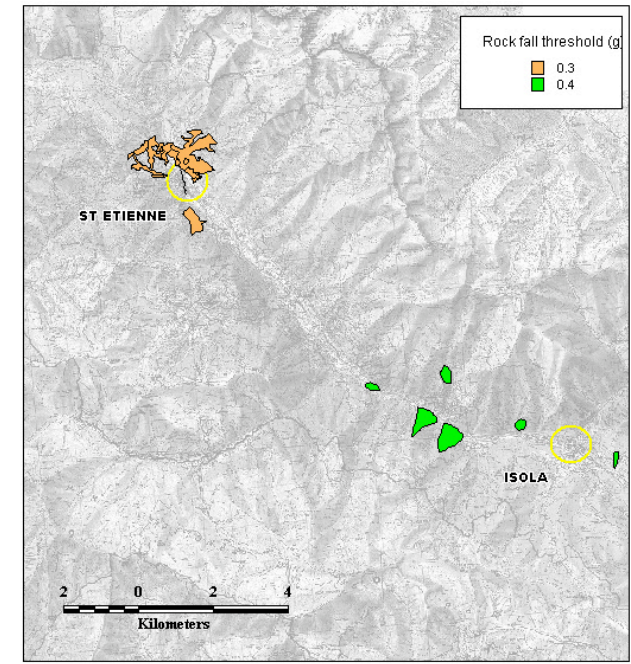
Hazard parameter assessment Induced hazards threshold values



Liquefaction



Landslide



Rock fall



STEP 3

Vulnerability assessment vs vibrations and induced hazard: principles



For each object
the values of targeted simple parameters

Acrit vs vibration (failure)
Acrit vs induced phenomena (failure)
(except for building)

Object vulnerability



Acrit



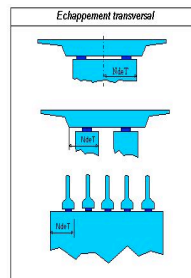
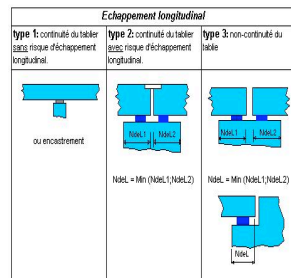
STEP 3

Vulnerability assessment vs vibrations and induced hazard: case of bridges

the **SISMOA** method (Thibault and Davi , 2006)

The first step of the analysis consisted in assessing the vulnerability of bridges based on geometrical and typological criteria :

$$V = V_{\text{general}} \times \max (V_{\text{deck}} ; V_{\text{piers}} ; V_{\text{abutments}})$$



Induced effects related risks on bridges :

Bridges vulnerabilities to liquefaction and landslide are based on foundations type, depth and eventual tubing.

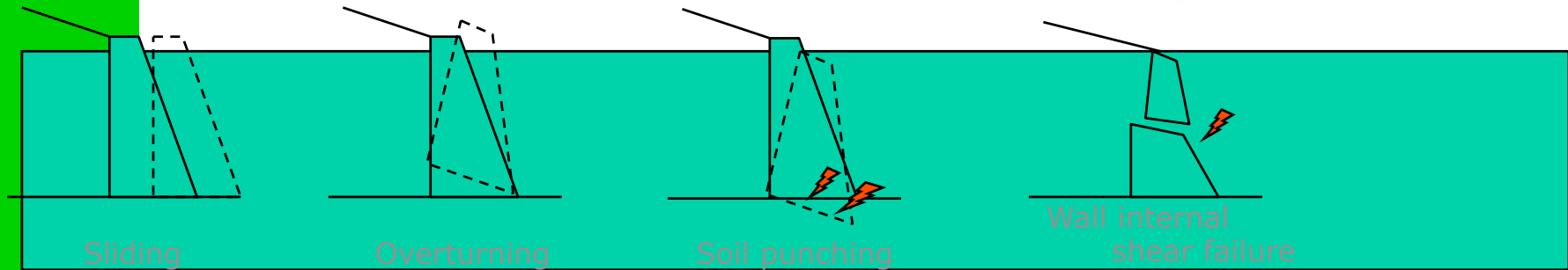
Vulnerability to rock falling is based on deck and supports materials, size and redundancy as well as existing protections (wires, protective screen, ditch ...)



STEP 3

Vulnerability assessment vs vibrations and induced hazard: case of retaining walls

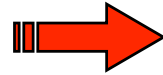
*the SISMUR method,
Thibault and Criado, 2009, see poster #70)*



Based on simple criteria,
Vulnerability (Acrit) is defined
for Vibration and induced effects

STEP 3

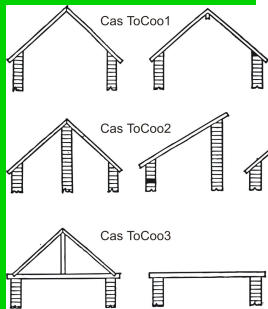
Vulnerability assessment vs vibrations and induced hazard: case of urban area



Building typology survey

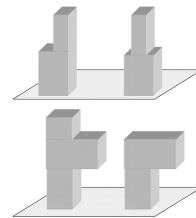
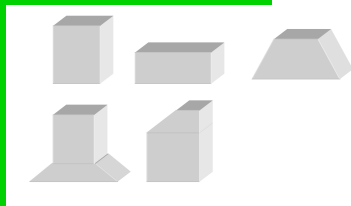
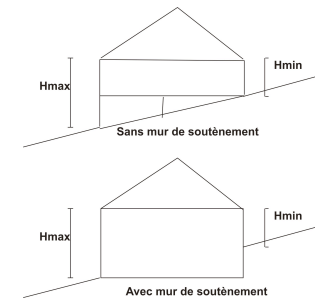
based on a visual expertise and some basic criteria.

- ➔ Typology :
 - Masonry structure
 - Wood structure
 - Adobe
 - Reinforced concrete structure
 - Steel structure
- ➔ Construction age (pre-code)



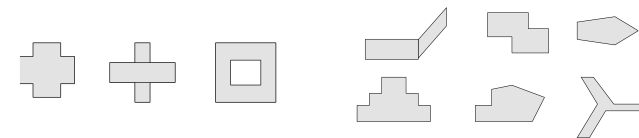
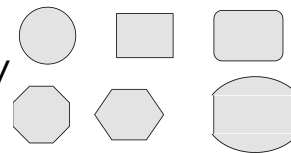
➔ Roof shape

➔ Soil condition and basement quality



➔ Elevation regularity

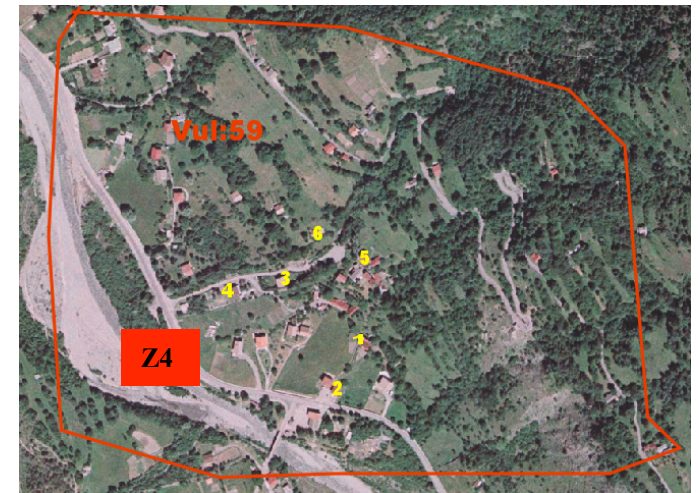
➔ Horizontal regularity



STEP 3

Vulnerability assessment vs vibrations case of urban area:

building typology by district: V_I



$V_I=65$



$V_I=56$



$V_I=59$

Responsabilité, territoire, culture, développement durable
Énergie et climat
Prévention des risques - Intra-urbain

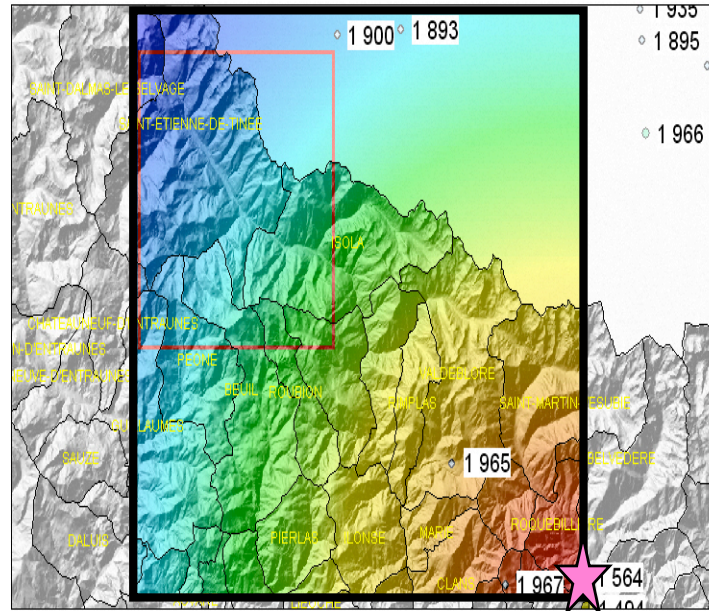
STEP 4

Hazard assessment

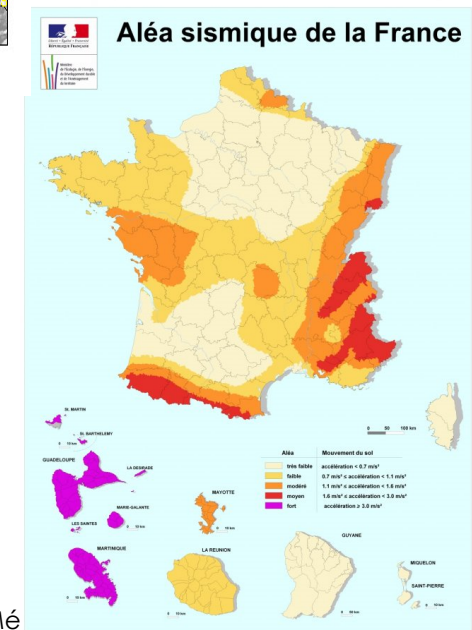
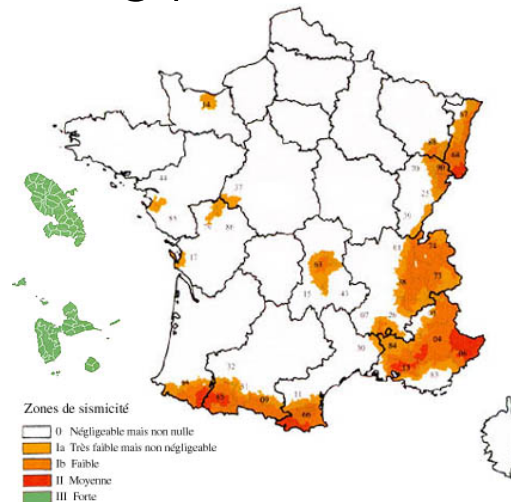
Choice of scenario: PGA assessment on rock

1) Using empirical attenuation law (Ambraseys, 1996)

Any earthquake
(M, location)



2) Using predefined values of PGA



STEP 4

Hazard assessment

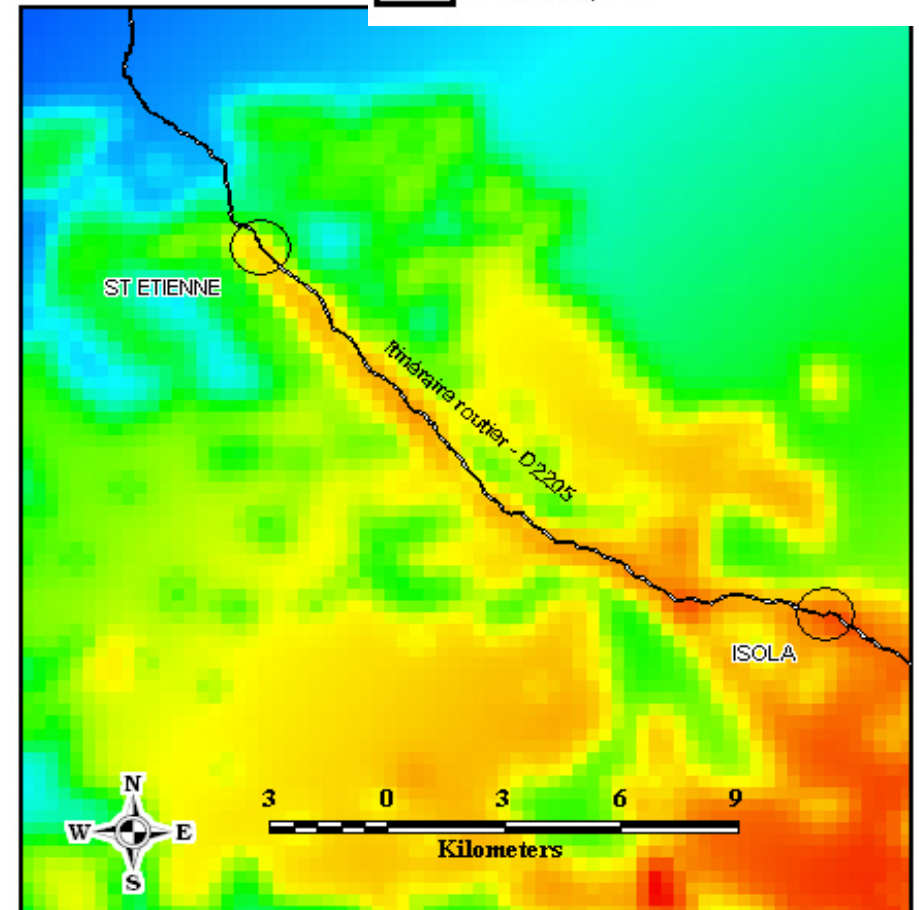
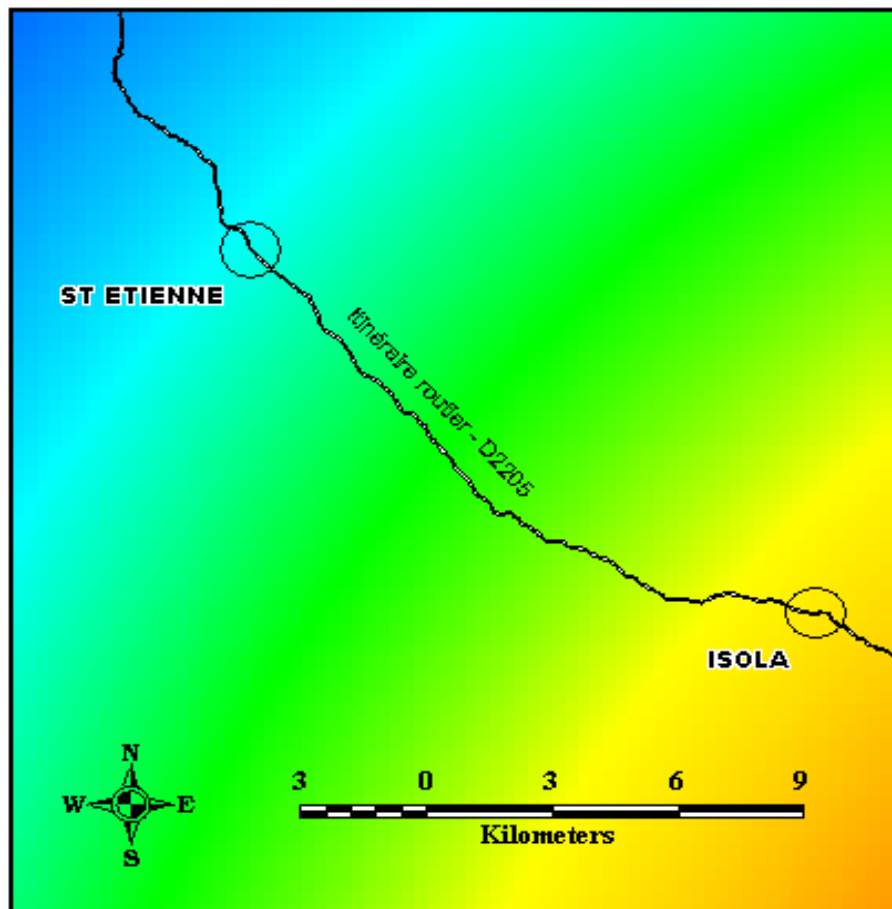
Choice of scenario: PGA assessment **soil**



MAXIMAL ACCELERATION (IN G= 9.81 M/S²)

- 0,0305
- 0,0389
- 0,0475
- 0,0558
- 0,0806

- Road - D2205
- Limit of study area

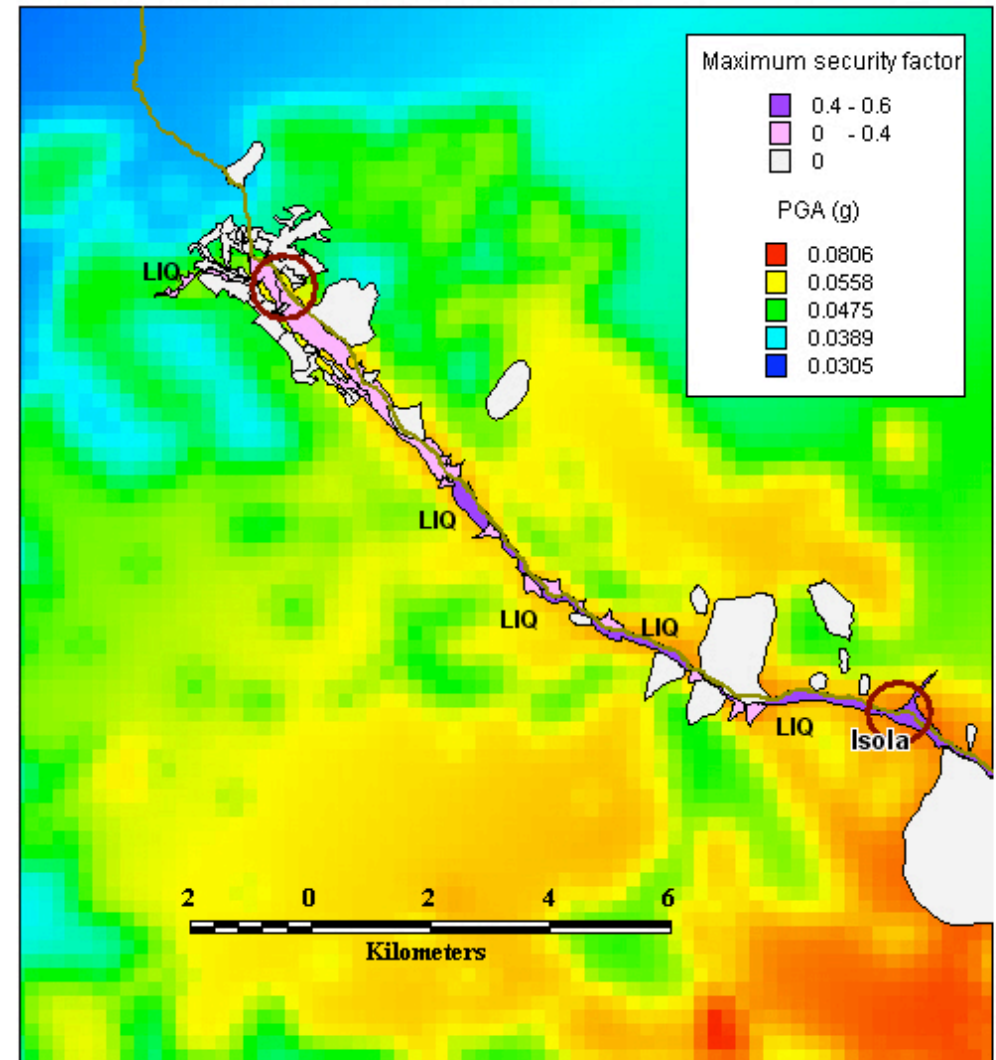


STEP 4

Hazard assessment - tentative of improvement Induced hazards security factor

FSi (security factor)	A_{vib}/T_i	Induced phenomenon occurrence
0	Below 0.5	The phenomenon can not appear
Between 0 and 0.4	Between 0.5 and 0.8	The phenomenon is not very probable
Between 0.4 and 0.6	Between 0.8 and 1.2	The phenomenon is probable
Between 0.6 and 1	Over 1.2	The phenomenon certainly appear

$$FS_i = \left(0.703 * \ln \left(\frac{A_{vib}}{T_i} \right) \right) + 0.5057 ; 0 \leq FS_i \leq 1$$



Bertrand et al, 2007

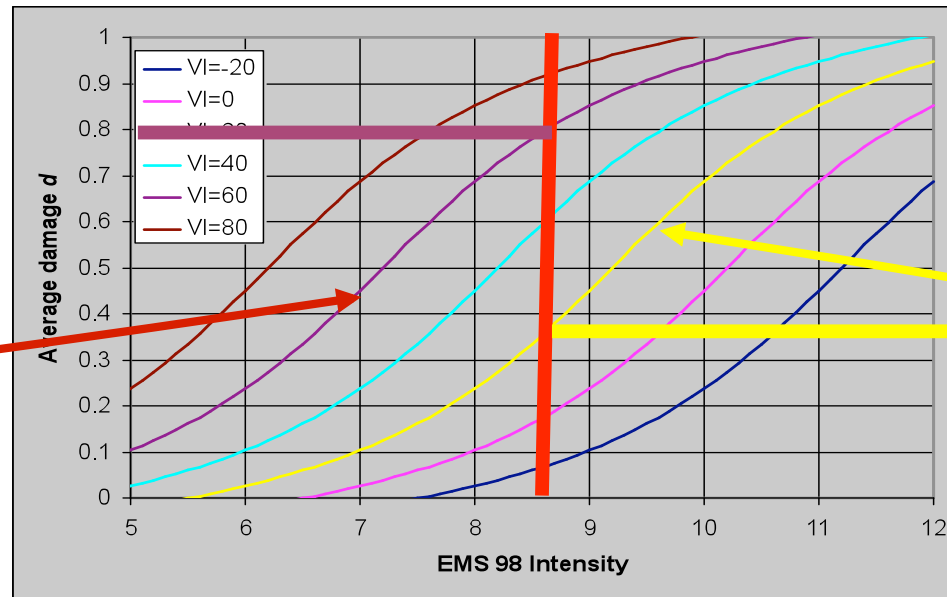
STEP 5

Building damage assessment

Fragility curves:



$V_I=60$



$V_I=20$



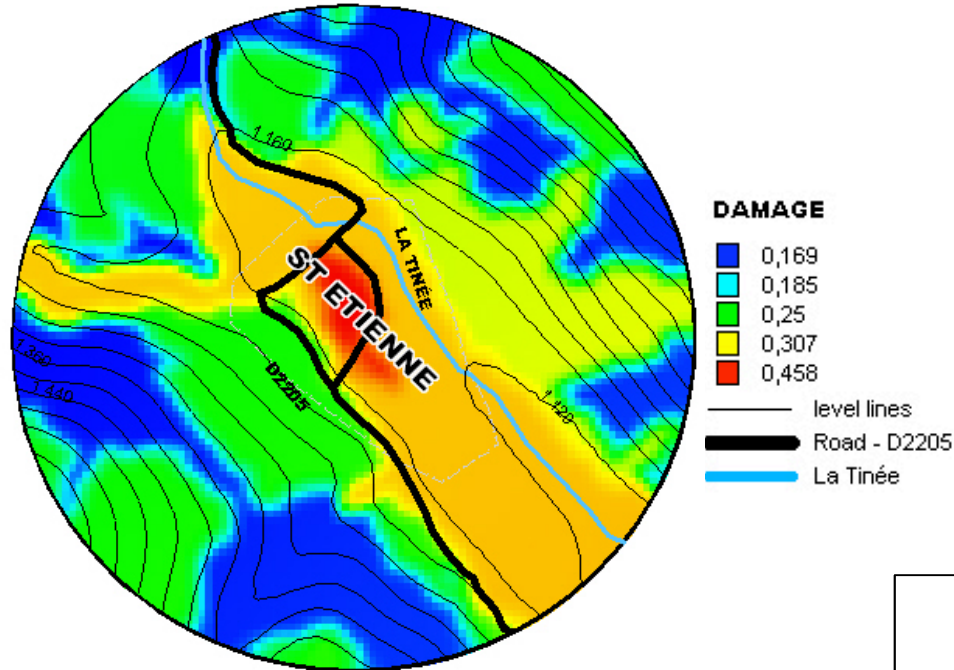
Intensity deduced from
Acceleration (empirical law)

$$d = \left[0.5 + 0.45 * \arctan(0.55 * (I - 10.2 + 0.05 * V_I)) \right]$$

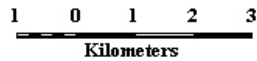
(Giovinazzi and Lagomarsino, 2003)

STEP 5

Building damage assessment

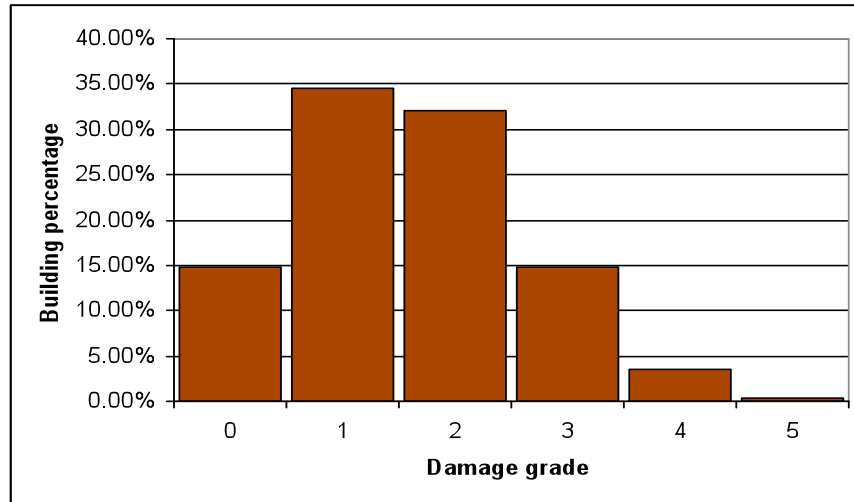


- DAMAGE**
- 0,169
 - 0,185
 - 0,25
 - 0,307
 - 0,458
- level lines
 - Road - D2205
 - La Tinée



Damage distribution (EMS98 grades)

$$p_k = \frac{5!}{k!(5-k)!} \cdot d^k \cdot (1-d)^{5-k}$$



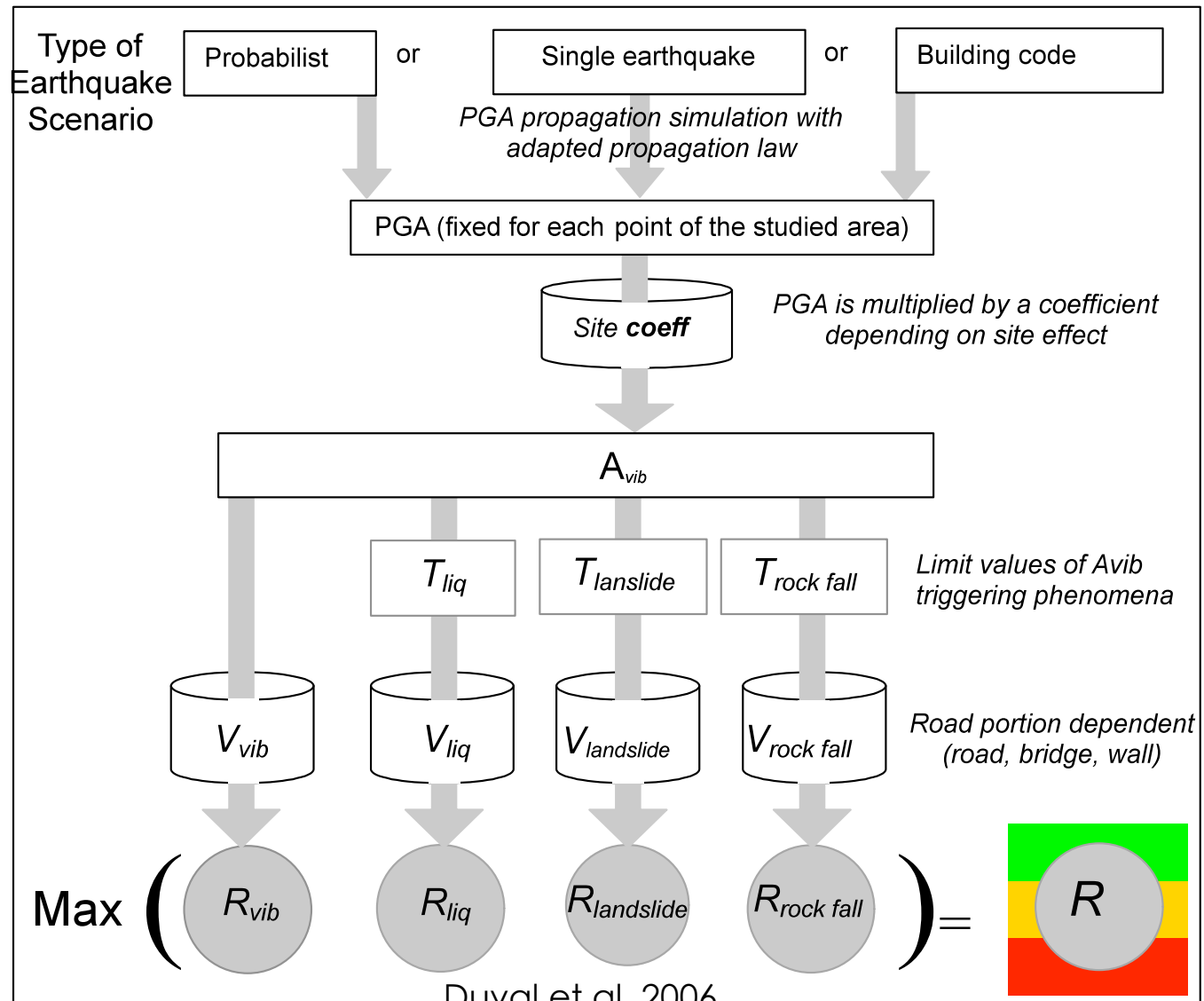
STEP 6

Road cut off assessment

$$R = f_{\text{object}} (A_{\text{vib}}, V_{\text{phenomenum}})$$

with $0 < R < 1$

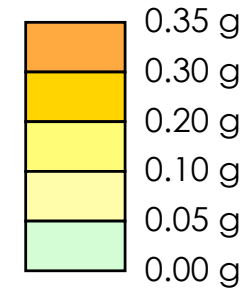
$V_{\text{phenomenum}}$ is A_{crit}



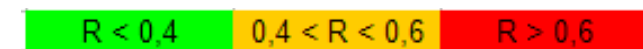
STEP 6

Road cut off assessment

Principles of Geographic Information System



Road section response to the chosen seismic scenario :



Road failure assessment: tentative of improvement

A recent survey: trying to take into account nearby buildings that could collapse on itinerary

Photo1

Photo2

Hauteur bâtiment (m)	Nombre d'étages exact N
24	7
Hauteur/voie (m)	Distance/voie (m)
18	12
largeur voie (m)	Voie coupée
12	partiellement
Commentaires	
Transparence. Baionette: descente de charge.	

Résultats "bruts" analyse Vulnéralp 1.0

lv moyen	lv min	lv max
22,92	9,03	36,81
Dommages GNDT I=VI		
0,12		
Dommages GNDT I=VII		
0,26		

Ajustement* de lv moyen

* Ajustement de la méthode Vulnéralp 1.0 basé sur les observations de terrain, l'expérience et l'évaluation de la présomption de vulnérabilité du bâti existant.

lv ajusté: 48

Justification de l'ajustement du résultat

Variations progressives d'inertie. Forme (10). Légère descente de charge en baionette (5). Poteaux poutres remplissage maçonnerie (10).

CETE Méditerranée

Identifiant	Coordination	Etude	Enquêteur	Date
000001	000001	PPRS NICE	Challemarg	19/02/2008
Adresse projet		Code Postal	CAMX U Y	
RUS - BP "Le Calvaire" 5 Av Raymond Feraud		2000	1822670 32	
		Commune	CAMB U X	
		Nice	000004 01	

Typeologie	Rocher	Craie en pente	Epoque de construction	Forme terrasse
Y102	EnS02	EnP02	EnC01	EnC02
Y201: Maçonnerie	EnS01: oui	EnP01: oui	EnC01: Avant 1945	ToC01: oui
Y202: Béton armé	EnS02: non	EnP02: non	EnC02: Entre 1946 et 1970	ToC02: non
Y203: Métallique			EnC03: Entre 1970 et 2000	
Y204: Bois			EnC04: Après 2000	
Y205: Terre				

Nombre d'étage: N001

Régularité en élévation: ReE1: oui, ReE2: non

Régularité en plan: ReP1: oui, ReP2: non

Commentaires: une unité est régulière et elle possède deux axes de symétrie sans angles remarquables.

Structures régulières

Structures irrégulières

Structures irrégulières

Photo1

Photo2

Hauteur bâtiment (m)	Nombre d'étages exact N
21	7
Hauteur/voie (m)	Distance/voie (m)
12	12
largeur voie (m)	Voie coupée
12	oui
Commentaires	

Résultats "bruts" analyse Vulnéralp 1.0

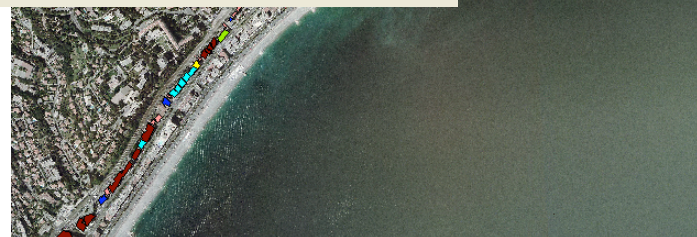
lv moyen	lv min	lv max
24,4	8,25	46,14
Dommages GNDT I=VI		
0,13		
Dommages GNDT I=VII		
0,20		

Ajustement* de lv moyen

* Ajustement de la méthode Vulnéralp 1.0 basé sur les observations de terrain, l'expérience et l'évaluation de la présomption de vulnérabilité du bâti existant.

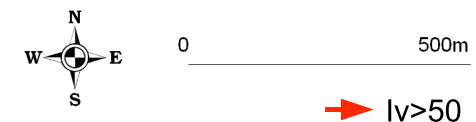
Justification de l'ajustement du résultat

Chemises (5) Garages (5)



Typologie des bâtiment le long des itinéraires de secours

- ▶ T1 « Maison individuelle », (67)
- ▶ T2 « immeuble de ville », (44)
- ▶ T3 « immeuble bas », (14)
- ▶ T4 « vieux immeuble de ville », (21)
- ▶ T5 « immeuble moyen d'habitation », (13)
- ▶ T6 « immeuble d'habitation régulier », (29)
- ▶ T7 « immeuble d'habitation irrégulier », (58)
- ▶ T8 « architecture complexe », (14)



CETE Méditerranée, 2008

Mapping earthquake effects at large scale

Difficulties encountered:

- Hazard and vulnerability are roughly assessed
- but a single limited object can generate large consequences (specially for itinerary)
- Hard to assess uncertainties at the different levels of the approaches (hazard and vulnerability)

Possible improvement:

- The “statistical” approach used for urban area must be used very carefully, another more accurate approach is clearly needed.
- Improving the threshold values for induced phenomena
- PGA is certainly not the key parameter especially for liquefaction but also for structure: Changing the representation of threshold type instead of PGA (duration, cycle number, Arias intensity ...)



Methodology overview

