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SITE RESPONSE EVALUATION OF METRO MANILA USING MICROTREMOR OBSERVATION

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ABSTRACT

This study is an international project that deals with the seismic microzonation of Metro Manila, Philippines using microtremor observations. In this paper, the initial results of the microtremor observations are discussed. The results disclosed that the distribution of predominant frequencies plotted on map showed a relationship with the distribution of soft sedimentary layers and the damage distribution of the 1968 Luzon Earthquake . The predominant frequency areas of high relief , such as in the hilly areas, is very high. Whereas, in the low-lying areas underlain by soft sediments, predominant frequency is very low. In the damaged area caused by the 1968 Luzon (Casiguran) Earthquake, predominant frequencies are very low, so by this low frequency is suggested us that the damaged buildings had been generated resonance with the earthquake ground motion. By this research, these results will be useful data to make seismic microzonation in Metro Manila.

KEYWORDS

Site response, Microtremor, Predominant frequency, Metro Manila, Seismic microzonation, Philippines, Earthquake

OBJECTIVE

Metro Manila is a rapidly growing urban center in the Philippines and its population reached a staggering number of eight million in 1990. This is distributed in a land area of 630 sq.km, making it the most densely populated areas in the country. The metropolis is bounded by the Manila Trench to the west , by the

Casiguran and Philippine Fault to the northeast and by the Lubang Fault to the southeast. The Marikina Valley Fault System, which was recently found to be active, directly transacts the metropolis. The above tectonic setting makes the study area vulnerable to earthquake hazards as evidence by its past earthquake history dating from the 1500s up to present. (Table 1). Any earthquake therefore originating from any of the above earthquake generators can have a great hindering impact on the economic development being experience at present.

This research aims to generate useful and basic data for seismic risk mitigation in Metro Manila. As an initial step in the implementation of the project, seismic microzonation maps will be drawn based on microtremor observations.

METHODOLOGY

The microtremor observation which was conducted in this study is a part of the joint project between Japan and the Philippines on seismic microzonation . The overall components of the project are summarized in the flow chart shown in Figure 1. During the implementation of the project beginning 1995 up to 1998, borehole data analysis, topographic map interpretation, high density microtremor observations, P and S wave velocity measurements, strong ground motion observations and high density intensity surveys are planned to be conducted to generate basic information necessary for detailed seismic microzonation. The final output will be the generation of microzonation maps showing the level and distribution of expected acceleration, velocity or intensity. Such maps are necessary in the evaluation of seismic risks in the Metro Manila area. With the use of microtremor data, site response evaluation was conducted and the results are discussed in this paper. We shall correlate the results of site response study with the results of other activities in the final phase of the project.

THE SURVEY AREA

The map of the study area is shown in Fig. 2. The Metro Manila is composed of seven cities namely, Manila, Quezon , Pasay, Caloocan, Makati, Pasig and Mandaluyong and 10 municipalities consisting of Las Pinas, Malabon, Marikina, Muntinlupa, Navotas, Paranaque, Pateros, San Juan, Taguig and Valenzuela. Quezon city is the capital of the Philippines.

SEISEMICITY AND GENERAL GEOLOGY

Seismic Activity and Historical Earthquakes which Affected Metro Manila

The Marikina Valley Fault System is the nearest fault line to the metropolis but no recent earthquake could be related to this fault's activity. However, large earthquakes from other nearby earthquake generators had affected the area several times. Some of these had been destructive. In particular, these earthquakes

severely damaged Manila or portions of it in the years 1645, 1852, 1863, 1869, 1880, 1968 and 1970.
Aside from other factors like depth and nearness to epicenter, damage from earthquakes in Metro Manila is also controlled by local geology. Metro Manila is underlain by both deltaic and volcanic deposits. The western part of the metropolis is built on delta deposits from the Pasig River and thus, seismic intensity is usually amplified due to this characteristic. On the eastern part of Metro Manila, thick volcanic sediments underlie the metropolis except for the Marikina Valley river deposits originating from the Marikina River.

The 1968 Luzon Earthquake(The 1968 Casiguran Earthquake) and its Damage

Earthquake:(UNESCO 1969)
Local time: August 2,1968, 4:20 AM   Epicenter:16.522N 122.201E
Depth: 30 km   Magnitude:7.3

Damages::
Death:270 persons   Injured:261 persons
Damages of buildings: Collapsed 1(Luby Tower apartment), Very Severe 3, Severe 2, Moderate 5
Moderate 5, Severe Local 3, Local 1

Damaged area located at the alluvial fan area by Pasig River border on the Manila Bay.

Topography and Geology

A large part of Metro Manila is a low plateau stretching from the southern foot of the Sierra Madre Mountain Range to slope of Taal Plain. This plateau separates lowlands near Laguna de Bay and the coastal margins of Manila Bay. The Pasig River and the Marikina River are two Major rivers that drain off the sea.
The central part of Metro Manila is composed of a thick sequence of well-bedded tuff and tuffaceous clastics of Guadalupe Formation covered by less than two meters of weathered soil. This separates two areas with soft ground layers, the Marikina Valley plain in the east and the Pasig River delta plain in the west, both with deep alluvial deposit layers(Fig.3)(Besana *et al* 1992)
The Pasig River delta plain has an average elevation of less than 5 meters, a roughly concave shape, poor drainage and gentle slope towards Manila Bay. This plain is composed beach and estuarine deposits in north and lagoonal and beach sediments in the south derived from clastics formerly and actively dumped by the Pasig River.(Besana *et al*,1993)
The Marikina Valley plain, a flat-lying sedimentary plain of the Marikina River, is fast being developed into residential and commercial areas. It is composed of very deep alluvial deposits and lies between the Sierra Madre Mountain Range and Guadalupe plateau. The sharp contact between this alluvial plain with the plain with Guadalupe plateau is the western segment of Marikina valley Fault System(MVFS). Recent studies show that this fault system is active(Punongbayan *et al*,1995) and may have been responsible for some of the historical earthquakes the struck Manila.(USGS Report, 1995)

MICROTREMOR OBSERVATION

Survey Procedure and Instrumentation

The study area was subdivided into square grids of one km by one km where intersection of these grid-lines were used as microtremor observation points. Urbanized areas and area with thick alluvial deposits were measured more densely than the rest. Measurements were conducted using two sets of three-component wide band seismometer connected to an amplifier and data recorder.

Predominant Frequency Distribution

The predominant frequencies for each site were determined by H/V Spectrum Ratio which was developed by Nakamura (Nakamura *et al* 1986). The distribution of predominant frequencies for the study area are shown in Fig. 6. It can be observed from this figure that in areas of high relief, such as in the hilly areas east of the Sierra Madre range and the Guadalupe Plateau, the predominant frequency is very high. Whereas, in the low lying areas underlain by soft deposits, predominant frequency is very low (less than 1.5 cycle/sec).

The Marikina Valley

A large part of this area lies on top of very thick alluvial deposits (Fig. 5). Along its eastern and western borders lies the Marikina Valley fault System which is believed to be active based on geomorphological evidences and recent results of trenching and carbon dating. Fig.5 correlates well with Fig. 4 as areas underlain by alluvial deposits showed a very low range of predominant frequencies and hilly areas and the plateaus on the borders showed high to middle range in frequencies. The above suggests that the alluvial deposits in the plain is soft and very deep. This further supports the projected depth of deposits as shown in the contour map of alluvial thickness in Fig. 3.

Correlation with the Damaged Area of the 1968 Luzon (the 1968 Casiguran) Earthquake

The damage area of the 1968 Luzon earthquake is shown in Fig. 6. The black square mark shows the location of the Ruby Tower building which completely collapsed killing many of its occupants. Fig. 3 suggest that the building site is underlain by very deep alluvial deposits from the Pasig River. Points number 80 to 84 of line 14 and 16 as shown in Fig. 6, lies within or close to the location of this building. Within the damage area, the predominant frequencies obtained are very low (less than 1.5 sec.). Most of the damaged buildings have at least 6 to 11 floors which suggests possible amplification of ground motion by resonance. Omote et al. (UNESCO 1969) also measured microtremors in the area and they found out that predominant periods are about 0.4 to o.55 secs. in the damage areas and about 0.25 to 0.3 in the plateau areas.

CONCLUSIONS

Followings are conclusions reached in this research:

1. It can be observed that the predominant frequency in areas of high relief, such as in the hilly areas of Sierra Madre Mountain and Guadalupe Plateau, is very high. Whereas, in the low-lying areas underlain by soft sediments, predominant frequency is very low.

2. Predominant frequencies in the Marikina Valley Plain show very clear contrast that there are very low frequencies in plain area, whereas there are very high in both side of mountain and plateau area.

3. In damaged area caused by the 1968 Luson (the 1968 Casiguran) earthquake, predominant frequencies of subsoil are very low. This result is suggested us that the damaged buildings had been generated resoance with the earthquake ground motion.

In this paper, authors discussed only on the predominant frequency of microtremor in the area, but they have to discuss on the amplification characteristics with same microtremor data as next step. But these results in this paper are suggested us that the microtremor measurements will be one of useful methods for seismic microzonation in Metro Manila, same like another data, strong ground motion records, bore hole data, PS velocity data, etc.

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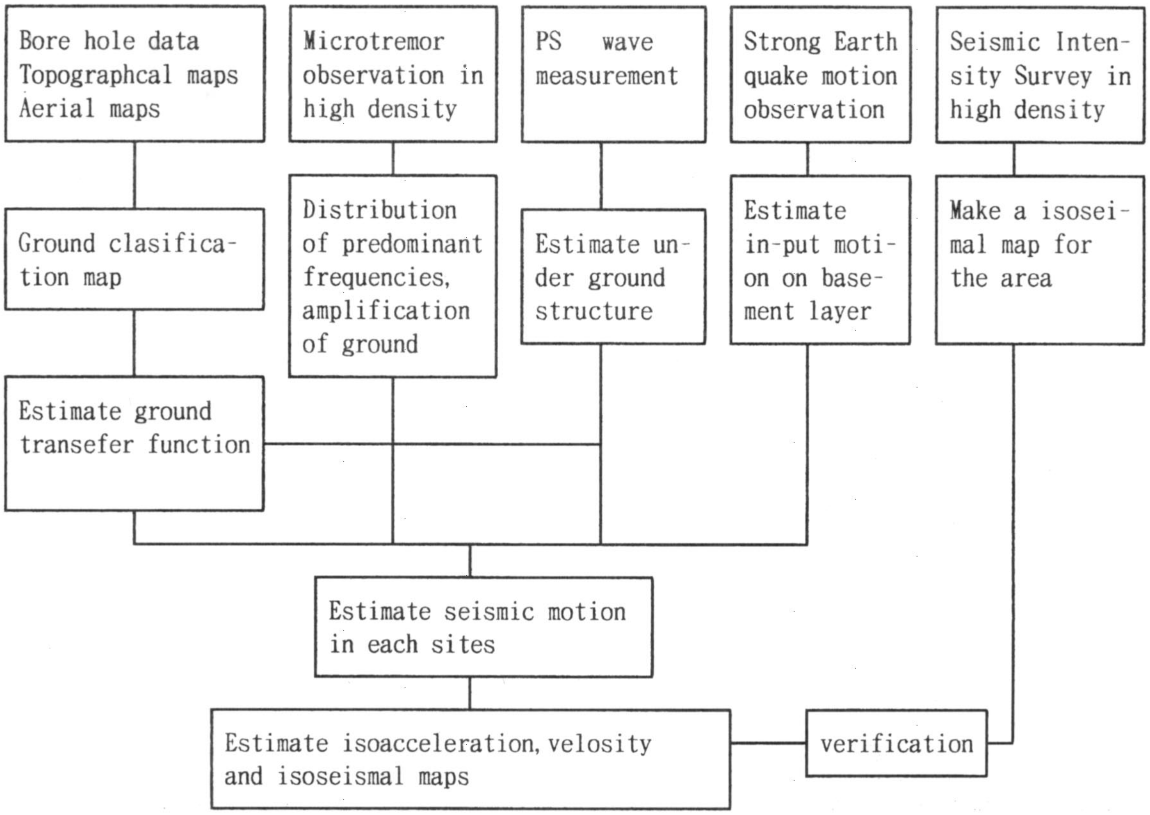

Fig. 1 Study Flow of the Seismic Microzonation in Metro Manila

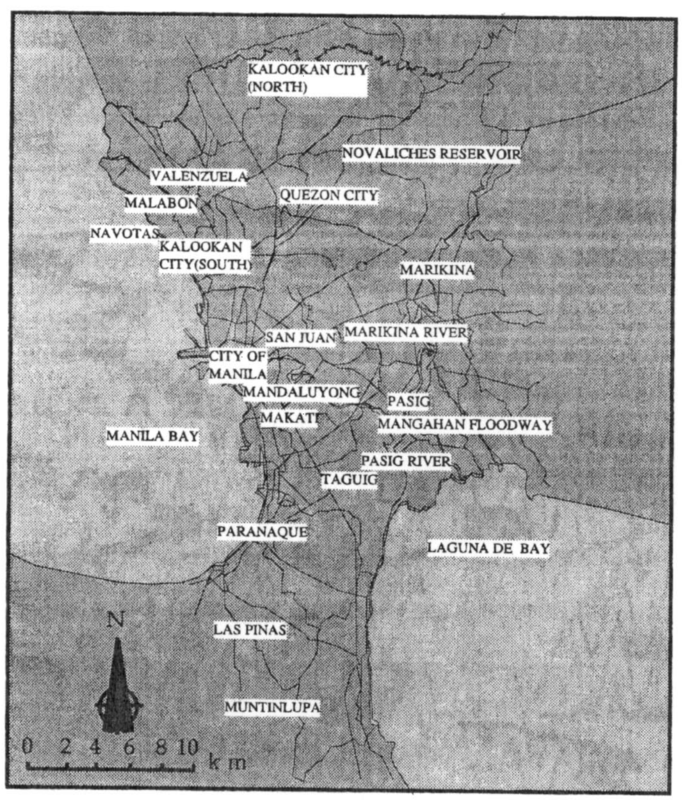

Fig. 2 Study Area, Metro Manila, Philippines

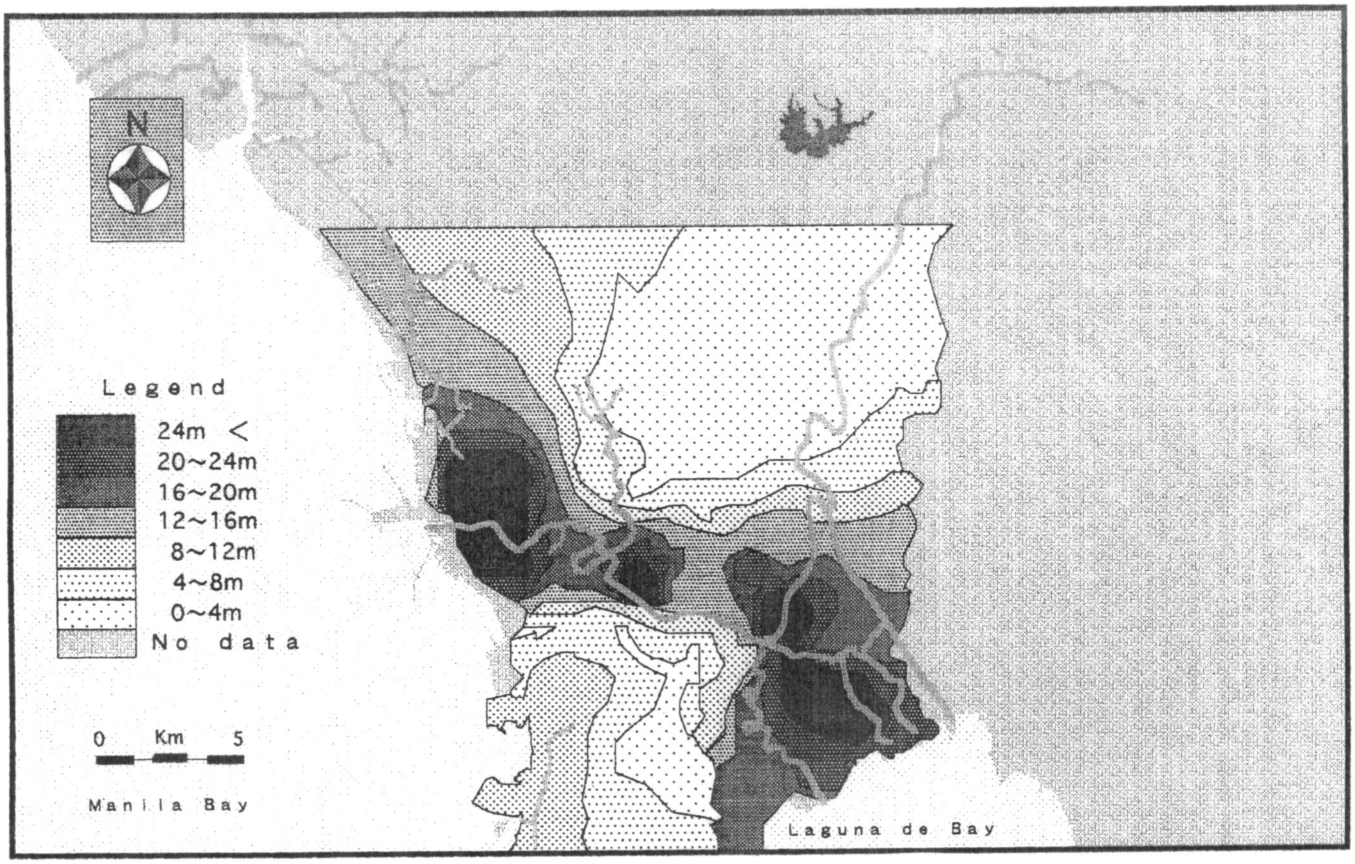

Fig. 3 Counter Map of the Depth of Alluvial Deposit Soft Layers (after Besana et al)

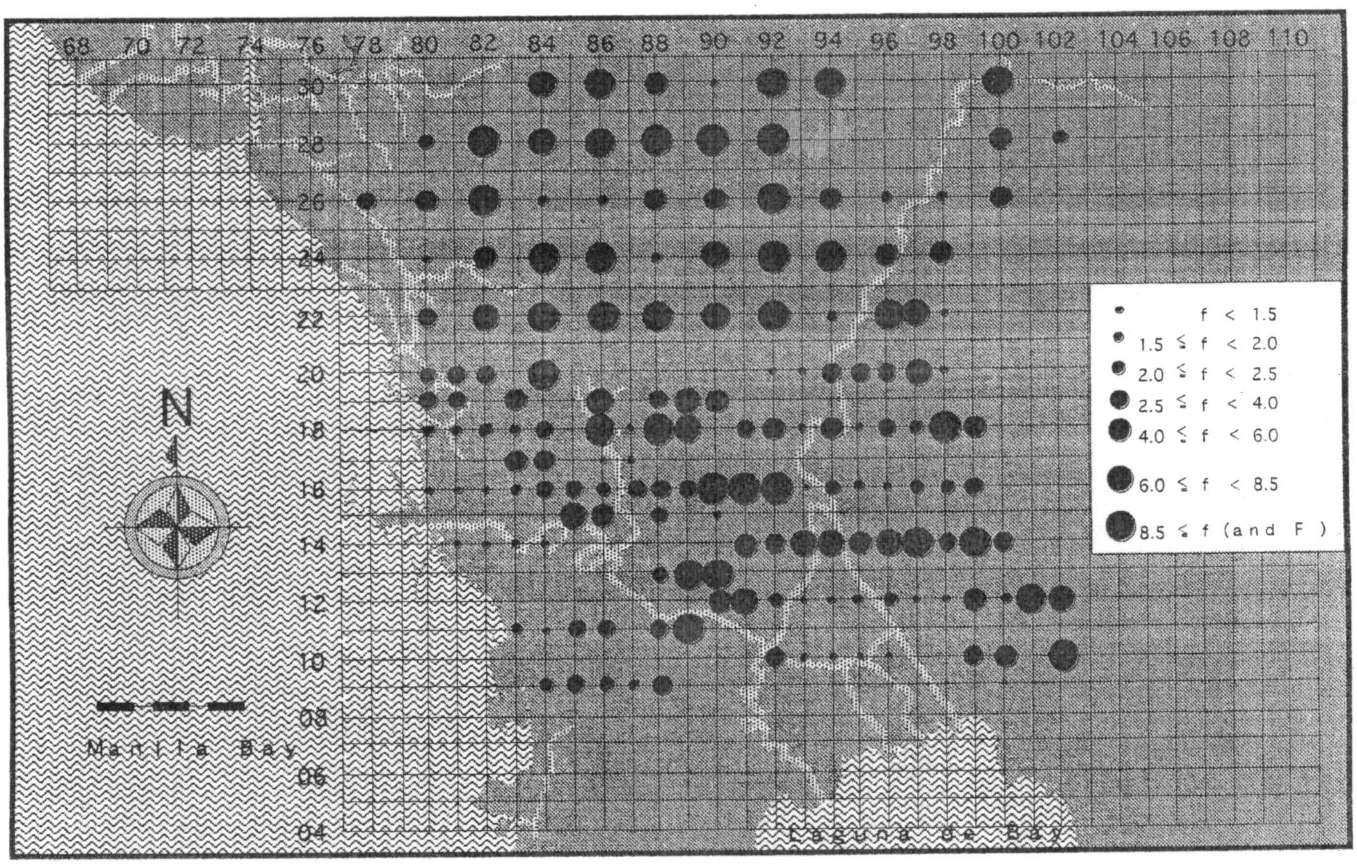

Fig. 4 Predominant Frequency Distribution Evaluated by Microtremor

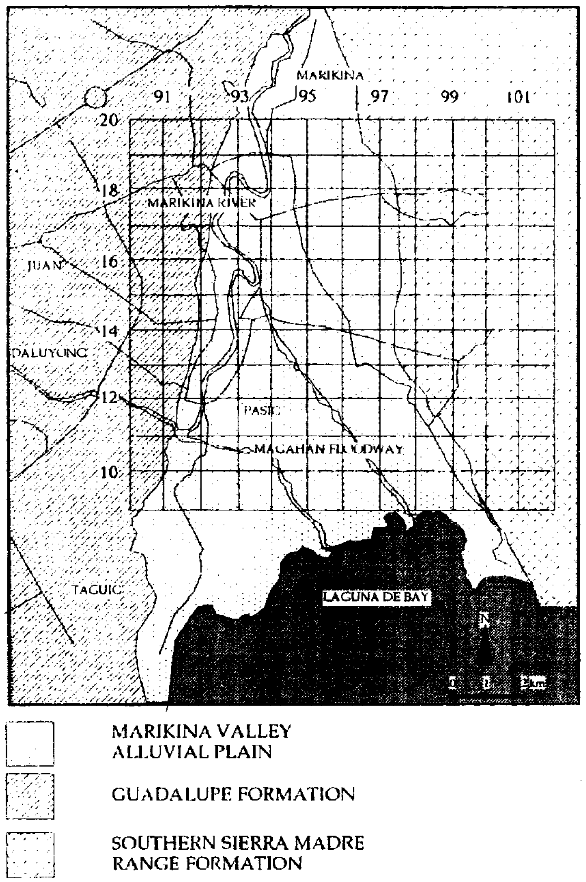

Fig. 5 Geological Clasiffication of Marikina Valley Plain

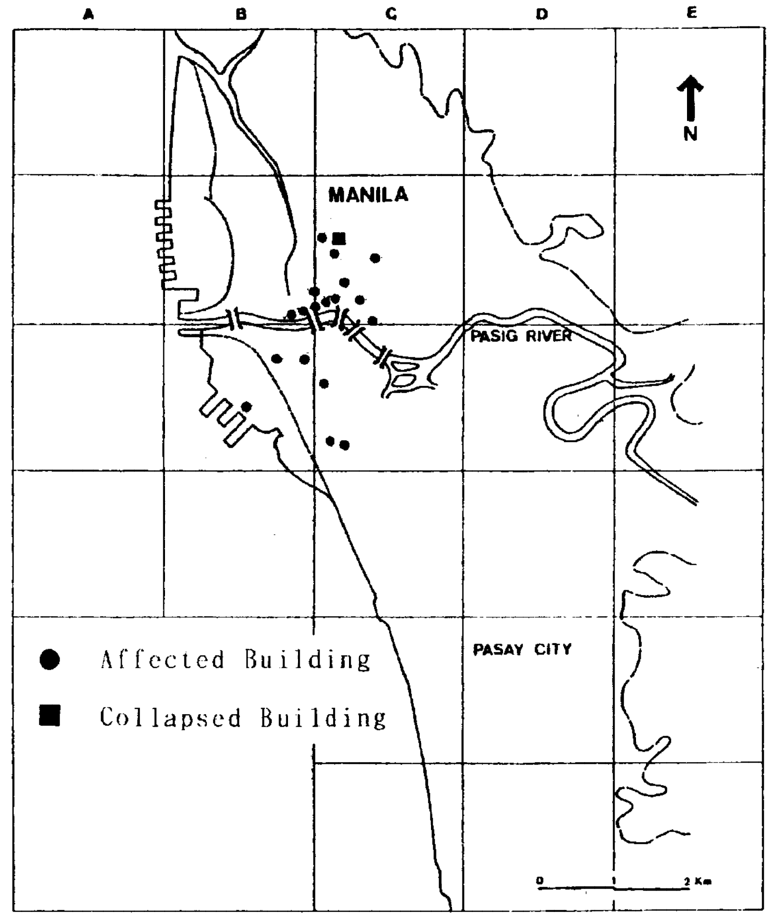

Fig. 6 Locations of the Buildings Damaged by the 1968 Casiguran Earthquake (after UNESCO 1969)