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EARTHQUAKE ZONATION MAPPING IN CONTINENTAL AUSTRALIA PRACTICAL APPLICATIONS IN EARTHQUAKE MITIGATION

J.M.W. RYNN, P.R. HUGHES, E. BRENNAN, H.J. STUART and I.S. PEDERSEN

Centre for Earthquake Research in Australia
PO Box 276, Indooroopilly, Brisbane, Queensland, Australia 4068

ABSTRACT

The need for preparedness to reduce potential losses from earthquakes in all urban areas of the world is a reality. It is no longer viable to rely on probabilistic earthquake hazard estimates alone - earthquake risk is a dual function of hazard and vulnerability. Recent experiences show that the scope of earthquake disasters is increasing - as population increases, the built environment / infrastructure / community services increases; and hence the vulnerability is ever increasing as time progresses. One element towards earthquake mitigation is earthquake zonation mapping, a multidisciplinary approach to provide practical information in preparedness to reduce the human toll and minimize damage in future earthquakes. The effect in plate margin regimes is fully recognized. For continents, recent devastating earthquakes thereon have shown the need to extend the international effort across the entire world. The United Nations IDNDR program is, today, a facilitator of necessary mitigation measures. One such case in point is that of the continent of Australia for which a proactive multidisciplinary earthquake zonation mapping project is in progress, one of the many projects of the Emergency Management Australia national IDNDR program.

KEYWORDS

Earthquake; risk; vulnerability; mitigation; zonation mapping; practical applications; IDNDR.

INTRODUCTION

The vulnerability to earthquake in all major urban areas, whether they be on plate margin or continental regimes, and whether they be large land masses or small island nations, has become a reality. The need for mitigation measures is of high priority. The experiences from devastating earthquakes over the last few years (such as 1989 Loma Prieta, USA; 1990 Philippines; 1992 Cairo, Egypt; 1993 Hokkaido - Hansei - Oki (Okushiri), Japan; 1994 Northridge, USA) and the successful application of the goals and targets of the United Nations IDNDR program in the first half of its Decade (1990 - 1994), have attested to this. Most recently, the January 1995 Hanshin (Kobe), Japan, earthquake pointedly re-emphasised the necessity for preparedness across the total community spectrum - from response and rescue, through earth sciences and engineering to emergency services, sociology and economics. While the historical records for large damaging earthquakes on continents shows them as "rare" occurrences, they also exhibit many disastrous consequences (Fig.1; from Brennan, 1993) - such was the case for Australia with the 28 December 1989 Newcastle earthquake (Rynn *et al.,* 1992).

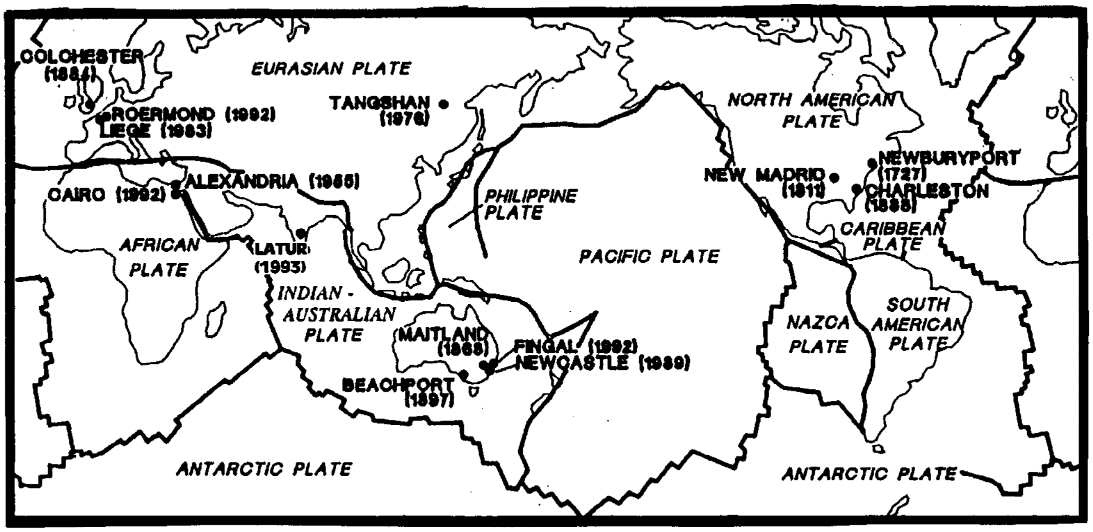

Fig.1. Some damaging continental earthquakes.

For Australia, the time-coincidence of the December 1989 Newcastle earthquake and the inauguration of the IDNDR in January 1990 were the catalysts to seriously consider earthquake mitigation measures. The project "Earthquake Zonation Mapping of Urban Areas in Australia" was facilitated by the Australian Government's Emergency Management Australia (EMA) through its Australian IDNDR Coordination Committee (as reported at the World IDNDR Conference, Yokohama, Japan, May 1994; EMA, 1994). The premise to pursue this earthquake zonation mapping concept was detailed by Rynn (1991) who showed that the "*potential to reduce losses from future earthquakes is indeed both a realistic and achievable goal, well within the capabilities of the Australian community*". The concept was based on several studies presented at the 4th International Conference on Seismic Zonation, Stanford University, USA, in August 1991 (EERI, 1991).

In the six years since the inception of the project, earthquake zonation mapping has been completed for the Cities and Environs of Sydney, Brisbane, Newcastle and Melbourne, with that for Adelaide currently in progress. The outcomes of these studies have already had practical applications in several avenues relevant to emergency management. These results provide an "information resource" in terms of PREPAREDNESS for the future - strictly in accord with the goals and targets of IDNDR and the Australian IDNDR criteria. Their application has now extended from the national effort into international collaboration with several overseas countries.

THE AUSTRALIAN EARTHQUAKE SCENE

Earthquakes have been considered by Australians to be very "rare" occurrences in their own environment and only effect the "earthquake-prone" areas of the world (such as California, Japan, New Zealand etc). As part of this zonation research, and prompted by the 1989 Newcastle earthquake, a comprehensive review of damaging earthquake occurrences in Australia was undertaken by Rynn (1994). It was shown that Australia was not immune from the earthquake peril. Since European settlement in 1788 through 1989, sixty-six significantly damaging earthquakes have occurred in relation to modern-day urban areas (Fig.2; from Rynn, 1994). The need for earthquake mitigation measures is imperative.

Specific mention must be made of the 1989 Newcastle earthquake. Detailed studies by Rynn *et al.*, (1992) showed the extreme effects that even a moderately-sized earthquake (Richter magnitude ML 5.6) could have on a modern urban area. Many lessons have been learnt: extensive damage and felt areas (Fig.3; from Rynn *et al.*, 1992); geological controls to damage, specifically Quaternary alluvial and artificial-fill sediments in terms of amplification, liquefaction and lateral spreading; detailed attenuation relation (Fig.4; from Rynn *et al.*, 1992); built environment, engineering and infrastructure effects (Cantle and Moelle, 1993); role of the local government authority (Stuart, 1993); socio-economic effects.

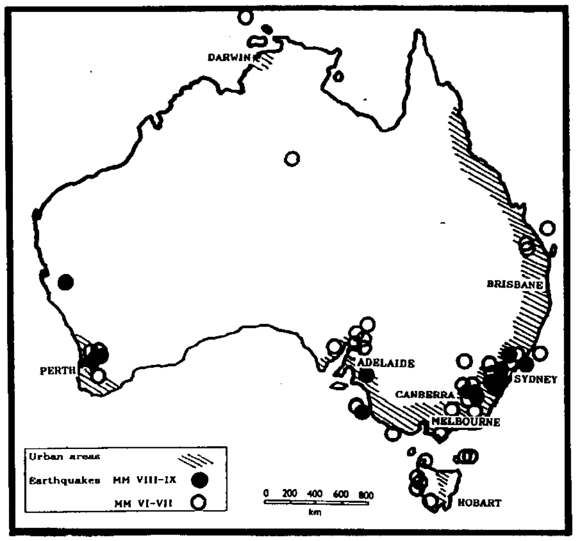

Fig.2. Damaging earthquakes and urban areas in Australia.

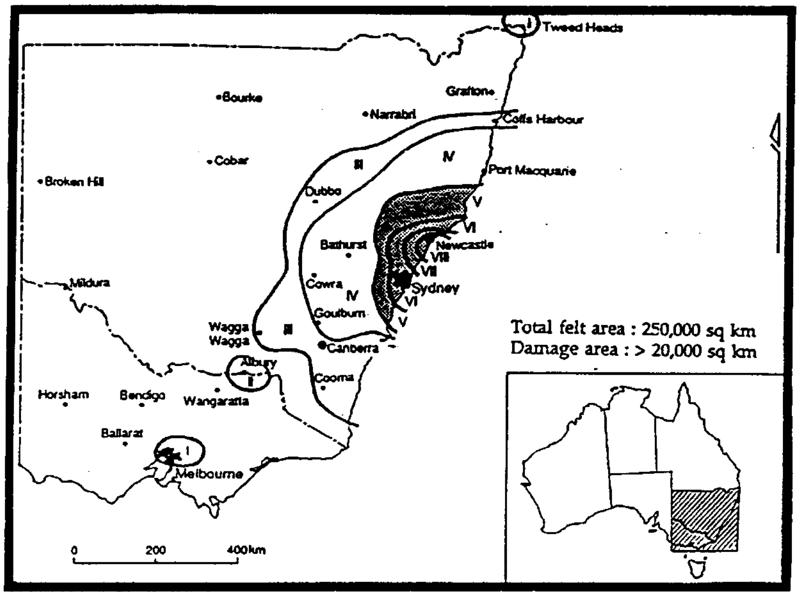

Fig.3. Isoseismal map of 1989 Newcastle, Australia, earthquake ML 5.6.

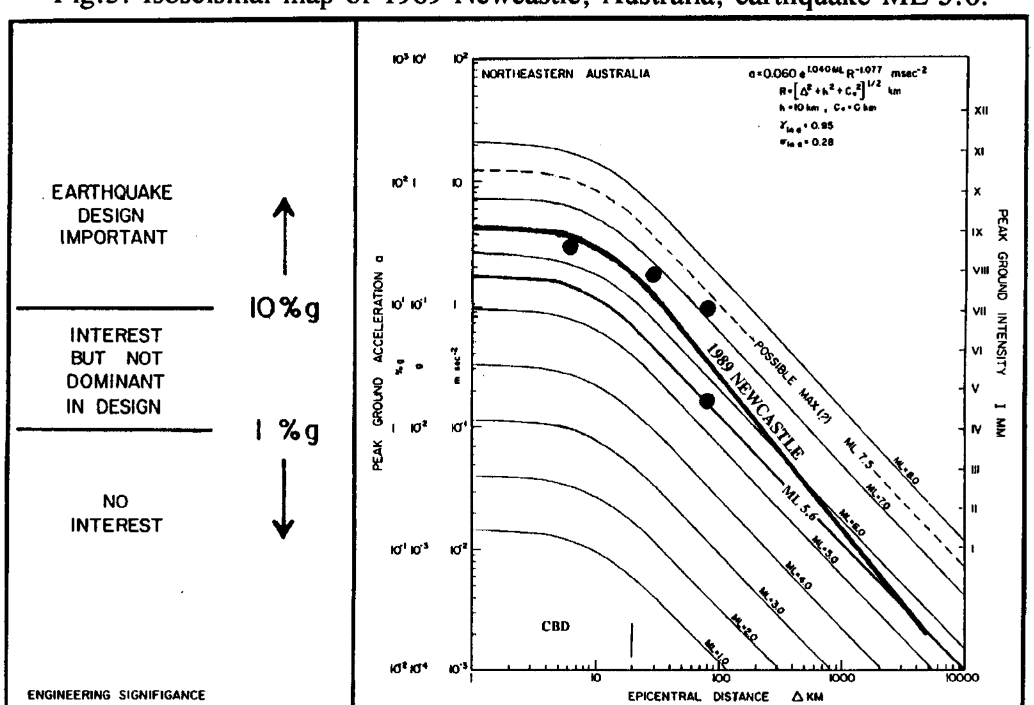

Fig.4. Attenuation relation for 1989 Newcastle, Australia, earthquake ML 5.6.

EARTHQUAKE ZONATION MAPPING FOR AUSTRALIA

The overall **concept** to earthquake zonation mapping in Australia is shown in Fig.5, with the **project plan** shown in Fig.6.

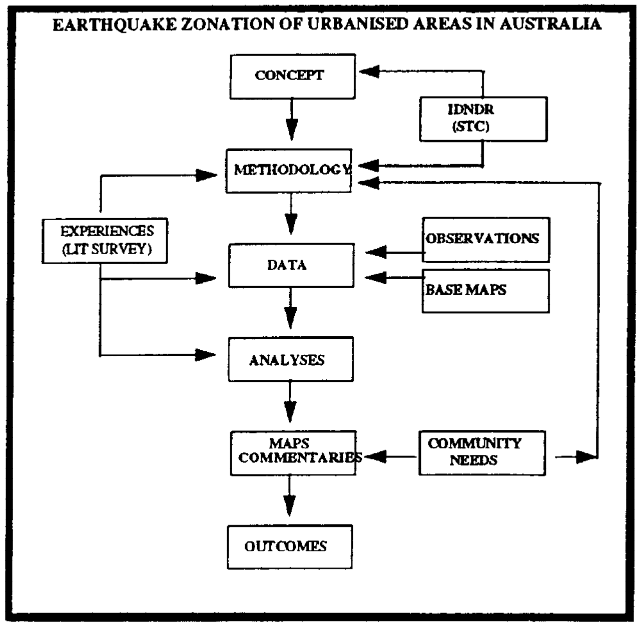

Fig.5. Concept of earthquake zonation mapping adopted for Australia

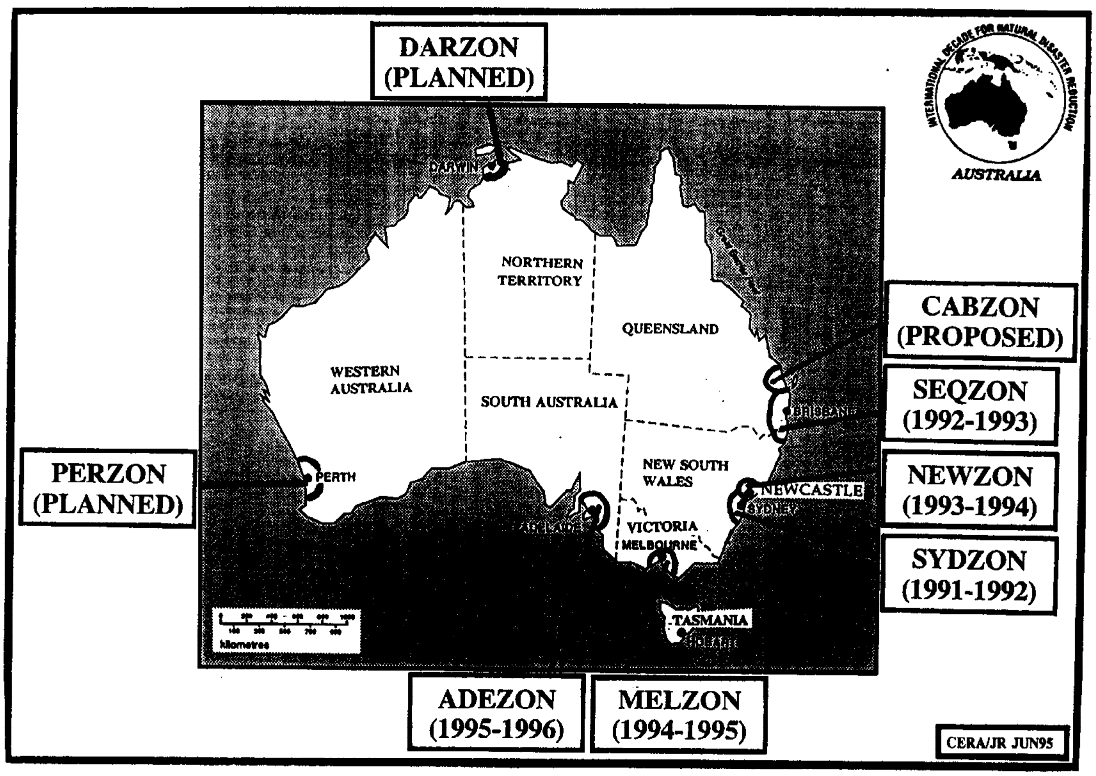

Fig.6. Earthquake zonation mapping for urban areas in Australia

The **methodology** invokes a multidisciplinary approach integrating all relevant and available data from seismology, geology, engineering, built environment and infrastructure, disaster management and insurance, medical, sociology and socio-economic aspects (details in Rynn, 1993). Two significant elements have proven vital to the project: (a) the involvement of national (EMA), State and Local Government emergency services authorities from the inception has ensured all the needs of such authorities have been met (the practical approach); (b) international collaboration and cooperation has been afforded, primarily through IDNDR and the World Seismic Safety Initiative (WSSI) of the International Association for Earthquake Engineering (IAEE) (Shah *et al.*, 1995).

Earthquake zonation maps for four urban areas have been completed : The City of Sydney and Environs (SYDZON), Southeast Queensland (Brisbane - Gold Coast - Sunshine Coast - Toowoomba) (SEQZON), The City of Newcastle (NEWZON) and The City of Melbourne and Environs (including Geelong, Gippsland and Latrobe Valley) (MELZON). An example is shown in Fig.7. The zonation for the City of Adelaide (ADEZON) is currently in progress. The outcomes provide quantitative and qualitative information on potential earthquake sources, geological conditions, potential peak ground motion acceleration and intensity, geological controls to damage (amplification, liquefaction, lateral spreading) and possible future damage to the built environment and infrastructure. Commentaries accompany the maps to detail relevant information in each of the integrated disciplines.

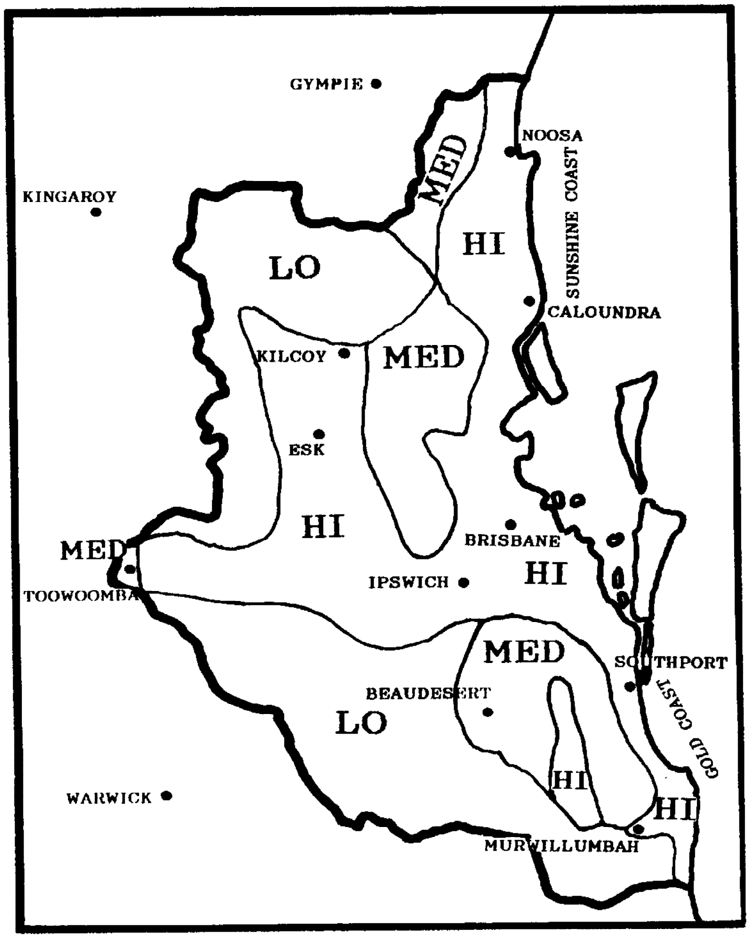

Fig.7. Earthquake zonation map for Southeast Queensland, Australia (SEQZON).

KEY TO MAP

GENERALISED EARTHQUAKE ZONATION MAP PARAMETERS FOR SYDNEY, SOUTH EAST QUEENSLAND AND NEWCASTLE

FOR EARTHQUAKE OF RICHTER MAGNITUDE ML 6.0 AT EPICENTRAL DISTANCE 50-100 KM

VULNERABILITY	HI	MED	LO
Ground Failure	High	Moderate	Low
Ground Shaking	High	Moderate	Low
Geology	Alluvial fill	Metamorphics Shales	Volcanics Sandstones
Liquefaction	High	Low	Low
Landslides	High	Possible	None
Built Environment	Urban	Urban	Rural
Density	High	High or medium	Low
Buildings	Residential Industrial	Residential Commercial	Residential
Critical Facilities	Many	Some	
Max Intensity (MM)	>VII	VI-VII	V-VI
Peak Ground Acceleration (%g)	>15-20	5-15	<5

Practical Outcomes

The **outcomes** of this earthquake zonation mapping project, both quantitative and qualitative, have been designed to be of practical application for :

- earthquake and building codes
- land-use planning
- disaster planning
- emergency management
- emergency personnel training
- insurance needs
- rescue and response
- community education
- simulated earthquake exercises.

The project with its outcomes satisfies two sets of criteria :

1. IDNDR/STC Targets
   (a) National assessment of risk
   (b) National and local level mitigation plans.
   (Note that IDNDR/STC Target (c) - Warning Systems - is not applicable herein because of the non-predictable nature of earthquakes.)
2. Australian IDNDR Criteria
   (a) Improve capacity to mitigate effects of natural disasters
   (b) Application of existing scientific and technical knowledge
   (c) Closing critical gaps in knowledge to reduce loss of life and property
   (d) Disseminate information for assessment and mitigation
   (e) Develop measures for assessment and mitigation.

An **evaluation** of this project is given in EMA (1994; Table 6) where its aptitude has been demonstrated in terms of the functions and benefits of the above sets of criteria for both national (Australia) and international use.

This endeavour has already seen some **benefits to the community** as an "information resource" in terms of earthquake disaster awareness and preparedness. For example, in the State of Queensland, several training exercises, seminars and workshops for emergency services personnel have been conducted, based on the SEQZON mapping (Fig.7). In addition, a **simulated earthquake exercise** *"BRISQUAKE 93"*, for an ML 6.0 earthquake with an ML 4.5 aftershock, based on SEQZON and the lessons for the 1989 Newcastle and recent relevant overseas earthquakes, was conducted for the City of Brisbane and environs (capital city of the State of Queensland) in October 1993 (Millican *et al.,* 1995).

ZONATION AND HAZARD

The question that is central to earthquake mitigation is that of the assessment of **seismic "risk"**. In the context of this project, the definition followed is :

RISK = HAZARD X VULNERABILITY,

where each term is defined for maximum applicability to a practical situation, summarised in Fig.8.

The seismic "HAZARD" is the domain of the seismologists, a probability estimate based on the earthquake data alone, usually mapped for an entire nation (McGuire, 1993). Several problems for application to earthquake engineering arise, such as map scale, limitations and parameter uncertainties. Hughes and Rynn (1993) discussed these for Australia in relation to the *Gaull et al.,* (1990) hazard map and its implementation (with slight modifications) to the recently revised Earthquake Load Code

AS1170.4-1993 (Standards Australia, 1993). Earthquake zonation includes these "HAZARD" estimates (as part of the seismological data input) in the analytical method, and then seeks to define "RISK" by integration with "VULNERABILITY" in the multidisciplinary analyses. "VULNERABILITY" contains both the physical environment and the social environment (Fig.8). A simplified comparison between "HAZARD" and "ZONATION" is shown in Table 1.

RISK = HAZARD X VULNERABILITY

HAZARD = TECHNICAL / SCIENTIFIC

↓

PROBABILISTIC EARTHQUAKE HAZARD MAPS
GEOLOGICAL HAZARDS MAPS

VULNERABILITY = ENGINEERING + HUMANITIES

ENGINEERING	HUMANITIES
↓	↓
BUILDINGS	SOCIO-ECONOMIC
INFRASTRUCTURE	PUBLIC HEALTH
LIFELINES/UTILITIES	INSURANCE
CRITICAL FACILITIES	CULTURAL
CODES OF PRACTICE	EMERGENCY MANAGEMENT
LAND USE	GOVERNMENT AUTHORITIES

Fig.8. Practical definition of Risk

TABLE 1

COMPARISON OF EARTHQUAKE HAZARD MAPPING AND EARTHQUAKE ZONATION MAPPING FOR PRACTICAL APPLICATIONS IN EARTHQUAKE MITIGATION

PARAMETER	EARTHQUAKE HAZARD MAP	EARTHQUAKE ZONATION MAP
EARTHQUAKE EPICENTRES	X	X
HISTORIC DATA/CATALOGUES		
STRUCTURAL GEOLOGY - CRUSTAL	X	X
STRUCTURES/TECTONICS		X
POTENTIAL EARTHQUAKE SOURCES		X
GEOLOGICAL CONTROLS TO DAMAGE -		X
SURFACE GEOLOGY (ALLUVIALS AND ROCK)		
BUILT ENVIRONMENT		
BUILDINGS (ENGINEERED AND NON-ENGINEERED)		X
RESIDENTIAL		X
COMMERCIAL		X
INDUSTRIAL		X
CRITICAL FACILITIES		
EMERGENCY SERVICES		X
HOSPITALS		X
SCHOOLS		X
INFRASTRUCTURE/LIFELINES		
UNDERGROUND SERVICES (WATER, GAS, OIL PIPE LINES)		X
ELECTRICITY		X
TRANSPORTATION		
ROAD, RAIL, AIR, SEA		X
COMMUNICATIONS		X
ACCESSIBILITY OF ROADWAYS/BRIDGES		X
OUTCOMES		
POTENTIAL GROUND MOTIONS	X	X
POTENTIAL AMPLIFICATION		X
POTENTIAL LIQUEFACTION		X
POTENTIAL LATERAL SPREADING		X
POTENTIAL LANDSLIDES		X
POTENTIAL TSUNAMI DAMAGE		X
EMERGENCY MANAGEMENT		X
DISASTER PLANNING / TRAINING		X
SIMULATED EARTHQUAKE EXERCISES		X
COMMUNITY EDUCATION		X
LAND USE PLANNING		X
APPLICABILITY		
ENGINEERING CODES	YES	YES
EARTHQUAKE RISK	NO	YES

CURRENT STUDIES

Mapping for the remaining major urban areas (this "regional" approach) is continuing. By the end of the Decade, selected "local" areas (local government authorities) are to be zoned in detail, with application to GIS mapping. Other current studies are in emergency management (preparation of guidelines for awareness and preparedness; earthquake exercises for selected local areas) and earthquake engineering (definitive attenuation relations; information for earthquake code revisions).

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