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Risk-Sensitive Land Use Planning: Towards Reduced Seismic Disaster Vulnerability

The Case of Marikina City, Metro Manila, Philippines

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ABSTRACT

Many megacities in the world are located in highly seismically active regions, including Metro Manila, the National Capital Region of the Philippines. This research aimed to find out how land use planning can be applied as a long-term proactive approach in reducing the seismic vulnerability of seismically challenged cities in the Philippines using Marikina City, Metro Manila as a case study. Marikina City is traversed by the western splay of the Valley Fault System. Disaster risk is high not only because of the direct exposure of the city to a future probable large earthquake, but also because population growth and urban development continue unabated. This means a larger number of people and urban infrastructures are vulnerable to a seismic disaster.

Earthquake hazards assessment was conducted to select a probable scenario earthquake. Using available geologic studies and historical earthquake records, parameters of the scenario earthquake were determined using the deterministic approach. The scenario earthquake was then used to assess the physical, human, and spatial vulnerability of the city. An Excel-based program called RADIUS was used in both hazards evaluation and damage assessment. The results are effective in establishing the seismic vulnerabilities of places and people across the urban space.

Results of the risk analysis have implications on the existing urban form and land use pattern of the city. High-risk areas in the city are identified such as the traditional commercial district, commercial corridors, and urban poor resettlement sites, among others. In view of this, the strategy of risk-sensitive land use planning is proposed as a unifying approach for seismically challenged towns and cities. Risk-sensitive land use planning utilizes familiar planning tools and techniques such as overlay zones and open space network development. By combining risk analysis with the standard planning process, risk-sensitive land use planning is a systematic and logical method to achieve the objective of reducing seismic vulnerability and risk while producing long-lasting urban improvements towards safer and sustainable urban settlements.

KURZFASSUNG

Zahlreiche sogenannte ‚Megacities' liegen in den seismisch aktivsten Zonen der Welt. Dies trifft auch für Manila, die Hauptstadt der Philippinen zu. Fragestellung der vorliegenden Arbeit ist, wie mit Hilfe der Anwendung räumlicher Planung eine langfristige und vorbeugende Strategie zur Verminderung der seismischen Verwundbarkeit speziell großer Metropolen unterstützt werden kann. Als Fallstudie dient ‚Marikina City', einer der großen Bezirke von Manila, die von den westlichen Ausläufern des Marikina-Grabenbruch-Systems durchzogen ist. Das Katastrophenrisiko in diesem Gebiet ist sehr hoch. Es ist zum einen von einem mit hoher Wahrscheinlichkeit eintretenden schweren Erdbeben betroffen; zum anderen wachsen Bevölkerung und Stadt seit einiger Zeit immer schneller. Eine zunehmende Zahl an Menschen, Gebäuden und Infrastrukturen sind künftigen Erdbeben ausgesetzt.

In der vorliegenden Arbeit werden zunächst die mit Erdbeben verbundenen Gefahren abgeschätzt, um in deterministischer Weise und anhand verschiedener Anhaltspunkte ein ‚Szenario-Erdbeben' zu definieren. Hierbei wurden in erster Linie geologische und tektonische Studien, historische Erdbebenereignisse, und weitere vorhandene Daten ausgewertet sowie ortskundige Spezialisten befragt. Vor diesem Hintergrund wurden die voraussichtlichen physischen Schäden, die voraussichtlichen Zahlen menschlicher Opfer, sowie die wahrscheinliche räumliche Verteilung der seismischen Verwundbarkeit der Stadtregion ermittelt. Diese Bewertungen wurden anhand vorhandener und eigens zusätzlich erhobener Daten EDV-gestützt verarbeitet und räumlich verknüpft (Programm RADIUS). Die Ergebnisse der rechnerischen Auswertungen lassen sich effektiv in raumbezogene Aussagen umsetzen, die für die Ausarbeitung planerischer und sonstiger Handlungsempfehlungen zugrunde gelegt werden.

Zunächst haben die Ergebnisse dieser Risikoanalyse Implikationen für Städtebau und Flächennutzung. Gebiete mit sehr hohen und hohen Gefahrenrisiken schließen unter anderem die traditionellen Einkaufsbereiche und die meisten wichtigen kommerziellen Achsen ein, ebenso zahlreiche Armenviertel und Umsiedlungsquartiere. Vor diesem Hintergrund wird sodann eine Strategie einer auf die Erdbebenrisiken eingehenden Stadtplanung entworfen, um die Ansätze für die künftige Planung seismisch gefährdeter Siedlungsbereiche insgesamt zu bündeln. Dabei werden übliche und gebräuchliche Planungsinstrumente und Techniken verwendet, wie die Überlagerung von Nutzungskarten, Infrastrukturplänen, Freiraumsystemen, usw. Indem die Risikoanalyse in den üblichen Planungsprozess integriert wird, können hiermit die entscheidenden Schaltstellen der Planung und Politik, aber auch die Öffentlichkeit insgesamt erreicht werden. Auf diese Weise lassen sich nachhaltige Verbesserungen im Sinne einer größeren Sicherheit von Siedlungsbereichen auch in den durch Erdbeben betroffenen Regionen erzielen.

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for Jerry, Trina and Chloe,
the wind beneath my wings

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PREAMBLE

The risk assessment of Marikina City as an example may act as an eye-opener to both the public and private sectors about the potential social and economic costs of an earthquake. Marikina City is a booming city in Metro Manila. Other cities and towns in Metro Manila are competing against each other to attract investments in various ways and fast-track their development. Like Marikina City, they are likewise exposed to seismic hazards. A large earthquake could derail Marikina City's continuing progress and bright future, if it is suddenly caught flat-footed because possible disaster mitigation measures have not been implemented before the earthquake. Given the present development trend in Metro Manila towards high-density land uses and high-intensity development, risk-sensitive land use planning can be considered as a pro-active, long-term investment that will eventually pay off for everyone.

Urban planners and decision-makers in government can find the study useful in making their comprehensive land use plans and urban development schemes more responsive to the threat of seismic hazards through systematic integration of seismic risk assessment into the land use planning process. Incorporating hazards and vulnerability assessments into the planning process is an important means to achieve "sustainability" in urban land use and development, an oft-repeated word in most comprehensive land use plans (CLUP) of towns and cities across the country. Sustainable development is almost always the rallying cry of CLUPs. However, if hazard identification and vulnerability evaluation have not been part and parcel of the planning process, when vulnerable towns and cities are not prepared or even aware of seismic hazards that could cause death, injury, and property damage, how could any land use plan be called in anyway sustainable? It pays to be prepared and to plan to make communities resilient to natural hazards in order to safeguard the lives of people and their possessions from the vagaries of nature. Therefore, vulnerability and disaster risk reduction should no longer be treated separately from other sustainable development goals of uplifting the quality of life and well being of the people. The goal of reducing disaster losses of natural disaster mitigation should not remain isolated from the broader goals of sustainability.

This study also puts land use planning on the map of disaster mitigation in the Philippines. There are many non-structural measures that have been applied in the country for disaster reduction and mitigation. These include early warning systems, community-based disaster preparedness and management, and information/communication campaigns. However, land use planning for seismic disaster reduction has never been undertaken. Land use planning can be used to reduce disaster losses before they happen instead of cleaning them up again and again. The emphasis is now on disaster reduction and preparedness rather than disaster response and emergency relief issues. In this regard, the use of land use planning as a tool for disaster reduction becomes useful.

Finally, risk-sensitive land use planning is a relatively new area of interest, particularly in the Philippines. There is also a dearth of studies on the spatial aspects of disaster mitigation. This research fills in these gaps in disaster studies. Although natural hazards evaluation has been done for Metro Manila and for other parts of the country that have been recent sites of disasters, this has not so far been applied in the field of land use planning and urban development. Land use planning thus still remains to be fully explored as a means to reduce disaster risks.

CHAPTER 1

LIVING DANGEROUSLY: THE URGENT NEED TO REDUCE THE RISK OF EARTHQUAKE DISASTERS

1.1 Introduction

Since time immemorial, the world has witnessed countless extreme natural events. As humans populated the continents and spread their settlements even in marginal areas throughout the ages, the risks due to natural phenomena such as earthquakes, typhoons, and floods have continually increased.

According to the United Nations (2003c), natural hazards have increasingly resulted in enormous loss of life and injuries and devastated the economy and environment of many vulnerable countries. In 1999 alone, more than 700 large-scale disasters occurred that claimed the lives of about 100,000 people and caused economic losses of US $100 billion worldwide, which translates to an annual increase of 10 percent during this decade (UN/ISDR, 2003b). Record losses of about US $198 billion were recorded in 1995, the year of the Kobe, Japan earthquake, which was equivalent to 0.7 percent of global gross domestic product (Benson and Clay, 2003). The UN (2003a) projects that global economic losses from disasters would reach $300 billion U.S. dollars a year by 2050, if no interventions to reduce disasters are done. In this light, the UN in December 1989 declared 1990 to 2000 as the International Decade for Natural Disaster Reduction to promote disaster mitigation to reduce human and material losses and economic disruption caused by natural disasters.

Many countries in the world are exposed to natural hazards. Forest fires ravaged several states in the US in 2000, while water submerged European towns and cities along the Elbe River in the summer of 2002. The so-called millennium flood that crippled parts of Europe highlighted the transboundary character of natural hazards (MunichRe Group, 2003). These catastrophes also attest that natural disasters do not discriminate between developed and developing countries.

In some cases, earthquakes can cause more casualties and property damage. The 4 June 2000 Sumatra earthquake (M=7.9), the 13 January 2001 El Salvador earthquake (M=7.7), the 26 January 2001 Gujarat earthquake (M=7.7), and the 21 May 2003 Algeria earthquake (M=6.8) are but a few of numerous seismic disasters that claimed thousands of lives and millions of dollars in property losses. The Hindu Kush region in Afghanistan endured a double whammy in the year 2002 when the earth rocked on 2 March (M=7.4) and again on 25 March (M=6.1). The disaster further aggravated the already wretched conditions in the war-torn country. The earthquake that struck the ancient city of Bam, Iran on 26 December 2003 (M=6.5) caused cataclysmic losses that it is considered as one of the worst natural disasters in recent history. Official figures cited at least 30,000 dead, 50,000 injured, and 100,000 homeless. It wiped out about two-thirds of the built-up area made mostly of traditional mud-brick dwellings.

Major earthquakes can kill thousands of people and obliterate entire communities in a matter of seconds. In the 20th century alone, more than three million people were killed in earthquakes.

1.1.1 Increasing Vulnerability of Megacities and Developing Countries

Although natural disasters seem more frequent and widespread resulting to exponential increase in human and material losses, there is no evidence of growing number or intensity of natural hazards.[1] One reason for escalating disaster losses is the worsening vulnerability of human settlements to natural hazards, particularly in the developing world.

Asia, for instance, suffered 43 percent of all disasters related to natural events in the last decade alone (UN/ISDRa, 2003). Aside from being located in highly active seismic zones and low-lying coastal areas subject to tropical cyclones, many developing countries in Asia are densely populated and a considerable percentage of the populace live on hazardous lands.

According to the UN (2000), of the 4.6 billion people in the developing world in year 2000, 40 percent or 1.84 billion people were urban. The level of urbanization in East Asia and the Pacific was around 40 percent, while South Asia was 30 percent urban and still growing. In the Philippines, 48 percent of the population in 2000 was urban.

By the year 2015, the world population is expected to exceed 7.2 billion. About 5.8 billion of this would be living in developing countries, 48.5 percent of which would be living in urban areas. This means, in 10 years or so, about one billion people more would be living in cities in the developing world. This means either cities would grow bigger through physical expansion or urban densities would increase. Most likely, it will be both. If present trends continue, a big chunk of the world urban population would be cramped in the megacities of Beijing, Dhaka, New Delhi, Metro Jakarta, Metro Bangkok, Metro Manila, Mexico City, and Sao Paulo.

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[1] Although there is no observed increase in the occurrence of other natural hazard, a debate rages on the changing frequency and intensity of hydro-meteorological disasters due to global climate change.

Primate cities and metropolises in developing countries have been around for decades. However, the phenomenon of megacities, or urban regions with at least 10 million people, is fairly recent. The nonstop growth of megacities in the developing world represents a new vulnerability in itself. Many are located in hazardous regions in the world, where they are exposed to typhoons, floods, landslides, and earthquakes. This exposure is exacerbated by socio-economic factors that make these cities more vulnerable such as rapid population growth, haphazard urban development, environmental degradation, and worsening poverty.

Rapid population growth in megacities continues unabated due to both natural increase and in-migration. Cities are magnets for poor rural migrants, who leave the agricultural countryside to search for a better future in the city. Lack of affordable land and housing within the city gives no choice for the urban poor but to build informal dwellings in hazardous and marginal sites like riverbanks, floodplains, or steep slopes.

The use of improper design and low-quality construction materials by unscrupulous private developers, builders, and public works contractors increase the physical vulnerability of the city to earthquakes. Inadequate drainage system and improper garbage disposal degrade the environment and increase the probability of flash floods. A degraded environment increases the likelihood and amplifies the impacts of natural hazards (Alabala-Bertrand, 2003; Wisner, 2003).

Continuing rapid urbanization means greater concentration of physical capital assets and investments in cities. As the urban area eats up more space into the countryside, rural areas are eventually incorporated into the megacity. The uncontrolled sprawl of mega-urban regions creates more urban problems (e.g., slums, squatting, uncollected garbage, no running water, etc.) as local governments fail to provide even the most basic services to the people.

These processes drive the vicious cycle of vulnerability of megacities to natural hazards. Lastly, poor understanding of disaster risks by decision makers compounds the problem of increasing vulnerability to disasters. Hence, the risk of cities suffering disasters resulting from cataclysmic earthquakes has never been greater.

1.1.2 The Philippines: Most Disaster-Prone Country in the 20th Century

The Philippines has experienced a number of natural disasters in the past few decades. Its geographical and geologic setting exposes it to many natural hazards: typhoons, storm surges, floods, tsunamis, volcanic eruptions, earthquakes, and landslides (Punongbayan, 1994; Lanuza, 1994; Mangao et al., 1994; Gonzales, 1994; Brown, Amadore and Torrente, 1991; and

NLUC, 1991). The country's 7,107 islands are surrounded by the South China Sea, Philippine Sea, Sulu Sea, and Celebes Sea (see Map 1a) and lies in the path of powerful typhoons (cyclones accompanied by winds of more than 117 kilometers per hour), probably second only to Taiwan in terms of typhoon severity (Hearn and Hart, 2003).

Map 1a. Philippine map and location of Metro Manila.
(Source: Encarta Encyclopedia, Microsoft Corp.)

An average of 20 typhoons per year affect the Philippine Area of Responsibility (Punongbayan, 1994; Brown, et al., 1991). From 1990 to 1994, the country was ravaged by 11 typhoons resulting to a death toll of 6,434 and more than 1.2 billion U.S. dollars in damages (Gonzales, 1994). The typhoon season normally starts in July and lasts until November. As a result, flash floods and river floods occur in this time of the year.

In an unforgettable typhoon-induced disaster in August 1999, landslides buried alive at least 23 people and injured more than 30 residents of Cherry Hills Subdivision, a middle-income hillside residential village in Antipolo City in Rizal Province. Destroyed were 120 of the 200 houses worth 1.5 million U.S. dollars. Typhoon "Helming" unleashed torrential rains that submerged the cities of Metro Manila such as Marikina, Manila, Quezon, Caloocan, Malabon, Navotas, Makati, Mandaluyong, and San Juan in four-day long floods that were three meters deep in some areas. The major rivers of Pasig, Marikina, and San Juan overflowed, forcing the evacuation of 662,724 persons. Flood-related accidents such as drowning and electrocution killed a total of 60.

The country also lies within the Circum-Pacific Ring of Fire, a highly tectonic region characterized by volcanic and seismic activities. As a result, there is a preponderance of active faults and subduction zones in the region. Sudden movements caused by the interaction of major tectonic plate boundaries along trenches and active faults produce a high level of seismicity within the Philippine archipelago (Map 1b). The Eurasian Plate subducts eastward along Manila Trench, while the Philippine Sea Plate subducts westward under Luzon Island along the East Luzon Trench, resulting in a high seismic activity in the country. Aside from earthquakes on more distant plate-boundary faults, the country is similarly subject to earthquakes on numerous nearby active crustal faults.

In April 1991, Mount Pinatubo erupted, transforming several towns at its foot into virtual ghost towns. It was dubbed as the volcanic eruption of the century. Ensuing rains soaked the volcanic ash fall, causing the collapse of roofs and even entire buildings, while winds spread volcanic ash as far as Metro Manila. The government estimated that the eruption affected 2.1 million people in 364 *barangays*[2] in five provinces, completely or partially destroyed 75,236 houses, damaged about US $32 million worth of assets of 599 firms, and US $17 million dollars in foregone production losses (Lacsamana, 1994). It became a lingering disaster as lahars [3] continued to plague the Central Luzon region for the next 10 years.

There are on average five detectable earthquakes everyday in the Philippines. From 1968 to 2003, the country has already experienced 12 destructive earthquakes. Sudden-onset hazards such as earthquakes become deadlier as everyone is caught unaware and do not have time to flee to safer areas. During typhoon events, in comparison, people would receive early warnings from the government's meteorological agency a few days before the typhoon lands. Local governments have time to evacuate people away from the path of the typhoon, especially those who live along rivers and creeks as well as time to prepare the necessary logistics for disaster response and relief operations.

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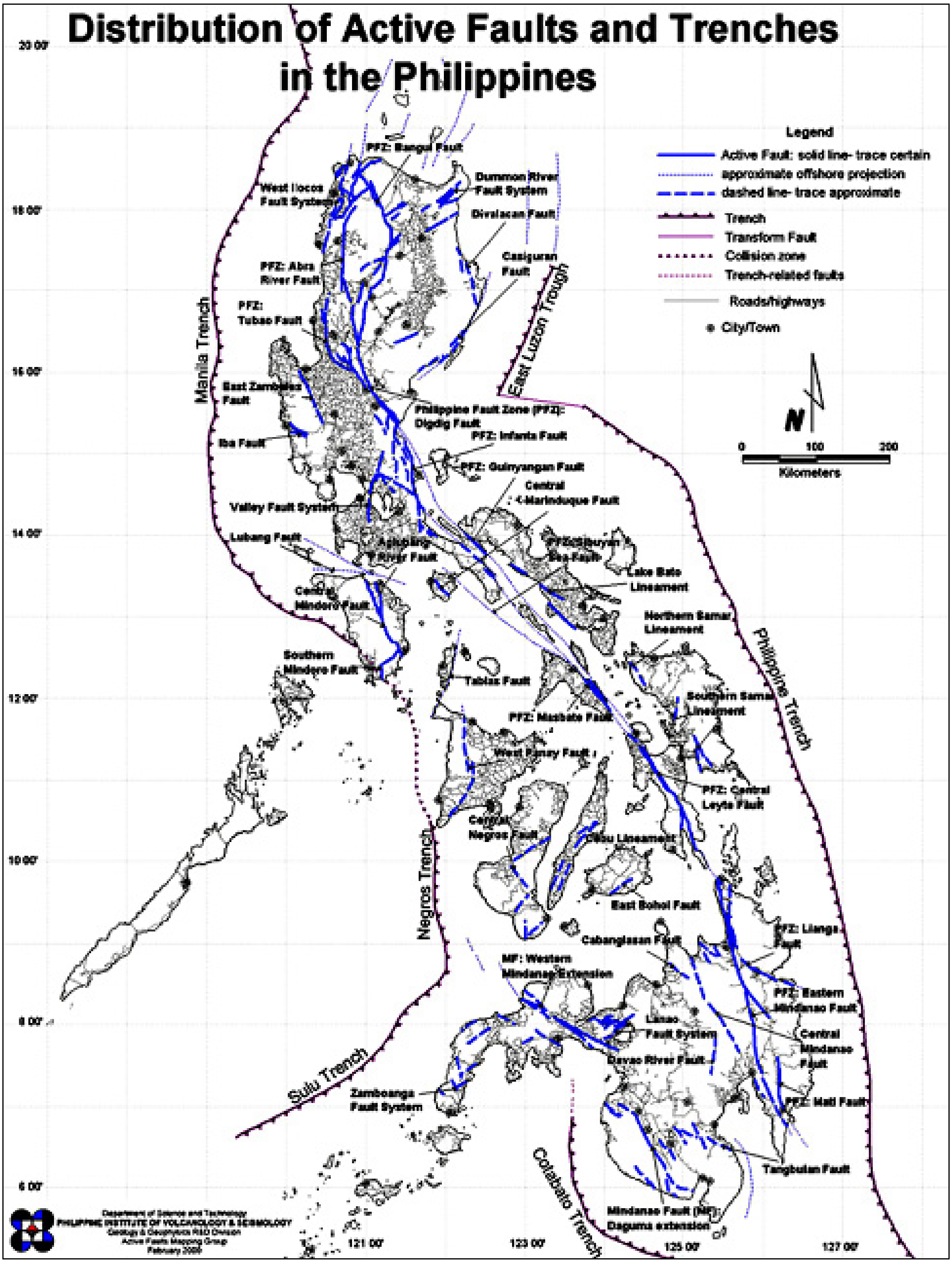
[2] A *barangay* is the smallest geo-political unit in the Philippines.
[3] Lahars are pyroclastic deposits on the slopes of the volcano that are mobilized by heavy rainfall and surge down to the surrounding plains like mudslides.



Map 1b. Earthquake generators in the Philippines. (Source: PHIVOLCS website.)

On 16 July 1990, an earthquake with a magnitude of 7.8 on the Richter Scale struck the main island of Luzon. According to the field report by Hopkins, et al. (1992), the disaster claimed more than 1,600 lives, injured over 3,500 people, rendered 148,000 homeless, adversely affected 1.61 million people, and exacted about 90 million US dollars in property damage. The earthquake spawned dramatic events such as the soft story collapse of the five-star Hyatt Terraces Hotel due to strong ground vibrations in Baguio City (Figure 1a) and the sinking of about half of the central business district of Dagupan City as a result of liquefaction (Figure 1b). The failure of many lifelines such as major bridges, roads, electric supply system, and telecommunications led to the isolation of hard hit areas such as Baguio City.

Figure 1a. Five-star Hyatt Terraces Hotel in Baguio City collapsed due to strong ground shaking. (Source: PHIVOLCS website.)

Indirect economic losses as well as intangible social and psychological effects are more difficult to quantify. One can imagine the magnitude of both direct and indirect losses the country has suffered through the decades. In view of this, the Philippines has been identified as the most disaster-prone country in the twentieth century, followed by India as a distant second and by the United States in third place (Kovach, 1995).

Figure 1b. The foundation of this building in Dagupan City failed due to liquefaction. (Source: PHIVOLCS website.)

1.1.3 Destructive Earthquakes in the Philippines

Earthquakes pose a grave danger to many cities and urban areas in the Philippines. According to the government's Philippine Institute of Volcanology and Seismology (PHIVOLCS), the country suffered 12 destructive earthquakes in the last 35 years alone, from 1968 to 2003 (Table 1a). This means, the archipelago was on average hit by one destructive quake every 3 years. So far, the deadliest quake in Philippine history is the 1976 Mindanao earthquake. The official death toll was 4,791 and 2,288 missing persons, although some international agencies pegged the number of fatalities at around 8,000. In terms of damage to property and assets, the 1990 Luzon earthquake proved to be the most destructive, destroying 116,000 dwellings and displacing 148,000 people.

Table 1a. Some Destructive Earthquakes in the Philippines, 1968-2003

Disaster Event	Magnitude	Epicenter	Impact
2 August 1968 Casiguran Earthquake	Ms=7.3	Casiguran, Quezon Province	270 persons killed and 261 injured. A 6-storey building in Binondo in the city of Manila collapsed while several major buildings near Binondo and Escolta were structurally damaged. Several millions of dollars in property damage.
17 March 1973 Ragay Gulf Earthquake	Ms=7.0	Calauag, Quezon Province	98 houses destroyed; one theater/restaurant and several other buildings collapsed; one church, many school buildings and 270 houses partially damaged; non-structural damage in a flour mill; one bridge collapsed and 3 others damaged; 300 m of railway twisted; and roads cracked.
17 August 1976 Moro Gulf Earthquake	M=7.9 Ms=7.8	Cotabato Province	4,791 died; 9,928 injured; 2,288 missing; and estimated 93,382 displaced; more than 700 kms of coastline in Pagadian City devastated by a tsunami that was responsible for 85% of deaths, 65% of injuries and 95% of those missing; 10 buildings and all waterfront warehouses collapsed; and numerous commercial buildings damaged.
17 August 1983 Laoag Earthquake	M=5.3 Ms=6.5 Depth=42 kms	30 kms east of Laoag City, Ilocos Norte	16 deaths; 47 wounded; 27 reinforced concrete frame buildings and houses and 4 churches damaged; roads cracked; most bridges suffered differential settlement of approach or abutment to as much as 30 cms.

Disaster Event	Magnitude	Epicenter	Impact
8 February 1990 Bohol Earthquake	M=6.8	17 km east of Tagbilaran City, Bohol Province	6 perished; 200 wounded; 7,000 rendered homeless and 46,000 displaced; around 3,000 structures partially damaged and 182 completely ruined including 2 historical churches; 200,000 sq. m. of fishponds affected due to cracked dikes; 2 bridges collapsed and roads damaged.
14 June 1990 Panay Earthquake	M=7.1 Depth=15 kms	Culasi, Antique Province	8 fatalities; 41 injured; 15 percent of residential dwellings and 4 bridges in Culasi collapsed while the rest of structures were damaged; 8 other structures also totally ruined and many buildings damaged in surrounding towns.
16 July 1990 Luzon Earthquake	M=7.8	Rizal, Nueva Ecija Province	over 1,600 lives lost; 3,500 hurt; 93,000 homes damaged and 23,000 destroyed rendering 148,000 homeless; negatively affected agriculture, tourism and mining; 1.61 million people adversely affected; many commercial buildings in Dagupan City settled due to liquefaction; most hotels and buildings in Baguio City collapsed including Hyatt Terraces luxury hotel; 117 schools in Metro Manila damaged; lifelines such as roads and bridges totally destroyed or heavily damaged.
15 November 1994 Mindoro Earthquake	M=7.1	Mindoro	78 killed 41 of which were drowning deaths due to the tsunami; 430 injured; 1,530 houses swept away by the tsunami; 6,036 structures damaged; electric supply for the island of Mindoro interrupted for 6 weeks; roads and bridges became impassable.
7 June 1999 Bayugan Earthquake (and its aftershocks)	Ms=5.1 Depth=7 kms	Agusan Valley Region	Poorly built structured collapsed; some structures, roads and bridges damaged; a number of people reportedly injured.
6 March 2002 Palimbang Earthquake	M=6.8	81 km SW of Isulan, Sultan Kudarat Province	8 perished; 41 hurt; 48 public and commercial buildings and 36 schools damaged; 7 bridges and 4 road networks ruined.
15 February 2003 Masbate Earthquake	M=6.2 Depth=22 kms	28 kms east of Masbate City, Masbate Province	Many non-engineered houses totally collapsed; some schools, roads, bridges and flood control infrastructures declared unsafe after the quake; structures near the fault badly damaged.

Source: PHIVOLCS website.

Based on the Philippine country study of Brown *et al.* on disaster mitigation and prevention (1991), there has been little systematic hazard mapping in the country on a scale and scope useful for risk analysis. Piecemeal natural hazard assessment in the Philippines is usually done in areas where a disaster has already occurred and when there is public outcry for improving the system of disaster management of the government. Unfortunately, the general public's attention on disaster matters is short, and the whole event is forgotten until the next disaster strikes. Also, attention to the risk of natural disasters has been paid only recently in the national physical planning process. Areas prone to various natural hazards are lumped together under the label "environmentally constrained areas" (ECAs) as indicated in the National Physical Framework Plan (1993-2022). The ECAs, however, have been determined only at the regional level. It remains for local government units to identify and evaluate natural hazards and delineate hazardous areas in their respective jurisdictions.

1.1.4 Impacts of Earthquake Hazards on Cities

Without a doubt, seismic disasters breed adverse long-term socio-economic consequences for cities and urban areas, contribute to economic instability, and an atmosphere of uncertainty (Benson and Clay, 2003). Examples of direct negative effects and losses are (Albala-Bertrand, 2003; Quarantelli, 2001):

- Many people are killed and injured or losses in human capital.
- Collapsed or damaged homes or losses in residential capital.
- Destroyed or damaged buildings, plants, and offices as well as critical facilities such as hospitals and schools and infrastructures such as roads, bridges, water supply and distribution system, power system, and telecommunication systems or losses in structural capital.
- Damaged machinery and equipment or losses in fixed capital stock.
- Loss of historic buildings and monuments.

Indirect negative consequences are more difficult to quantify as the techniques for evaluating them are more complicated and not as well developed, but these losses may be important as the more direct losses. Some of these are (Albala-Bertrand, 2003):

- Temporary or permanent displacement of people.
- Temporary or permanent business displacement, e.g., lower production output, loss of income from sales due to damaged roads.

- Work disruption or total stoppage, e.g. loss of jobs and income, lost productivity arising from injury.
- Reconstruction and rehabilitation costs.

Direct and indirect damage also lead to long-term impacts particularly to developing countries. Morever, sustainable development is challenged. A concrete example is the devastation of Honduras in the wake of Hurricane "Mitch." The country's water supply system had suffered great damage that set back the country's water service coverage to a level 30 years prior to the disaster (Osorio, 2003). Three decades of development efforts were wiped out in one week, not to mention the additional resources and time necessary to regain its previous status of development.

In many developing countries, the national capital is often the primary engine of growth. When an earthquake hits an urban growth center, the economic momentum could be adversely affected because the capital's assets and other resources could be heavily damaged, some of which may not be replaced at all. Economic productivity could be reduced, while potential long-term investments, in both physical and human capital, could be disrupted (Benson and Clay, 2003). Funds may be diverted to emergency and relief activities and used in the slow and difficult process of recovery, scarce resources that could otherwise be used for economic and social development programs. The cost of reconstruction and rehabilitation of development assets adds to the burden of government after a disaster. As an indicator of increasing costs of disaster rehabilitation, the Asian Development Bank allocated 6 percent of loans for reconstruction efforts in the 1980s. This rose to 20 percent in the 1990s (DKKV, 2002). Likewise, the quality of life of the people could suffer as a result of injuries, diseases, sudden loss of basic social services and transportation, and a degraded urban environment.

Mitigating seismic disasters must therefore be seen as a means to attain sustainable social and economic development, particularly in cities where so much is at stake. Sustainability of earthquake-prone cities and urban areas is highly questionable, if disaster reduction is not part and parcel of their development plans. Natural disaster reduction must be undertaken within the ambit of sustainable urban development. Failure to acknowledge the seismic vulnerability of many Philippine cities, especially the national capital region of Metro Manila, to seismic disasters will be costly in terms of human and property losses and in terms of the consequences for sustainable urban development.

Seismic disasters, however, may be reduced or their potential impacts mitigated. Although natural hazards such as earthquakes cannot be entirely avoided even with cutting-edge technology, the seismic vulnerability of cities can be modified.

1.2 The Urgent Need to Reduce Earthquake Disaster Risk in the Philippines

Realizing the need to reduce the impact of earthquake disasters especially in cities and urban areas, the study focuses on the formulation of land use planning measures that can reduce vulnerability of Philippine cities to seismic hazards. Seismic hazards, unfortunately, are seldom taken seriously as a factor in land use planning and urban development in the Philippines. Comprehensive land use plans (CLUPs) are regularly formulated and updated by local governments units at the local and provincial levels. The local level CLUPs contain the social and economic aspirations of a municipality or city. Physical and environmental factors are considered such as the presence of natural resources, environmental quality and protection, and tourism potentials. Population trends and economic strengths are likewise assessed. Political objectives are often only implied in CLUPs.

As far as natural hazards are concerned, one may notice that these are discussed in the area's physical profile, but in a cursory manner at best. Most of the time, only typhoons and flooding are given attention. Even then, only a superficial discussion of natural hazards is provided. No in-depth evaluation of the hazards is made, much less the potential impacts on the city's social and economic development and environment. Curiously, many towns and cities have emergency management plans for typhoon and flooding. These plans usually consist of pre-disaster evacuation plans as well as response and emergency operations during the first hours and days of the disaster. Pre- and post-disaster planning for long-term disaster mitigation for flooding is usually lacking.

With regards to earthquakes, earthquake disaster mitigation plans for seismically challenged towns and cities in the Philippines are not known to exist to this researcher. Public and private schools, however, are required by the government to conduct earthquake drills from time to time. Aside from this, seismic hazards are generally not in the public consciousness. Land use planners either simply ignore seismic hazards as they perceive them merely as a vague threat compared to the pressing problems they face in the here and now, or they are in the dark as to where and how to begin integrating seismic risk assessment in the customary process of land use planning. In any case, seismic or natural disaster mitigation planning has seldom been, if ever, a part of the overall process of land use planning.

This is because the prevailing dominant thinking in disaster mitigation in the Philippines only emphasizes emergency response and relief, where provision of relief goods preoccupy the government during the emergency period (Zoleta-Nantes, 2000) and the event is easily forgotten until the next disaster strikes. Consistent with this reactive approach, structural solutions that aim at resisting rather than mitigating the impact of disasters are prioritized, especially in the field of flood mitigation (Smith and Ward, 1998; ADB, 1991). The structural approach focuses on either predicting the hazard or modifying its impact (Blaikie *at al*., 1994). One prime example of this disaster management strategy in the Philippines is the construction of the FVR dike to protect the communities in Central Luzon from cascading lahars during the rainy season in the years following the Mount Pinatubo eruptions. In fighting floods, dikes are usually built to prevent the overbanking of rivers into riverside settlements during typhoon season. Such structural measures require huge capital outlays and maintenance costs.

In addition, early warning is also used to by the Philippine government in order to alert people of oncoming typhoons and floods and advise them to evacuate distressed areas through the mass media. Early warning systems also require investments in the installation of expensive equipment. Although early warning puts the exposed community one step ahead of the natural hazard, this method is also reactive in nature and thus must be complemented with longer-term strategies such as flood plain management. Many typhoon and flood-prone communities around the country also do not have evacuation and emergency preparedness plans, which render early warnings to a large degree futile.

The practice of disaster management has evolved through the years towards a more holistic approach, shifting its focus from post-disaster response and relief to disaster mitigation (Pearce, 2003). Before, response to the problem of natural disasters came from a geophysical and technocratic viewpoint. The underpinning paradigm relied on physical and engineering means to modify the natural hazard itself. In the field of flood control, structural measures such as flood embankments, levees, and channel modification were the norm. Science and technology were applied to adjust or control the environment to change the impact of the hazard on people and their settlements.

The present approach of natural disaster reduction combines both structural and non-structural mitigating measures with emphasis on coping with or adjusting to natural hazards rather than fighting them (Davis and Gupta, 1991). In the field of seismic disasters, big strides have been made in earthquake and structural engineering research that aim to further improve building design for earthquake-resistant buildings. Increasing attention has also been given to the spatial and land use aspects of seismic hazards and disaster mitigation, although the utility of planning in natural disaster reduction has not been so widely recognized even by local planners themselves as well as policy makers (Burby, 1999; Berke, 1998). Nevertheless, land use planning as a means of reducing disaster risk is slowly being applied as a tool to make earthquake-prone cities safer and sustainable (e.g., Kuroiwa, 2002; Nelson and French, 2002).

Traditionally, land use planning in the Philippines is not thought of as a tool to reduce the risk of natural disasters. In spite of scientific and research advancements in the field of natural hazard assessment in the country, there is still a yawning gap between natural hazards research and the application of pertinent into land use planning. It is this gap that this study intends to fill, however partially.

1.2.1 Research Questions and Objectives

The study aims to find out how land use planning that is based on risk analysis can be used towards seismic disaster reduction in a highly urbanized area such as Marikina City in Metro Manila, Philippines. Marikina City was chosen as the city naturally lends itself as a study area for two reasons. First is because of its high seismic exposure. Marikina City is cut by the West Valley Fault, a major splay of the Valley Fault System consisting of two faults trending north-northeast. The downthrown graben in the middle of the two almost parallel faults is geographically known as Marikina Valley, where Marikina City is nestled. The leading government seismology research institute, the Philippine Institute of Volcanology and Seismology (PHIVOLCS), has determined in early 1990s that the Valley Fault System is indeed active (Daligdig *et al.*, 1992). In addition, a recent paleoseismic study undertaken by Nelson et al (2003) showed that the fault system poses a greater seismic hazard than previously thought. Aside from the Valley Fault System, which is the most proximate hazard to Marikina City, there exist as well several earthquake sources that have violently rocked the Metropolitan Manila area in the past. Second, the case study area is large enough to demonstrate the proposed methodology and, at the same time, small enough to be manageable given the limited financial resources available for the study.

The starting points for this study are: Given the regional geologic setting of Marikina City, what seismic hazards pose a potential threat to the city? What is the maximum probable earthquake that might be reasonably thought to affect the city of Marikina? What is the probability of such an earthquake happening during the time span of a generation? Are there parts of the city that are more exposed to seismic hazards?

Large earthquakes pose hazards in the form of ground shaking and collateral hazards such as surface rupture, landslides, and liquefaction. Although the *when* of earthquakes is still not possible to predict accurately, the *where* of seismic hazards can be identified provided the necessary geologic information is available. The geology of the city plays a central role in determining which specific areas within the city are exposed to stronger ground shaking or liquefaction hazards. Surface faulting is also location-specific. As the destructiveness of seismic hazards depends on the size of the earthquake, its proximity, and local sub-surface conditions as well as the uses of the land, the spatial vulnerability across the city can be determined.

Physical vulnerability, on the other hand, depends on how buildings and infrastructure respond to ground shaking during an earthquake. The study then seeks to answer the following questions: How vulnerable is the city of Marikina to a future probable earthquake? In light of a probable earthquake, how much damage or losses could the city of Marikina suffer? Based on the characteristics of the building stock and intensity of ground shaking, which localities within the city could suffer more physical damage or property losses? How many people could lose their life or suffer from serious injuries?

As evidenced by earthquake disasters all over the world, loss of life and injuries after earthquakes are mostly due to partial or total building collapse. This was vividly demonstrated by the collapse of Ruby Tower, a six-story structure in downtown Manila, which claimed 268 deaths out of the 270 total casualties in the August 1968 Casiguran earthquake. After assessing the physical vulnerability of a locality, human vulnerability expressed in terms of loss of life and injuries can be approximated.

The results of the risk analysis are then applied in land use planning to arrive at the implications on the present urban form and land use pattern of the city. Land use planning strategies and measures that can reduce vulnerability and therefore disaster risks are then developed. The questions asked are: What land use and urban development processes contribute to the vulnerability of the city? How then can land use planning minimize the seismic vulnerability of the city and thereby reduce the risk of earthquake disasters? In what manner can planning controls and regulations be applied to effectively make the city a safer place to live? What specific land use planning measures are most feasible in the case of Marikina City?

Based on these questions, the objectives of the research are the following:

1. Identify and evaluate the natural hazards that threaten the city of Marikina and select a probable scenario earthquake.
2. Assess the physical, human, and spatial vulnerability of the city using a scenario earthquake and estimate the expected consequences of this scenario earthquake.
3. Based on the results of risk analysis, formulate land use planning strategies and measures that would reduce seismic vulnerability and therefore disaster risk of the city of Marikina.

1.3 Research Framework of the Study

1.3.1 Definitions and Concepts

This research uses a variety of concepts related to natural disasters such as seismic hazards, vulnerability, and risk analysis as well as concepts in land use planning. The term "disaster" has many meanings depending on the perspective being used, i.e. sociological, political, environmental, or journalistic. Discussions of the definitions of *disaster* also abound in the literature of disaster research (e.g. Shaluf *et al.*, 2003; Quarantelli, 2001; Quarantelli, 1998). For the purposes of this study, a widely accepted definition of disaster is used, that of the UN Department of Humanitarian Affairs (UN/ISDR, 2003a): "A serious disruption of the functioning of the community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community/society to cope using its own resources." As calamitous events of such severity, disasters cause massive damage, disrupt daily community activities, and overwhelm the capacity of the community to respond with locally available resources. The criterion of disrupting everyday community life, which seems to be the common factor among the definitions in the literature, excludes events like a plane crashing into a forest or an earthquake occurring on an uninhabited island. Disasters have also been typified into natural, man-made, or hybrid depending on its origin, and whether they are brought about by slow-onset hazards like drought or by sudden-impact hazards such as earthquakes.

Defining "natural disasters" has also been a contentious issue due to their complex and multi-dimensional nature. For some, a natural disaster is simply the realization of a natural hazard, a perspective that ignores the sociological or economic dimensions of disasters. Some authors assert that no disaster is entirely natural or caused only by factors inherent in the environment over which man has no control, as some human-induced disasters such as famine (which is usually connected to wars or violent conflicts) and technological disasters often have interlocking man-made and natural causes (El-Masri and Tipple, 1997; Blaikie *et al.*, 1994). Varley (1994) further insists that although some natural hazards such as floods and earthquakes are natural phenomena, the impacts associated with them are not.

In general, a hazard means either a natural event or human activity that could potentially inflict harm on people and their possessions and on the environment as well. In the field of environmental risk assessment, an environmental hazard may be a hazardous chemical in the environment, a natural hazard, or a hazardous technology (Congressional Research Service, 1998). Natural hazards are taken to be a part of the environment, i.e. they are natural sources of danger. They are intrinsic processes of nature that could threaten human life as well as a society's physical and economic assets (Frampton, 1996; Davis and Gupta, 1991). An urban natural hazard, as defined by Albala-Bertrand (2003), is "a risk that threatens the city, its population, and socio-economic activities", a definition that incorporates the concept of probability.

In other words, natural hazards are extreme natural phenomena that threaten people and the physical and socio-economic assets that support them. Such hazards include geophysical hazards such as earthquakes and volcanic eruptions; atmospheric hazards such as typhoons; hydrological hazards such as floods and droughts; and mass movement hazards such as landslides and avalanches. Natural hazards may occur in unpopulated areas. But, a natural disaster can only occur when people and their possessions get in the way of a hazard event. Here then enters the concept of vulnerability.

Like the concept of natural disaster, there is no universally accepted definition and measurement of vulnerability (Alwang *et al.*, 2001; Weichselgartner, 2001). The concept of vulnerability recognizes that natural hazards in themselves do not cause disasters, but disasters happen as an outcome of the interaction of biophysical conditions, i.e. presence of natural hazards, and vulnerable conditions of people exposed to such hazards (UN/ISDRb, 2003; UN/ISDR, 2002; Alwang *et al.*, 2001; Smith, 1996; Kovach, 1995; Blaikie *et al.*, 1994). Natural hazards play only a secondary role as "trigger events" of disasters.

Some researchers further assert that vulnerability is socially constructed—that it is a product of unsafe conditions of people due to certain political, social, and economic factors such as socio-economic class, ethnicity, gender, and age, which are the "underlying factors" and root causes of disasters (e.g., Morrow, 1999; El-Masri and Tipple, 1997; Cannon, 1994; Varley, 1994). Studies along this line focus on the reasons that cause differential capacity of various social groups such as women, children, informal settlers, and the elderly to deal with hazards. Political factors such as access to resources and ability to participate in decision-making, i.e. political vulnerability, have been recently also a subject of vulnerability studies (e.g., Zoleta-Nantes, 2000).

In the past few years, urban vulnerability to disasters, particularly that of megacities, have become a focal point (Weichselgartner, 2001). Such studies vary in theme, but many focus on the potential huge losses that urban areas may incur due to disaster risks and how these potential losses can be reduced (e.g., Godschalk, 2003; Villa and Walrod, 1999; Kreimer *et al.*, 1995).

Mitigation, as opposed to disaster response and protection, is now the focus of attention, especially within the context of reducing potential damage and in concert with sustainable development initiatives (Newton, 1997). Mitigation strategies, which are sustained measures taken before a disaster occurs and are aimed at reducing its risk and impacts on society and environment, may involve both structural and non-structural measures (UN/DHA, 1992). As natural disasters have both anthropogenic and natural components, humans then play a central role in disaster mitigation. This means that natural disasters can be mitigated, but not fully prevented, by conscious human action. Vulnerability of populations and settlements to extreme natural events can be modified and reduced by increasing the resilience of communities and implementing disaster mitigation measures that promote safer conditions in urban settlements, even those situated in naturally hazardous areas.

One of the aims of this study is to demonstrate how seismic disaster mitigation and the land use planning process can be integrated. Land use planning can be defined as a systematic process that seeks to allocate rationally and judiciously scarce land resource to achieve certain development objectives in light of competing demands for land from various stakeholders. In the Philippines, land use planning is an ongoing process and is widely practiced as a means to achieve socio-economic and sometimes environmental objectives. Through the years, the planning system of the government has acquired a certain degree of sophistication and lately has become more effective and efficient. A hierarchy of plans and planning levels from the local, provincial, regional to the national has evolved, facilitating functional vertical and horizontal linkages between the different levels and across sectoral concerns of government.

The Philippine land use planning system today is decentralized, multi-level, and inter-sectoral in character. The Local Government Code of 1991 (Republic Act 7160) has shifted more power to govern and, together with it, more responsibilities to local government units

(LGUs) through devolution and local autonomy. Corollary to this, land use planning has become primarily a local government pursuit. It is at the local level where precise location and distribution of land using activities can be pinpointed on the ground. The local government is tasked to formulate its own vision and development agenda within the context of higher level plans. Higher level plans such as provincial and regional physical framework and development plans provide at most macro socio-economic policy guidelines and indicative land use plans, which need to be translated in detail through local comprehensive land use plans (CLUPs). The CLUP is comprehensive as it embodies different sectoral development strategies (e.g., local economy, social development, infrastructure and transportation, and local governance) and gives a spatial dimension to the overall development strategy. It aims to provide strategic guidance for future local public and private investments. They are usually prepared, implemented, and updated on a five- to ten-year cycle.

1.3.2 Conceptual Approach

Risk is another complex concept having various definitions in the literature. Every person may face some degree of voluntary (e.g., when one decides to go skiing) and involuntary (e.g., when one is exposed to an unavoidable extreme natural event such as a hurricane) risk everyday. In the disaster context, risk is defined as "a measure of the expected losses due to a hazard event of a particular magnitude occurring in a specific area over a specific time period" (ICE, 1995). Risk is also defined as the probability or chance of occurrence of an adverse effect on human health or the environment due to exposure (voluntary or involuntary) to an environmental hazard (Ferrier and Haque, 2003; Congressional Research Service, 1998; Smith, 1996; Blaikie *et al.*, 1994).

Risk, as used in this study, is a function of the natural hazard described in terms of magnitude, return period, and probability of occurrence and vulnerability of an individual, group of people, buildings, or the whole urban area. Risk is therefore understood as the probability of a defined natural hazard and the magnitude of the consequences of the occurrence in terms of potential losses (Benson and Clay, 2003). Hence, in this study, risk is the probability of suffering adverse effects or incurring damage or losses in a significant earthquake event.

The conventional equation for disaster risk is (Ferrier and Haque, 2003; UN/ISDR, 2002; ADB, 1991):

$$\text{Disaster Risk} = \text{Hazard} \times \text{Vulnerability}$$

The use of disaster reduction and mitigation measures is introduced in the risk equation as follows (Wisner, 2003):

$$R = (NH \times V) - M$$

This widely accepted shorthand for disaster risk is adopted as the guiding framework in this study, with modifications:

$$R = (SH \times UV) - M$$

where R is the disaster risk of the city, SH means seismic hazards, UV means the seismic vulnerability of an urban area, while M represents the ability to implement disaster mitigation measures, whether structural or non-structural or both, by local and national government institutions, non-government organizations, and the affected community itself. Disaster mitigating measures raises the capacity of the city to recover faster from a disaster or to be more resilient, which lowers disaster risk (Alwang *et al.*, 2001). Resilience is the other side of the same vulnerability coin. These are favorable conditions that alter the vulnerability of the community, such as the presence of community or civic organizations, social networks, and related coping mechanisms (Benson and Clay, 2003). Being resilient means being able to recover from the negative consequences of a natural disaster in the shortest time possible.

This research uses the concept of risk as the conceptual framework. This framework shows that it is the combination of the threat of seismic hazards with vulnerable conditions or elements in an urban area that produces a disaster. In this study, seismic hazards in Marikina City are represented by a single scenario earthquake that is chosen to portray a likely destructive earthquake event in the future.

Vulnerability, in this study, is taken to mean as the susceptibility of urban settlements to the adverse impacts of seismic hazards. It can be assessed and quantified in terms of the potential for or sensitivity to damage and losses in case of a probable earthquake event (Ferrier and Haque, 2003; Panel on Earthquake Loss Estimation Methodology, 1989). Vulnerability describes how severely a city's exposed elements can be adversely affected by an earthquake (Cardona *et al.*, 1999). Losses include deaths and casualties and property damage incurred due to the susceptibility of the city's physical fabric to earthquakes.

Three aspects of urban seismic vulnerability are considered in this study: spatial, physical, and human. Spatial vulnerability stems from the condition of some cities that are sited in naturally hazardous regions. Cities located in seismically active regions and close to sources of earthquakes, such as San Francisco or Tokyo for instance, are at the outset more vulnerable to seismic hazards. The exposure of an entire city to earthquakes already implies potential losses in a future earthquake event. Moreover, spatial vulnerability can be further delineated within the city, as the impacts of an earthquake are not uniform. There may be places within the city that are more vulnerable depending on its geology. A place within a city could suffer more damage or losses due to more intense ground shaking, liquefaction, or surface faulting, compared to another locality, as some seismic hazards occur only specific geologic environments. For instance, liquefaction hazards do not occur randomly in space. They occur only in areas that are geologically delimited by saturated, near surface, loose sediments such as those found in alluvial basins and floodplains. The severity of ground shaking also varies across a city that is underlain by different types of rocks. Soft soil areas are more prone to stronger ground shaking as demonstrated by past earthquakes such as the 1968 Casiguran, Philippines, 1985 Mexico City, and 1989 Loma Prieta earthquakes. Surface faulting is also fixed in geographic location and can occur only along the fault line. The size of the zone of deformation due to surface rupture may extend up to several meters on both sides of the fault line. In short, seismic hazards are location-specific, which gives seismic vulnerability a spatial dimension. As a consequence, structures located in relatively hazardous areas are more vulnerable than others, unless they are seismically designed to withstand earthquake forces.

Furthermore, a city is composed of different land uses. The intensity of the use of land, how densely populated a place is, or if high-occupancy buildings are present depends on the demands of socio-economic activities carried out in that particular place. In this regard, land use can be utilized as an indicator of exposure of a locality within a city that is located in a hazardous area. For example, more intense land uses such as resettlement areas and commercial centers contain more people and structures compared to a low-density residential community. Resettlement areas and commercial centers possess a higher exposure in terms of population and number of buildings compared to other areas within the city. Some land uses likewise perform important urban functions and are thus more sensitive to seismic hazards. Spatial vulnerability is therefore a function of location and exposure to hazard. Exposure describes the elements of a city that are subject to the physical demands imposed by the hazard and is therefore a contributing factor to a city's earthquake disaster risk (Cardona *et al.*, 1999). It is used as one of the main contributing factors in the earthquake disaster risk index (EDRI) that compares cities across the globe according to the magnitude and nature of their earthquake disaster risk. Therefore, the pattern of land use vis-à-vis the geographic distribution of seismic hazards combine to construct the spatial vulnerability of the city. It is thus closely related to physical vulnerability.

The pattern of vulnerability may also change depending on the interaction of the different classes of buildings at risk with the earthquake (ICE, 1995). A locality that is located in a high intensity area may become physically vulnerable if the building stock is highly susceptible to ground shaking. Physical vulnerability is related to buildings, houses, other habitable structures along with critical facilities lifelines, and public infrastructures. It is defined as the potential damage to a city's building stock and other structures. It largely depends on the interaction of existing structures with the ground during an earthquake and therefore also has a spatial dimension. The technical capacity of the built environment to withstand seismic forces is a significant factor in physical vulnerability (ICIMOD, 2001). A building seismically designed and properly constructed, for example, may be protected from earthquakes while a structure without seismic considerations may well fail. In this study, the occupancy type, kind of construction materials used, mode of construction, and density of buildings are the basis of the physical vulnerability of the area.

Earthquakes do not kill; buildings that collapse do. Immediate effects include death and injury, while long-term impacts include physical disability and damage to psychological health. As there is a strong correlation between the potential number of casualties in an earthquake event and the vulnerability of existing structures, the assessment of the physical vulnerability is used to estimate the potential number of fatalities and injuries or the human vulnerability of the area (ATC, 1985). Human vulnerability is thus assessed as a function of the physical vulnerability of the building stock of the city. Like physical vulnerability, human vulnerability also has a spatial domain (Weichselgartner, 2001).

The assessment of urban seismic vulnerability enables land use planners not only to estimate the expected damage in a given scenario earthquake but also to determine areas within the city that are more vulnerable than the others. In this regard, the use of planning measures such as land use regulations and development controls can be effective (Albala-Bertrand, 2003; Benson and Clay, 2003; Durham, 2003; Opricovic and Tzeng, 2003; Kuroiwa, 2002; Olshansky, 2002; Olshansky, 2001; Berke, 1998; Burby, 1999; Smith, 1996; ICE, 1995; Blaikie *et al*., 1994). Land use planning, as a form of non-structural disaster mitigation measure, has been recognized only recently as particularly useful in reducing the seismic vulnerability of the built environment. Even today, there are still political, legal, and social hindrances which stand in the way of applying land use planning in creating disaster-resilient communities (Godschalk, 2004; Burby, 1999).

As one of the four principle currents of planning, which includes social, economic and public policy, land use planning is a means to attain sustainability. (Leitao and Ahern, 2002). Land use planning must be centered on achieving a harmonious relationship between man and "his total natural and human living space" (Troll, 1971; Makhzoumi and Pungetti, 1999). Hence, land use planning is necessary to guide urban development away from hazardous sites, mitigate the expected earthquake losses, and reduce the risk of an earthquake disaster, which are all supportive of achieving of sustainable urban development. The application of land use planning in seismic disaster mitigation is a proactive and long-term investment, which an earthquake country like the Philippines cannot afford to ignore.

1.3.3 Methodology

The general method of risk analysis is used in this study. Risk assessment has been used extensively in estimating the risks chemicals and industries pose to the environment and human health since the 1970s. Borrowing from the field of environmental risk assessment, risk analysis is broadly defined to include any quantitative or qualitative scientific description of an environmental hazard, the negative effects as a result of exposure, conditions that may lead to or modify adverse effects, and uncertainties with regard to any of these factors. The most detailed and well established risk assessments are those used to assess human cancer risks of chemicals (Congressional Research Service, 1998). Other environmental hazards that remain as the highest human health risks are ambient air pollutants, indoor air including radon, pollutants in drinking water, and occupational chemical exposures. Generally, environmental risk assessment involves four steps: hazard identification, dose-response assessment, exposure assessment, and risk characterization. Risks affecting the environment and human well being that preoccupy risk analysts nowadays include global climate change, ozone depletion, habitat alteration, and loss of biological diversity.

Literature on risk analysis methodology, especially assessment of seismic risks intended for application in land use planning, is limited (Ferrier and Haque, 2003). However, numerous disaster studies use hazard evaluation and vulnerability assessment as indispensable tools in carrying out risk analysis for different types of natural hazards in various settings (e.g., Dolce *et al.*, 2003; Ferrier and Haque, 2003; Kijko *et al.*, 2003; Leiba *et al.*, 2003; Weichselgartner, 2001; Elnashai, 1995; ADB, 1991). Completing a hazard and vulnerability analyses before attempting to integrate disaster mitigation and planning is necessary (Pearce, 2003; ICE, 1995; Panel on Eathquake Loss Estimation Methodology, 1989). Risk analysis makes it possible to suggest rational decisions on how to mitigate effects of potentially disastrous earthquakes by combining the techniques of hazard evaluation and vulnerability assessment. Results of risk analysis can be used to develop non-structural mitigation measures such as land use planning (Smith, 1996; UNDRO, 1977).

Hazard evaluation is a process that provides knowledge of seismic hazards in terms of their nature, location, severity, frequency, and other parameters that are necessary in estimating future earthquake losses. There are geologic studies that have already identified and evaluated the seismic hazards that the study area is exposed to. This study extensively relied on this existing literature, as it is prudent and systematic to base any seismic risk assessment on reliable scientific work conducted by experts in the field of seismology and geology.

The second component of risk analysis is vulnerability assessment. Vulnerability assessment involves the quantification or estimation of potential earthquake losses of an area given a particular scenario earthquake (Panel on Earthquake Loss Estimation Methodology, 1989). The nature of vulnerability assessment varies according to whether the elements involved are people, buildings, lifelines, or economic assets and activities (ICE, 1995; Panel on Earthquake Loss Estimation Methodology, 1989). The vulnerability of buildings and population in Marikina City were assessed in this study. Likewise, the concept of exposure was applied in order to map the spatial vulnerability of the city.

Earthquake damage estimation was conducted with the use of a computer program called RADIUS. RADIUS is an earthquake loss estimation software that is suitable for a large-scale loss estimate studies (i.e. at the city or local level) and not for site- or building-specific vulnerability studies. This simplified manner of estimating expected earthquake losses makes it possible to delineate high-risk areas within the city. Maps are produced based on the grid (Excel-based) maps created by the RADIUS program. Particularly for the city of Marikina where no earthquake disaster reduction measures are in place, this loss estimation tool is of great value in this pioneering effort to develop land use planning measures aimed at reducing urban vulnerability and seismic disaster risk.

Proposals for land use planning strategies within the context of sustainable urban development are forwarded. Conceptual plans have been made for several localities or neighborhoods exposed to certain seismic hazards within the city to show how land use and urban development regulations that are risk-sensitive can be implemented.

CHAPTER 2

CITY OF HAZARDS, CITY OF HOPE: MARIKINA CITY, METRO MANILA, PHILIPPINES

2.1 Metro Manila: Regional Geographic Setting of Marikina City

Marikina City is located in the national capital region of Metro Manila. Metro Manila is a megalopolis, composed of contiguous 13 cities and 4 municipalities (Map 2a). It is the seat of government and the nerve center of the national economy.

Each city and municipality has its own local government headed by locally elected officials. The national capital region is under the administration of the Metro Manila Development Authority headed by a Chairperson appointed by the President of the Republic. This administrative apparatus assists the local government units in such metro-wide matters as transportation and traffic management (Figure 2a), solid waste disposal, public safety, and other issues of metropolitanization.

Map 2a. Administrative Map of Metro Manila.

Figure 2a. Flyovers and the MRT in Metro Manila. (Source: DOT Website)

2.1.1 Demographic, Physical and Economic Characteristics

Metro Manila has a land area of 636 square kilometers, 48 percent of which are alienable and disposable (Ibon Foundation, 2002). It was home to close to 10 million inhabitants in the censal year of 2000 (see Table 2a).

Metro Manila accounts for 0.15 percent of the total land area of the country, yet it contained almost 13 percent of the country's total population of 76.5 million in 2000. For the period 1995 to 2000, the annual population growth rate for the National Capital Region was 1.06 percent, much lower than 3.30 percent from the period 1990 to 1995. If the annual growth rate continues at 1.06 percent, then the metropolitan population would double in 65 years.

In 2000, population density in the mega-city in 2000 reached 15,927 persons per square kilometer, very high by any standard. The overcrowding was due mainly to rapid natural increase aided by considerable rural to urban migration. In comparison, by North American standards, an urban density of 5,000 per square kilometer is considered "high." Total number of households was 2,132,989 and the average household size was 4.62.

Metro Manila lies on the eastern shores of Manila Bay on the South China Sea. A large shallow fresh water lake, the Laguna de Bay, borders it on the south. Two major rivers, the Pasig and Marikina Rivers, constitute the primary natural drainage system of the metropolis. Pasig River flows from the lake for about 25 kilometers across the coastal plain into the sea. Marikina River, its main tributary, meanders for 35 kilometers across the Marikina Valley, which nestles the city of Marikina in its bossom.

Table 2a
Political Subdivisions of Metropolitan Manila, 2000

Towns/Cities	Population	Land Area (sq. km.)	Population Density	Growth Rate (1990-2000)
Quezon City	2,173,831	161.12 (25.84%)	13,492	2.67
City of Manila	1,581,082	38.55 (6.18%)	41,013	-0.13
Caloocan City	1,177,604	50.78 (8.14%)	23,190	4.43
Pasig City	505,058	31.00 (4.97%)	16,292	2.42
Valenzuela City	485,433	44.58 (7.15%)	10,889	3.62
Las Pinas City	472,780	41.54 (6.66%)	11,381	4.75
Makati City	444,867	29.86 (4.79%)	14,898	-0.18
Taguig City	467,375	45.38 (7.28%)	10,299	5.77
Muntinlupa City	379,310	46.70 (7.49%)	8,122	3.14
Paranaque City	449,811	47.69 (7.65%)	9,432	3.85
Marikina City*	**389,765**	**21.50 (3.45%)**	**18,129**	**2.34**
Pasay City	354,908	19.00 (3.05%)	18,679	-0.37
Malabon	338,855	15.76 (2.53%)	21,501	1.92
Mandaluyong City	278,474	11.26 (1.81%)	24,731	1.16
Navotas	230,403	10.77 (1.73%)	21,393	2.08
San Juan	117,680	5.94 (0.95%)	19,811	-0.75
Pateros	57,407	2.10 (0.34%)	27,337	1.11
METRO MANILA	9,931,155	623.53 (100.00%)	15,927	

Source of Population Data except for Marikina: NSO, 2000.
Source of Land Area Data except for Marikina: MMDA, 2004.
* Population data taken from NSO (CD-ROM copy), 2000a. Land area data taken from CPDO, 2000.

The metropolitan region can be divided into several physiographic areas, to wit: the Coastal Margin of Manila Bay on the west, Laguna Lowlands on the south, the Marikina Valley on the northeast, and the Guadalupe Plateau (Ibon Foundation, 2002).

The low-lying Coastal Margin includes the cities of Manila, Pasay, Malabon, Navotas, Paranaque, Calookan, Las Pinas, Valenzuela and the reclaimed areas in Manila Bay. The area is underlain by loosely consolidated sand, silt, gravel, and clay and has an average elevation of less than 5 meters above mean sea level. Flooding in these parts is often associated with the tidal variations of Manila Bay. Daily tidal movements can inundate lands up to 0.3 meters above mean sea level.

The Laguna Lowlands is located south of Marikina Valley and on the western shore of Laguna de Bay, a freshwater lake. The lowlands are a minor alluvial plain underlain by thick soils that have high water tables. It includes the shore land cities of Muntinlupa and Taguig.

Further inland lies another flood-prone area, the Marikina Valley. The valley, the alluvial basin of Marikina River, is on the east of Guadalupe Plateau and west of Sierra Madre Mountain Range and makes up 18.5 percent of the total metropolitan area (Besana and Daligdig, 1993). It nestles the cities of Marikina and Pasig and the town of Pateros. The valley has a slope of less than one percent, poor soil drainage, shallow water table, and low soil stability and is thus prone to flooding due to the overflowing of both Marikina and Pasig Rivers.

The Guadalupe Plateau, a low ridge making up around 62 percent of the metropolis, is underlain by hard volcanic rocks that rise up to 70 meters above sea level in some places. Metro Manila's best building sites are found here (Saldivar-Sali, 1992). The cities of Quezon, Makati, Mandaluyong, Pasig, Paranaque, Las Pinas, Muntinlupa and the town of San Juan are located in the plateau.

Metro Manila's huge contribution to the national economy showed its economic importance and dominance over other region. From 1986-1990, its economic contribution was 40 percent of the national industrial production and 42 percent of the service sector output of the whole country (Reyes, 1998). The gross regional domestic product (GRDP) grew at an average of 6.27 percent during the same period, higher that the country's average growth rate of 4.65 percent.

Its economy is largely based on the tertiary sector. It is presumed that the tertiary sector is bigger than what is captured by censuses due to the existence of a large urban informal service sector. In 1995, Metro Manila contributed about 41 percent to the national gross value added (GVA) in the service sector and 40 percent in the manufacturing sector (NSCB, 1995).

2.1.2 Internal Urban Structure of Metro Manila

Today, the metropolis has several central business districts (CBD), namely, the Manila CBD, Makati CBD, Ortigas CBD in the cities of Pasig/Mandaluyong, Cubao CBD in Quezon City (Reyes, 1998). Their respective historical development has resulted to the unique characteristics, functions, and form of each CBD.

Figure 2b. Inside Intramuros, the Walled City of Manila. (Source: DOT website)

Manila continues its historical role as a port city, tourist and recreation hub, center of trade and commerce, and seat of national government. It its territory ca n be found the former colonial city of Manila or Intramuros ("The Walled City"), founded by the Spanish colonial government in 1571 (Figure 2b).

The Manila CBD, situated in the Escolta-Binondo area, is the traditional CBD of the metropolitan area (Figure 2c). It is characterized by a large consumer and personal services and retail trade sector. With its multitude of small merchant stores, shop houses, and sporadic intrusions of modern retail stores and restaurants, it exudes an image of a "bazaar economy." Around this traditional CBD are high-density old residential neighborhoods, which now exhibit decay and blight.

Figure 2c. Binondo-Escolta, traditional CBD of Metro Manila. (Source: DOT Website)

In the south of the metropolis is the Makati CBD—the dominant modern business, financial, commercial, convention, service, and recreation center of the metropolitan region and, to some degree, of the entire country as well (Figure 2d). Makati is the most affluent and classiest city in the Philippines, where the country's rich and powerful prefers to live. It is a showcase of success of private sector led urban development (MMDA and JICA, 1996). In 1948, Roxas-Zobel-Ayala family (now Ayala Corporation) started to develop 979 hectares of swampy suburban land along Pasig River into master planned middle and upper class residential subdivisions.

Today, as the premier national financial and business center, Makati CBD is the base of headquarters of transnational corporations, major Philippine companies, banks, and foreign embassies. As opposed to the Manila CBD with its historical ambience, the Makati CBD, creating a well-known cityscape in the country, is completely modern, with imposing skyscrapers, high-rise office buildings, residential condominiums, world-class hotels, posh restaurants catering to a multicultural clientele, fashion boutiques, jewelry shops, and air-conditioned malls and shopping complexes selling mostly haute couture and imported products.

Figure 2d. Skyline of the Makati CBD, Metro Manila. (Source: DOT website.)

The 600-hectare Ortigas CBD in the city of Mandaluyong is yet another multi-functional modern CBD. It functions as a business, convention, shopping, residential, recreational, and educational. Like its Makati counterpart, it is also an example of a successful urban development initiative of the private sector. The Ortigas family conglomerate began developing the area in the 1950s, but it only started to boom in the late eighties. Predominant land uses include high-end commercial and residential land uses as well as humongous shopping and recreation complexes. De luxe hotels and office buildings are also present side by side with exclusive schools catering to the wealthy. Low-density residential enclaves and townhouses immediately surround the Ortigas CBD.

Figure 2e. Ortigas CBD in Mandaluyong City. (Source: DOT Website.)

In the late sixties, the Araneta family started to develop a 37-hectare property in Quezon City as an alternative recreational and shopping node in the northern part of the metropolis. With a coliseum of 32,000 seating capacity, several department stores, scores of retail shops, throngs of illegal hawkers on the street selling cheap local and imported merchandise (mostly from China), and movie theaters, Araneta Center became a traditional commercial district, but on a smaller scale compared to Manila CBD, and was the favorite shopping center of Manilans until the Makati CBD came into being (Figure 2f).

Figure 2f. Indicative Map of Cubao CBD. (Source: Araneta Coliseum website.)

In recent years, Cubao CBD is being redeveloped into a more contemporary business center that appeals not only to the masses but also to the upper classes that have purchasing power. The redevelopment capitalizes on the opportunity arising from the Cubao station of the Light Rail Transit along EDSA highway. At present, residential land use is practically non-existent inside the CBD, although high-density residential areas surround it. This would be changed with the new 20-year master plan prepared by foreign and local urban planning consultants. Residential and commercial condominiums are slated to rise within the center in the next few years.

These CBDs of high population density and high intensity land uses create a polycentric urban structure in the metropolis. A hierarchy is apparent among them, with the Makati CBD occupying the apex in terms of availability, quantity, and range of higher-order goods and services it offers. The Makati CBD is clearly the national center of action, influence, wealth, and prestige as far as business is concerned.

There also exist smaller, lower-rank business districts around the metropolis. Two such emerging nodes are Rockwell Center located in Makati City's backyard and Eastwood City in Libis, Quezon City. Rockwell Center is a mixed use of business, shopping, recreation, and high-residential uses. Eastwood City's major functions today are leisure and commercial in nature with its cluster of swanky restaurants and cinemas, although vertical residential and office developments are in the offing. They are joining the group of existing lower-rank nodes such as the Malate and Roxas Boulevard hotel-and-leisure node in Manila and the mixed-use developments of Fort Bonifacio Global City and Filinvest Corporate City in southern Metro Manila.

According to MMDA (1996), Metro Manila is predominantly residential in land use. Commercial land constituted 5.2 percent in 1990 and increased to 10.6 percent in 1994. Commercialization continues to develop, concentrating along major roads and at strategic intersections. Industrial land uses, on the other hand, accounted for 5.0 percent of the metropolitan land area in 1992. Small and medium industries are scattered throughout the metropolis, particularly in the cities of Marikina, Las Pinas, Paranaque, Muntinlupa, Valenzuela, and Quezon City.

2.1.3 Natural Hazards

Flooding hazards have been an eternal bane to millions of Metro Manilans. Flood disasters have claimed hundreds of lives and caused millions of property damage. Many natural factors cause flooding in Metro Manila such as typhoons, over banking of rivers, and heavy rainfall. However, flood risks are exacerbated by common man-made ills of an expanding metropolis such as encroachment of floodplains, siltation, and obstruction of waterways by garbage, among others. The negative effects of urbanization and related social causes of flooding in Metro Manila as well as in other Southeast Asian cities have been discussed in depth by many researchers (see Zoleta-Nantes, 2000; Smith, 1996; Blaikie, et al. 1994; Varley, 1994; Brammer and Khan, 1991) and will not be expanded on further.

In terms of earthquake hazards, Metro Manila is highly exposed and has suffered several large earthquakes throughout its long history. Chapter 3 discusses in more detail large earthquakes in the past and their disastrous impacts on historical Manila and the present-day metropolis.

2.2 The Study Area: Marikina City, Metro Manila, Philippines

2.2.1 Historical Background

According to the city's Socio-Economic and Physical Profile (CPDO, 2000), Marikina was founded in 1630. At that time, it was one of the many hamlets or *barrios*[1] outside the waled city of Manila or Intramuros, the Spanish urban base in colonial Philippines. After Spanish Jesuit missionaries erected the church of San Roque in the *barrio* of Jesus dela Pena, Jesus dela Pena was combined with the *barrios* of Barangka and Tañong to form a *pueblo* or town to

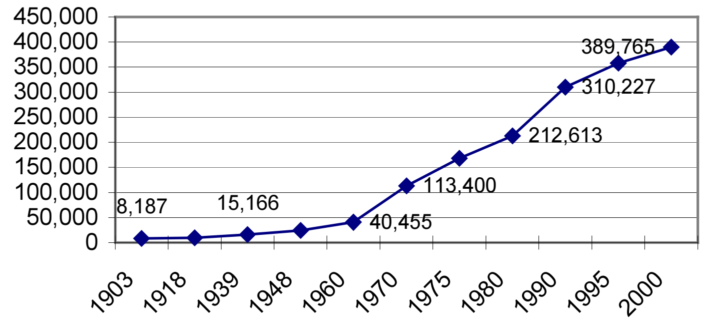
[1] A small farming village of 10 to 1000 houses clustered together by the fields.

expedite the activities of the mission. A municipality status under the province of Rizal was granted to the town in 1787 and was officially named Marikina in 1910.

From a rustic rural village huddled in a cozy bend of a river 374 years ago, Marikina expanded itself along the nurturing length of the river into the surrounding countryside. Due to highly fertile soils in the floodplains of the river, the town grew and prospered, producing traditional crops such as wheat (trigo), rice, and vegetables. For several centuries, it remained largely agricultural, until the rapid urbanization and industrialization in Manila began in the second half of the twentieth century.

At the time of the first census in the country in 1903, Marikina's population was merely 8,187. After the Second World War, Manila's reconstruction began. As it started to urbanize, migrants, searching for better economic opportunities, flocked in from different provinces. Slowly, as urbanization and industrial development of the primate city continued unabated, Marikina became a catch basin of Manila's spillover population. As early as the sixties, Marikina and other peripheral towns were beginning to experience rapid population growth due to in-migration and natural increase (Figure 2g).

Figure 2g. Population Growth of Marikina City, 1903 - 2000



By the 1970s, Marikina experienced a population explosion. From 40,455, the population more than doubled to 113,400. This trend continued apace as people in the city became more affluent and mobile, leading to an increasing demand for housing in Manila and in the suburbs. Master planned residential subdivisions began to sprout in Marikina, as land in the suburbs was relatively cheap and affordable. At the same time, the government an industrial dispersion program which prohibited new manufacturing plants and factories to locate within the city limits of Manila. New investments were redirected to the outlying areas instead. As a consequence, Marikina and other suburban towns got their fair share of industrial development and the concomitant migrant labor. Informal settlements in Marikina, mostly found on the banks of Marikina and Nangka Rivers and numerous creeks, also proliferated.

In 1975, the town was formally incorporated as part of the Metropolitan Manila Area by virtue of Presidential Decree 824. As population grew bigger due to natural increase and in-migration, residential development, both formal and informal, continued to take place well into the 1980s. Agricultural lands and rice fields, concentrated on the floodplains in Barangays Nangka, Concepcion Uno, Malanday, and Jesus dela Pena, eventually disappeared as more lands were used for residential and industrial purposes.

Marikina was officially declared a city in 1996. Today, it has 14 *barangays*, including the three original *barrios*. It has swiftly transformed itself from a farming village into a highly urbanized and industrialized city. It is famous for its export-quality shoes and aspires to become a highly modernized city in the mold of the city-state of Singapore.

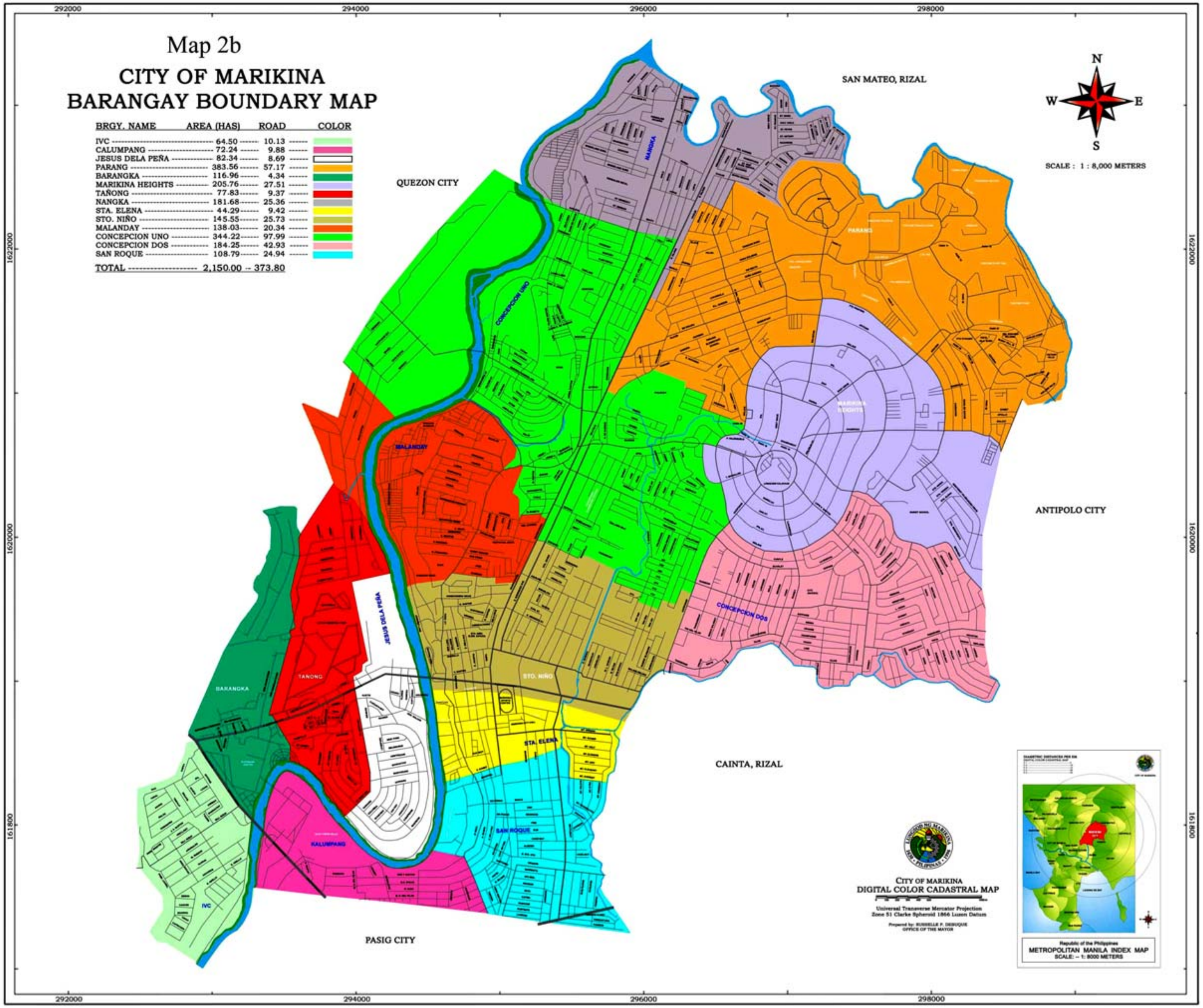
2.2.2 Physical and Environmental Characteristics

The city covers a land area of 21.5 sq km or 2,150 hectares (see Map 2b – Barangay Map). It is nestled in a valley formed by the Sierra Madre mountain range on the east and the gently rolling hills of Quezon City on the west. It is bounded on the north by San Mateo and Antipolo City, both of Rizal Province, and on the south by Cainta, Rizal and the city of Pasig. Its geographic coordinates are 14 35‘ latitude and 14 41‘ longitude. It has a tropical climate with a mean temperature of 27 degrees Celsius. The dry season is from November to April, while May until October is rainy.

2.2.2.1 Topography and Natural Drainage

Since Marikina lies on a valley, most of the city’s topography can be described as level and flat-lying, with slopes ranging from 0 to 2.5 percent (71 percent of the total land area or 1,569 hectares). This is found in the western and central portions of the city, which is sliced by Marikina River. The fertile floodplains were intensively utilized for agricultural uses before the thorough conversion of these farmlands into urban lands.

As the city’s primary natural drainage with a length of 10 kilometers, Marikina River shapes and influences the topography of the city. It drains the city from the northern barangay of Nangka down to Barangay IVC and eventually joins the Pasig River. A tributary of Marikina River, Nangka River also drains the eastern portion of the city and serves as the boundary between Marikina and San Mateo in Rizal Province. Seven other creeks likewise dissect the city. The disappearance of many creeks in the valley due to unchecked agricultural land conversion has rendered this vast area flood-prone. Man-made canals and a flood control system have been built by the city government to minimize vulnerability to flooding.


Map 2b
CITY OF MARIKINA
BARANGAY BOUNDARY MAP
BRGY. NAME AREA (HAS) ROAD COLOR
IVC 64.50 10.13
CALUMPANG 72.24 9.88
JESUS DELA PEÑA 82.34 8.69
PARANG 383.56 57.17
BARANGKA 116.96 4.34
MARIKINA HEIGHTS 205.76 27.51
TAÑONG 77.83 9.37
NANGKA 181.68 25.36
STA. ELENA 44.29 9.42
STO. NIÑO 145.55 25.73
MALANDAY 138.03 20.34
CONCEPCION UNO 344.22 97.99
CONCEPCION DOS 184.25 42.93
SAN ROQUE 108.79 24.94
TOTAL 2,150.00 373.80
SAN MATEO, RIZAL
QUEZON CITY
ANTIPOLO CITY
CAINTA, RIZAL
PASIG CITY
N
W
E
S
SCALE : 1 : 8,000 METERS
CITY OF MARIKINA
DIGITAL COLOR CADASTRAL MAP
Universal Transverse Mercator Projection
Zone 51 Clarke Spheroid 1866 Luzon Datum
Republic of the Philippines
METROPOLITAN MANILA INDEX MAP
SCALE: 1: 8000 METERS

Softly rolling hills (2.5 to 10 percent slope) are mostly found in the eastern part of the city in the direction of the mountainous city of Antipolo, a part of the chain of Sierra Madre. The western edge of Marikina is characterized by undulating terrain towards the low ridge of Quezon City. These gently sloping areas make up 29 percent of the city.

2.2.2.2 Surface Geology

Map 2c (Surface Geology Map) shows the surface geology of Marikina City. The area is underlain by four major types of rocks:

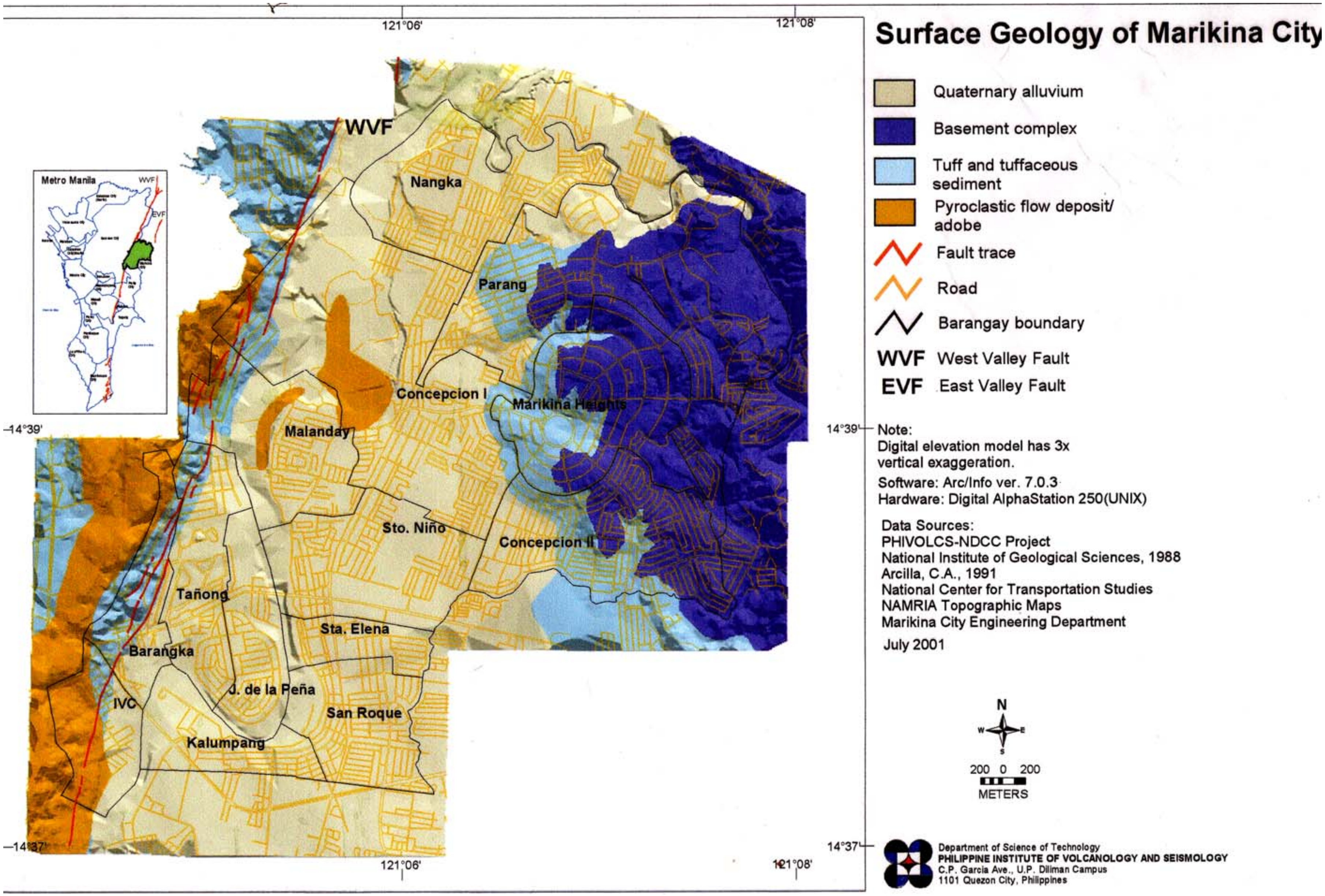
1. Basement complex and adobe bedrock, found in the hilly eastern side of the city towards the neighboring mountainous city of Antipolo.
2. Pyroclastic flow deposit/adobe underlying the gentle to moderately-sloping western edge of the city, found along the border with nearby Quezon City.
3. Tuff and tuffaceous units, i.e. inter-bedded shale and sandstone, lenses of limestone, calcareous shale, reworked sandy tuffs, and tuffaceous shale, found in both inner eastern and western sides of the city.
4. Quaternary alluvium composed of non-liquefiable sedimentary deposits, which form the wide flat-lying plains in the middle of the city.
5. Liquefiable alluvial deposits accumulating from 20 meters to 100 meters thick in some places, concentrated along the river and in the lowlands (Daligdig and Besana, 1993).

The last lithologic unit is added to distinguish areas that are underlain by alluvial deposits which are susceptible to liquefaction from areas which are not liquefiable based on the Liquefaction Hazards Map produced by PHIVOLCS.

2.2.3 Demography and Population Trends

Looking at Metro Manila's roster of towns and cities (Table 2a), Marikina City can be described as moderately populated in comparison with the other cities. Its population density was 18,129 persons per square kilometer. The city is divided into 14 political-administrative units or *barangays*. The breakdown of the population per *barangay* is shown in Table 2b.

Five *barangays* were the most populous, namely, Concepcion Uno (21 percent), Parang (17 percent), Malanday (11 percent), and Marikina Heights and Nangka with 8 percent each. Altogether, they accounted for 65 percent of the city population.


Surface Geology of Marikina City
Quaternary alluvium
Basement complex
Tuff and tuffaceous sediment
Pyroclastic flow deposit/ adobe
Fault trace
Road
Barangay boundary
WVF West Valley Fault
EVF East Valley Fault
Note:
Digital elevation model has 3x vertical exaggeration.
Software: Arc/Info ver. 7.0.3
Hardware: Digital AlphaStation 250(UNIX)
Data Sources:
PHIVOLCS-NDCC Project
National Institute of Geological Sciences, 1988
Arcilla, C.A., 1991
National Center for Transportation Studies
NAMRIA Topographic Maps
Marikina City Engineering Department
July 2001
N
200 0 200
METERS
Department of Science of Technology
PHILIPPINE INSTITUTE OF VOLCANOLOGY AND SEISMOLOGY
C.P. Garcia Ave., U.P. Diliman Campus
1101 Quezon City, Philippines
121°06'
121°08'
14°39'
14°37'
Metro Manila
WVF
EVF
Nangka
Parang
Concepcion I
Marikina Heights
Malanday
Sto. Niño
Concepcion II
Tañong
Sta. Elena
Barangka
J. de la Peña
San Roque
IVC
Kalumpang

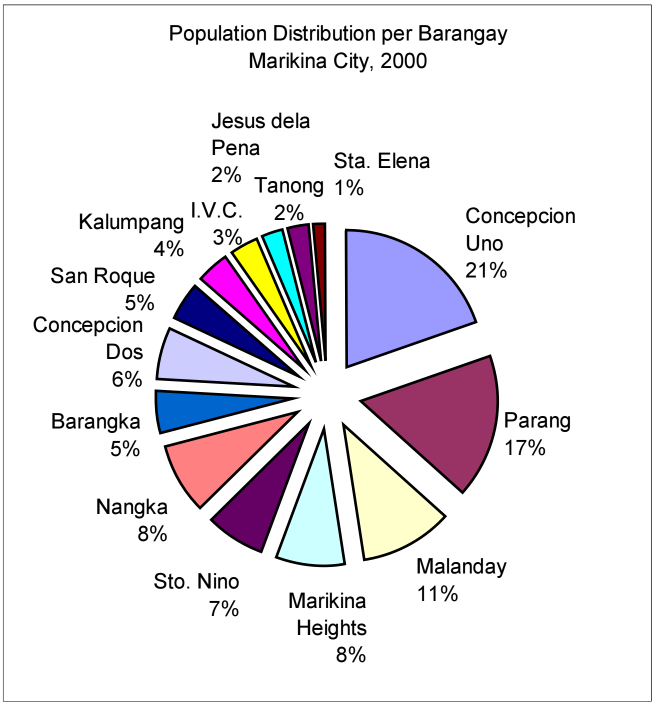
These *barangays* were also the biggest in terms of territory. The most densely packed barangays were Malanday, Concepcion Uno, Kalumpang, and IVC.

Table 2b

Population Statistics Per Barangay, Marikina City

Barangay	Population Size (2000)	Number of Households	Land Area (in sq km)	Population Density (2000)	Projected Population (2010)
Concepcion Uno	76,427	15,997	3.4422	22,203	96,577
Parang	66,004	13,774	3.8356	17,208	83,406
Malanday	42,256	8,847	1.3803	30,614	53,397
Nangka	32,273	6,385	1.8168	17,764	40,782
Marikina Heights	31,355	6,088	2.0576	15,239	39,622
Santo Niño	27,459	5,681	1.4555	18,866	34,695
Concepcion Dos	23,802	4,627	1.8425	12,918	30,077
Barangka	19,466	4,084	1.1696	16,643	24,598
San Roque	17,969	3,756	1.0879	16,517	22,706
Kalumpang	14,552	3,067	0.7224	20,143	18,388
I.V.C.	13,317	2,778	0.6450	20,646	16,828
Jesus dela Pena	9,742	2,001	0.8234	11,831	12,310
Tañong	9,461	1,927	0.7783	12,156	11,955
Sta. Elena	5,682	1,148	0.4429	12,829	7,180
MARIKINA CITY	389,765	80,160	21.5000	18,129	492,524

Source: Population size data from NSO, 2000a; Land area data from CPDO, 2000.



Concepcion Uno, Parang, Malanday, Marikina Heights and Nangka are the *barangays* hosting the resettlement sites of the city. This is the reason why these *barangays* became highly populated. Some of the biggest are Tumana, Libis, and Dona Petra Resettlement Sites in Concepcion Uno, Malanday Resettlement Site in Malanday, San Miguel Realty in Parang, and Camacho Resettlement Site in Nangka.

Based on the 2000 housing census, there were 1,667 households that were illegally occupying the land where their houses stood. If the figures for those whose land tenure status were unreported were added, this number would rise to 4,388 or 5.5 percent of the total number of households in the city. This number signifies the success of the resettlement program of the city government. In the beginning, when the program was implemented in 1993, the total number of informal settlers and squatters (i.e. those who did not own the land they were occupying) reached 45 percent of the total population in 1995 (MSO, undated).

Barangays Kalumpang and IVC became relatively dense due to their smaller land area. Barangay Sta. Elena had the least residents as land uses are predominantly commercial and institutional in nature, where Marikina City Hall, Marikina Sports Complex, Sta. Elena High School, Marikina Elementary School and Marikina Insitute of Science and Technology campus are located. Residential population in Barangay Tañong was also relatively comparatively low as Loyola Memorial Park, a spacious private cemetery, eats up about 30 percent of the barangay's land area.

Marikina City as a whole is a young city; that is, it is home to a very young population. Those aged 5 to 24 years old accounted for 41 percent of the total population (Table 2c). This age bracket represents the school age population as children in the Philippines start going to pre-school at age 5 or 6, normally finish high school at age 16, and graduate from college at age 20.

Table 2c
Barangay Population by Age Group, Marikina City, 1999

Barangay	Age Group			
	0-4	5-24	25-64	Over 65
Barangka	2103	7676	9128	559
Calumpang	1488	5732	6704	628
Concepcion Uno	10,293	31,327	32,868	1939
Jesus dela Peña	1043	3716	4553	430
Malanday	5600	17,042	18,609	1005
Nangka	3882	13,434	14,110	847
Parang	8297	28,023	28,065	1619
San Roque	1843	6888	8385	853
Santa Elena	403	2268	2694	317
Santo Niño	3132	10,692	12,499	1136
Tañong	1119	3684	4289	369
Concepcion Dos	2492	8792	11,153	1365
Marikina Heights	3821	13,445	13,298	791
Industrial Valley	1540	5394	5883	500
TOTAL	47,056	158,113	172,238	12,358

Source: NSO, 2000a.

However, according to the NSO census (1997), the working population includes those aged 15 years old and over. From the age group of 15 to 24 years old, 38,031 were counted to be in the labor force or those who were actively looking for gainful employment, accounting for about 40 percent of this age group. This means that a big chunk of the age group were already out of school or dropped out.

Again, not surprisingly, the barangays with the youngest population were the highly dense areas of Concepcion Uno, Malanday, Parang, Nangka, and Marikina Heights. In terms of the number of households, the five most populous barangays were not surprisingly also the biggest. The average household[1] size in Marikina City in year 2000 was 4.9 or an average of five persons in a household, which was comparable with Metro Manila's. The average number of children born to married women was two.

The average growth rate of Marikina City from 1990 to 2000 was 2.34. If this growth rate continues, the projected population by year 2010 is 492,524. The breakdown of the projected population per barangay is shown in Table 2b. Thirty years after the 2000 census, the population would double and reach 786,462, assuming the same growth rate.

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2.2.4 Economic Profile and Trends

In 1997, the size of the labor force was 153,462 almost 92 percent of which were gainfully employed. Majority of those employed were 25 to 44 years of age (77,131 or 55 percent). Male workers (78,077 or 55 percent) outnumbered the females (62, 811 or 45 percent).

Based on the breakdown of workers by major industry group (NSO, 1995), about 37,000 were employed in the manufacturing sector, while the tertiary sector employed 59,000. Tertiary sector refers to community, social, and personal services; financing, insurance, real estate, and business services; and wholesale and retail trade. Other industry groups such as construction employed 34,000 workers, transportation, storage and communication with 19,000, and electricity, gas, and water accounted for 1,000 workers, making a total labor force of 132,000.

[1] According to NSO, a household is a social unit consisting of a person or a group of persons who sleep in the same housing unit and have common arrangements in the preparation and consumption of food.

Table 2d Commercial Establishments by Type of Business, Marikina City, 1999	
Type of Business	Number
Sales	5,979
Service	2,034
Manufacturing	967
Property for lease	1,577
Food outlets/eateries	522
Amusement	209
TOTAL	11,288

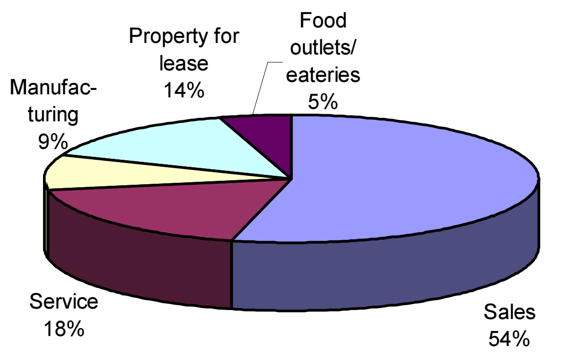


Figure 2i. Commercial Establishments in Marikina City, 1999

Using the 1999 data from the Business Permits and Licensing Office (BPLO) of the city government, Marikina's tertiary sector experienced positive growth from 1992 to 1999. In only 7 years, the number of business establishments rose from 6,988 to 11,288 (Table 2d), or a 61 percent rate of change, an astounding increase by any measure. For instance, 367 establishments were set up in the city from 1998 to 1999 alone. In 1999, the service sector was dominated by the wholesale and retail sale sub-sector, accounting for 54 percent of the total commercial establishments in the city (Figure 2i). This was followed by commercial establishments engaged in personal, community, and business services with 18 percent.

In terms of industries, 967 industrial firms were registered at the Marikina BPLO as of 1999 (CPDO, 2000). Of this, shoe manufacturers accounted for 333 or 37.5 percent. Marikina's shoe industry supplied 70 percent of the total shoe requirement of the country, establishing itself as the "Shoe Capital of the Philippines." Shoe making in Marikina in the not so distant past was merely a cottage industry, a family business or a household means of livelihood undertaken at home or in the backyard. Now, it has become a multi-million dollar industry and more export-oriented. Nevertheless, based on the number of workers from the database of Marikina City's Workers Affairs Office, many shoe manufacturers employ a work force of 10 to 30 workers, which are still classified as small to medium enterprises or SMEs.

Table 2e shows the types of industrial establishments that operated in Marikina City from 1995 to 1999 based on BPLO data. Aside from shoe manufacturers, Marikina also plays host to major industrial corporations such as Fortune Tobacco, Purefoods Corporation (food processing), Goodyear Philippines (tire makers), Noritake Mariwasa (porcelain makers), Paramount Chemical, Tower

Steel, Manila Bay Spinning Mills and Coats Manila Bay (thread and hosiery), Arms Corp of the Philippines (fire arms and ammunition) and Goya Nestle Philippines (confectionary).

Table 2e

Types of Manufacturing Firms in Marikina City, 1995-1999

Type of Industry	1995	1996	1997	1998	1999
Shoe Making	509	489	499	450	363
Slippers	45	45	43	50	34
Bag Making	58	50	42	42	37
Food Processing	161	170	183	197	203
Handicrafts	23	21	17	17	17
Garment	80	62	66	73	53
Furniture/Woodcraft	29	26	39	39	35
CIgarette	2	2	2	1	1
Iron works	14	8	55	57	23
Other manufacturers	208	255	142	171	201
TOTAL	1,129	1,128	1,088	1,097	967

Source: CPDO, 2000.

The city government is encouraging the shoe and footwear industry to become more competitive, not only in the domestic market but also in the global market as part of its continuing industrialization strategy. Export promotion is one of the cornerstones of the economic growth program of the city. In October 2002, in its bid to become internationally known in the global shoe industry, Marikina City produced a gargantuan shoe and thus garnered the recognition from the Guinness World Records as the creator of the world's largest shoe (17.3 ft x 7.7 ft x 6.6 ft), in which 30 people can comfortable fit inside.

Furthermore, in accordance with its industrialization thrust, the city government began in 1997 a tripartite agreement with management and labor to promote and preserve industrial peace. The objective was to make Marikina "strike-free" and "industry-friendly."

As an evidence of its success through the years, Marikina City was awarded the top honor as the Most Competitive Metropolitan City in the Philippines for 2003 in the Phlippine Cities Competitiveness Ranking Project conducted by a multi-sectoral consortium headed by the Asian Institute of Management (Figure 2j). Previously, in 2002, it ranked as the third Most Competitive Metro City nationwide, next only to Metro Davao and Metro Cebu, and the number one city in Metro Manila. The search evaluated urban centers throughout the country using a criteria based on economic competitiveness, effectiveness in providing a conducive atmosphere to industry and business, and ability to offer a higher standard of living to residents.

The year 2004 has been declared by the incumbent city mayor as an "investment year" for all economic sectors during which all sorts of business and financial incentives (e.g. tax breaks, no building permit fees, etc.) are offered to entice investors to do business in the city. Given these economic trends and development thrusts of the city government, Marikina is expected to continue its present path of economic development towards commercialization and industrialization.

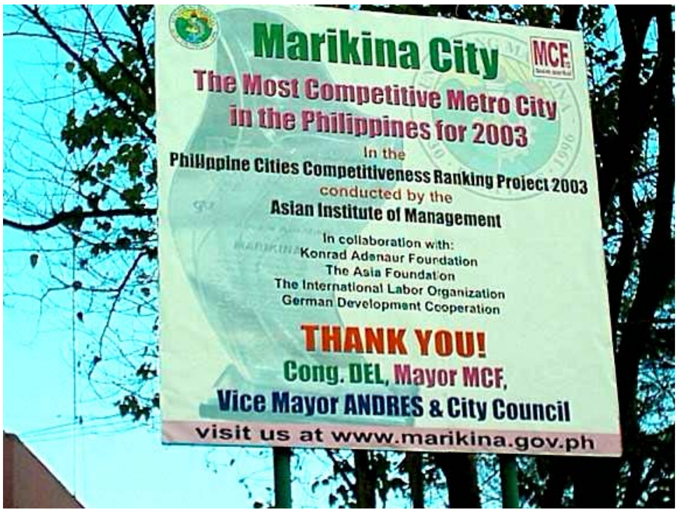


Figure 2j. Marikina City was chosen in 2003 as the Most Competitive Metro City in the country.

2.2.5 Disaster Management

The primary legal basis for disaster management in the Philippines is provided by Presidential Decree 1566 dated 11 June 1978, which seeks to strengthen national disaster control capabilities and establish a national program on community disaster preparedness. It mandates the creation of Disaster Coordinating Councils (DCCs) from the national level down to the local and *barangay* levels as well as the formulation of a National Calamities and Disaster Preparedness Plan. By requiring the creation of local disaster coordinating councils, the law emphasizes a policy of self-reliance among local governments and their constituents and the importance of local disaster management plans. Another pertinent legal mandate is the Department of Local Government's Memorandum Circular Number 89-10 issued in February 1989, which requires all regions and local government units to organize or reorganize their respective DCCs and the immediate operations thereof.

Pursuant to P.D. 1566, the National Disaster Coordinating Council (NDCC), the highest policy-making body for disaster management, was created. Its members include most of the Cabinet Secretaries, the Armed Forces Chief of Staff, and the Office of Civil Defense Administrator. At the regional level, there is the Metropolitan Manila Disaster Coordinating Council (MMDCC). Council member include the regional directors of various government line agencies and the Office of Civil Defense and the MMDA Chair. As a coordinating council, its main tasks are to monitor and evaluate activities on disaster preparedness as well as the control of operations during and after disasters (Dejoras, 1993). All DCCs are required to undertake disaster preparedness activities prior to any emergency situation such as training, periodic disaster drills and exercises, preparing contingency plans, stockpiling, and public information and education campaigns.

Marikina City has a long and varied experience in natural disaster management, particularly with regard to typhoons and floods. By virtue of Executive Order Number 0004-92, issued in 1992, the Marikina City Disaster Coordinating Council (MCDCC) was revived and reorganized with the City Mayor as Chair, Vice-Mayor as Vice-Chair, the City Engineer as Action Officer, the City Administrator as Disaster Coordinator along with 33 members who represent their respective offices (e.g., budget office, treasury, health, Rescue 161, local fire and police stations, motor pool, traffic engineering, community relations, general services, etc.) and the *barangay* captain of each of the 14 *barangays*.

Its organizational structure is the same with all other DCCs with three Staff Units (i.e. Intelligence and Disaster Analysis, Plans and Operations, and Resources Management) and eight Operating Services (i.e. Communications and Warning, Public Information, Rescue and Engineering, Transportation, Health and Medical, Public Safety, Fire Service, and Disaster Relief, Welfare and Rehabilitation).

The Marikina City Disaster Coordinating Council (MCDCC) has outlined a Calamity and Disaster Preparedness Plan for different natural hazards, e.g., Typhoons and Floods, Fires, Earthquakes, Epidemic, Mass Action, Power Failure, and Water/Air Disaster. The plan primarily outlines the division of tasks, the who-will-do-what during disaster relief and emergency operations. It basically enumerates a list of activities assigned to different persons or groups shortly before a disaster strikes, during the disaster itself, and the post-emergency period.

For instance, in a typhoon or flooding scenario, detailed activities listed under the pre-disaster period can be summarized as early warning and public information campaign and mobilizing personnel and resources for response and emergency operations (i.e. medical personnel, ambulances, and transportation for evacuating people). During the disaster, anticipated activities include rescuing trapped residents, providing first aid and treating injured victims, preparing emergency or temporary shelters with adequate sanitary facilities, evacuating hazardous areas and transporting victims to pre-designated evacuation centers, distributing relief goods such as packed food, clothing, and blankets, re-routing of traffic, and maintaining peace and order. In the post-disaster period, mass feeding and the provision of temporary mass shelters especially for homeless victims are expected to continue. Control of communicable diseases in calamity areas and rebuilding of destroyed houses are expected to be carried out in the post-disaster phase as well.

The emergency preparedness plan for a typhoon/flooding event is highly detailed and given the first priority, since past typhoon and flooding disasters are very fresh in the mind of both local government officials and residents. It must be noted that the city government has relocated many squatter communities from flood-prone areas along creeks and Marikina River, which have now been turned into a river park, to resettlement sites within the city through its ongoing Settlements Program. This program can be a cornerstone for a more vulnerability-focused, proactive approach to typhoon and flood disaster risk management.

Not surprisingly, attention given to earthquakes, another pertinent hazard but perhaps obscure to the minds of the people who have not experienced one in recent memory, is cursory. This could be because of the fact that there has been no earthquake disaster in recent memory in the city, and the possibility and impacts of an earthquake hitting the city is not manifested yet in the present collective consciousness. Earthquake disaster mitigation is not mentioned in the plan. What is mentioned is a pre-emergency period, which in this emergency preparedness plan refers to the time immediately before a disaster strikes, when there is enough time to warn people on an impending hazard. As earthquakes as a rapid-onset hazard can hardly occur with warning, no plan was therefore formulated for the pre-emergency period in an earthquake scenario, stating that (Marikina City, undated): "There may be scanty information available to forewarn the people of earthquakes/tremors."

Moreover, the emergency preparedness plan expresses optimism during th emergency situation itself by stating that, "Earthquakes/tremors may or may not result in disaster…." Nevertheless, during the emergency period, the disaster coordinating council and its various units will be on hand to implement emergency operations. During the post-emergency period, it is expected that there would be a need to treat the wounded, transport victims to evacuation centers, and extend loans to those whose houses were damaged by the earthquake.

Emergency management is an important component of natural disaster management. It includes advance planning and training necessary for emergency operations to be carried out successfully, relief activities during a disaster, and the post-disaster recovery period in which damage is repaired (NRCR, 1983). In short, the disaster preparedness plan of Marikina is an emergency management plan. It is geared towards disaster response and relief. The emphasis is during the disaster itself and, in the case of typhoons and flooding, the short time prior to the event.

Disaster mitigation or reduction, the other crucial component of natural disaster management, is not addressed in the plan. Mitigation measures are carried out long before a disaster occurs in order to reduce the potential long-term losses or impacts of a particular hazard (NRCR, 1983). Unfortunately, a seismic disaster scenario is given no attention at all in the emergency preparedness plan of Marikina. Recovery and rehabilitation measures are also not covered.

As it is, the Marikina City Disaster Preparedness Plan is very useful for responding to emergency situations, as the city is immediately on its feet to coordinate and control the situation. The reactive approach reflects the passive acceptance of disasters, particularly typhoons and floods, and that, at the same time, they should be prepared when it occurs. On one hand, this is good as emergency preparedness is necessary to take control of a disaster situation. On the other, a more proactive and long-term mitigation strategy is missing, which can handsomely complement the preparedness posture of the city. The possibility of reducing disaster risk and therefore future losses through disaster mitigation is not fully appreciated.

2.2.6 Spatial Patterns and Land Use Trends in Marikina City

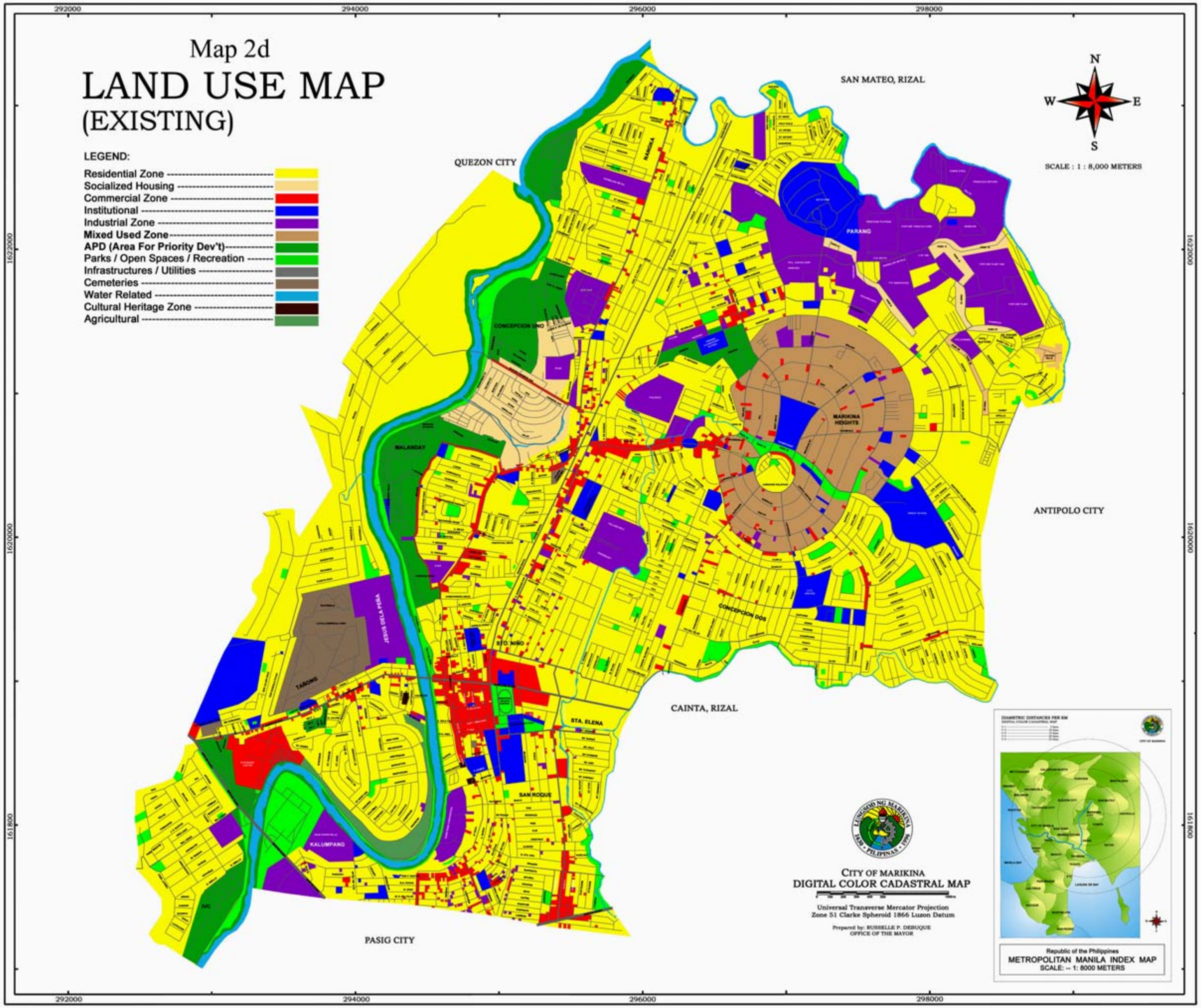
The spatial pattern of the City of Marikina can be described and analyzed in terms of the different major land uses that divide the city into several districts: commercial, residential, industrial, and institutional districts (Map 2d – Existing Land Use Map). As an overview, Table 2f summarizes the land uses in the city in terms of land area.

Table 2f. Land Uses in Marikina City, 1999

Land Uses	Area (sq. km.)	Percentage
Residential	8.1306	37.82
Industrial	2.8057	13.05
Area for Priority Development	1.7922	8.33
Commercial	1.3282	6.17
Mixed Use	1.5522	7.22
Institutional	0.7260	3.38
Open Spaces/Parks/Recreation	0.6191	2.88
Socialized Housing	0.4096	1.90
Cemetery	0.3789	1.76
Agricultural	0.0190	0.08
Cultural Heritage	0.0025	0.01
Roads	3.7380	17.39
Total	21.5000	100.00

Source: CPDO, 2000.

The types of land uses shown in Table 2f are general zoning categories. Mixed Use Zone refers to the entire Barangay Marikina Heights in which residential, commercial and light industrial land uses are allowed per Ordinance Number 47 enacted in 1989, while the Cultural Heritage Zones endeavors to protect two old historical Spanish buildings located along Rizal Avenue, one of which has been turned into a footwear museum.



Map 2d
LAND USE MAP
(EXISTING)
LEGEND:
Residential Zone
Socialized Housing
Commercial Zone
Institutional
Industrial Zone
Mixed Used Zone
APD (Area For Priority Dev't)
Parks / Open Spaces / Recreation
Infrastructures / Utilities
Cemeteries
Water Related
Cultural Heritage Zone
Agricultural
N
W
E
S
SCALE : 1 : 8,000 METERS
SAN MATEO, RIZAL
QUEZON CITY
ANTIPOLO CITY
CAINTA, RIZAL
PASIG CITY
PARANG
MARIKINA HEIGHTS
CONCEPCION UNO
CONCEPCION DOS
MALANDAY
NANGKA
STO. NIÑO
STA. ELENA
SAN ROQUE
JESUS DELA PEÑA
TAÑONG
KALUMPANG
IVC
292000
294000
296000
298000
1622000
1620000
161800
CITY OF MARIKINA
DIGITAL COLOR CADASTRAL MAP
Universal Transverse Mercator Projection
Zone 51 Clarke Spheroid 1866 Luzon Datum
Prepared by: RUSSELLE P. DEBUQUE
OFFICE OF THE MAYOR
Republic of the Philippines
METROPOLITAN MANILA INDEX MAP
SCALE: -- 1: 8000 METERS

The Area for Priority Development Zone is now either used for socialized housing projects of the local government or as resettlement site for informal settlers who used to live along Marikina River and creeks within the city.

For analytical purposes, the spatial pattern and land use will be discussed using the various functional zones or districts that exist within the city. The delineation of these zones is determined by their role or multiplicity of roles (existing as well as expected), common physical or social characteristics within the zones aside from the predominant type of land use.

2.2.6.1 Traditional Commercial District

The traditional commercial and business center of Marikina is found in the old *poblacion* in Barangay Sta. Elena. It is bounded by Rizal Avenue on the west, Bonifacio Avenue on the north, Shoe Avenue on the east and Paz St. on the south. It is a mixed-use district, although commercial and business activities predominate. As such, it exhibits an amorphous combination of predominantly commercial land use interspersed with residential and institutional land uses. It is a traditional commercial center in the sense that it is characterized by a concentration of individual retail, wholesale, and service establishments housed in their own buildings and not contained within one huge shopping mall (Figure 2k).

Figure 2k. New commercial buildings on Shoe Avenue.

The New Marikina Public Market is located here as well. Sporadic signs of modernization can now be found though in the presence of new multi-story commercial buildings and ubiquitous fast-food shops such as Jollibee, Chowking, and Greenwich. This district is expected to continue its role as a regional high-density commercial zone that serves not only local residents but also from adjacent cities due to the presence of the Public Market.

The commercial strip along Rizal Avenue is where numerous retail and wholesale shops as well as consumer and business service establishments of all types can be found, many of which are located on the first floor of low-rise commercial and residential buildings. This was the "downtown" of the previous decades. This amorphous commercial strip stretches northwards past Bayan-Bayanan Avenue towards Barangay Nangka. Rizal, Bonifacio, and Shoe Avenues are the primary arterials within the city and are plied by public transportation, i.e. jeepney[1] and bus lines, and private vehicles.

Commercial development eventually expanded along the major thoroughfares of Bonifacio Avenue and Shoe Avenue. The impetus for the commercialization along Shoe Avenue is the presence of several schools, i.e. Marikina Institute for Science and Technology, Marikina Elementary School, and Marikina High School (Figure 2l). It is also where the city hall of Marikina is located. The proximity of these government and educational institutions contributes to the commercial vibrancy of the district.

Figure 2l. Commercial and institutional establishments (Marikina City Hall) on Shoe Ave.

Commercial activities also rapidly developed along Bonifacio Avenue. This is the main thoroughfare that connects Marikina City to neighboring Quezon City. Retail and wholesale stores, banks, food outlets, and convenience shops mushroomed on both sides of the road in the usual street frontage fashion observed in innumerable commercial strips in perhaps every Philippine city.

[1] Jeepneys are the major mode of public transportation in urban areas in the Philippines.

This is considered here as another sign of a traditional commercial district. Buildings face toward the street in order to capture potential customers who are either driving by or walking on the sidewalk. By tradition, residences that face upon a major road artery sooner or later are converted into commercial use due to business opportunities afforded by accessibility and passing traffic.

Figure 2m. Typical commercial strip development on Bonifacio Avenue.

Hence, in this manner, a main arterial road is turned into a commercial strip, typically characterized by street-oriented commercial and business buildings intermingled with shop houses (buildings whose first story is used for commercial purpose) and residential structures. The intermittent presence of institutional uses, i.e. elementary schools and churches, are normal.

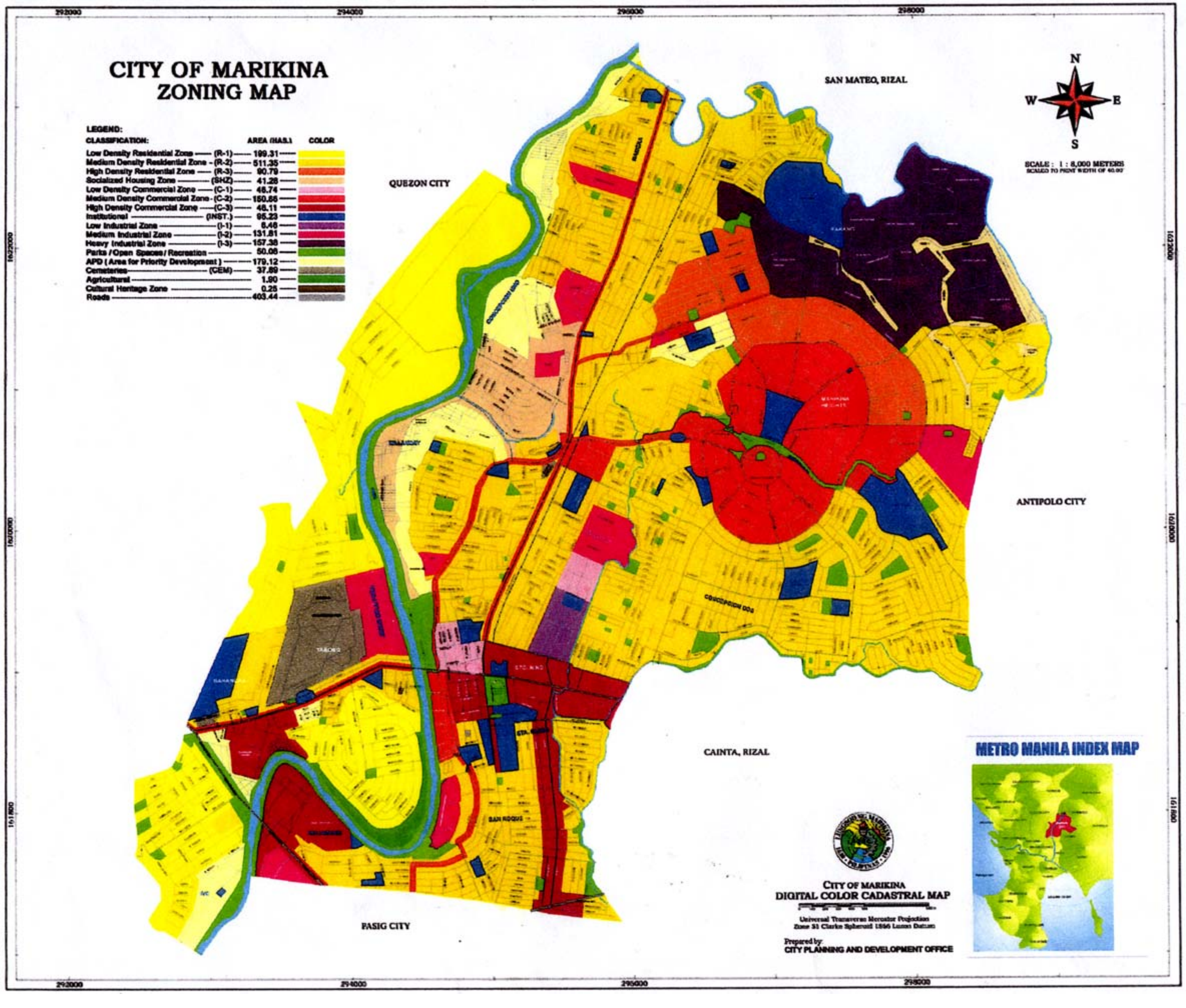
Inside this traditional business district, the New Marikina Public Market or "People's Mall" on W. Paz St can be found. The area around the Public Market can be described as a "superblock," as the city government has closed off to vehicular traffic some 439 meters of road leading to the Public Market and covered the streets with a roof to facilitate pedestrian traffic, namely, Jacinto St., Burgos St., F. Paz St., Cruz St. and E. dela Paz St. (Figure 2n).

Figure 2n. Roads from Shoe Avenue and Bonifacio Avenue leading to the Public Market have been covered with a roof, converting several grid blocks into a “superblock.”

In essence, the covered grid blocks have been combined to form one huge open marketplace, a sort of a consumers’ paradise, which revolves around the Public Market. As a result, residential houses within the superblock have been transformed into shop houses where the first floor is converted into retail and commercial shop and the second floor is maintained as living space to take advantage of the large consumer traffic on the streets .

The traditional commercial district is a sign of the organic physical growth of the town. The district originated from the site of the old *poblacion* or town center and has since then evolved into a regional commercial center. However, it is the result of the unplanned growth of the old “downtown area,” which expanded upon the dictates of the market forces and not due to conscious land use planning. As more and more people moved into the new subdivision developments around the *poblacion* in the 1970s and 1980s, requirements for commercial space likewise increased to supply the daily consumer needs of a growing residential population. As a result, the traditional commercial district is unstructured and formless and composed of a bewildering array of commercial, business, recreational, industrial, residential, and institutional land uses (Figure 2o). The district is expected to continue its traditional commercial functions and is zoned as a high-density commercial zone in the approved zoning plan of 2002 (Map 2e – Zoning Map).

Figure 2o. Organic growth of the traditional commercial center resulting to amorphous mixed land uses. An example is this house sandwiched between the Public Market (left) and a commercial building (right).


CITY OF MARIKINA
ZONING MAP
LEGEND:
CLASSIFICATION: AREA (HAS.) COLOR
Low Density Residential Zone (R-1) 199.31
Medium Density Residential Zone (R-2) 511.35
High Density Residential Zone (R-3) 90.79
Socialized Housing Zone (SHZ) 41.28
Low Density Commercial Zone (C-1) 46.74
Medium Density Commercial Zone (C-2) 150.66
High Density Commercial Zone (C-3) 46.11
Institutional (INST.) 95.23
Low Industrial Zone (I-1) 6.46
Medium Industrial Zone (I-2) 131.81
Heavy Industrial Zone (I-3) 157.38
Parks / Open Spaces / Recreation 50.06
APD (Area for Priority Development) 179.12
Cemeteries (CEM) 37.89
Agricultural 1.90
Cultural Heritage Zone 0.25
Roads 403.44
QUEZON CITY
SAN MATEO, RIZAL
ANTIPOLO CITY
CAINTA, RIZAL
PASIG CITY
N
W
E
S
SCALE : 1 : 8,000 METERS
METRO MANILA INDEX MAP
CITY OF MARIKINA
DIGITAL COLOR CADASTRAL MAP
Universal Transverse Mercator Projection
Zone 51 Clarke Spheroid 1866 Luzon Datum
Prepared by:
CITY PLANNING AND DEVELOPMENT OFFICE

2.2.6.2 Modern Commercial District

In its vision and mission statements, the present city administration aims to develop Marikina into a global, “cosmopolitan city of excellence” by becoming a “business hub that can hold its own in the global playing field.” The vision is summed up by the catchphrase: Marikina as Little Singapore.

One specific strategy of this goal is the development of the Business, Food, Finance and Commercial Triangle (BFFCT), where the recently established Riverbanks Center can be found. This particular area was envisioned to follow the footsteps of Makati City—to become a “Makati in Marikina.” The Riverbanks Center is a 14-hectare land that used to be the site of a mattress and foam factory. The city government saw the potential of transforming this piece of property in Barangay Barangka into a commercial center by capitalizing on the natural amenities offered by Marikina River. The traditional commercial center of the city is also becoming too crowded to accommodate any new large-scale development.

In the 1990s, Riverbanks Center was begun with the intent to become “Marikina’s central business district, generating for the city bigger revenues than its present sources combined, not to mention jobs that shall be created“ (Marikina CPDO, 2000). As opposed to the traditional commercial center, Riverbanks Center was master planned from scratch, in the manner of a planned unit development. It is an off-street development with clustered commercial structures that are oriented towards the river, spacious open and covered parking areas, and open spaces leading to the river promenade. Today, it is a thriving regional commercial and recreation center complete with a shopping mall, supermarket, hotel and convention center, covered flea markets, open air restaurants and cafes overlooking the river, night spots such as discos and music lounges, and open spaces (Figure 2p).

Figure 2p. Formerly a factory site, the Riverbanks Center begins to form the modern commercial district of Marikina City with its shopping mall, restaurants, leisure areas, and covered parking.

In addition, the large open space across the river located in Barangay Kalumpang is also envisioned to be the site of another large-scale multi-use development composed of hotel, restaurants, convention center, recreation, and related amenities. This riverside area as a whole is being planned to become the Central Business District of the city in line with its vision of becoming a "Little Singapore." It has been designated as a high-density commercial zone in the city's Zoning Map.

Still in conjunction with this vision, the Marikina River Park Development was launched in 1993. Overcrowded squatter settlements used to be concentrated along the Marikina riverbank. The river was used as the septic tank. As the objectives of this ongoing project are to transform the 220-hectare riverbank area into a tourist attraction and the biggest urban river park in the country, squatters were slowly relocated and awarded lands in resettlement areas in different parts of the city. As the river rejuvenates itself, amenities were added such as the 15-km river promenade and jogging path, bike lanes, a floating stage, picnic areas, gazebos, boat rides, and riverboats that transport people upstream from the Riverbanks Center (Figure 2q).

Figure 2q. Gazebos, promenade, bike and jogging lane and picnic areas in Marikina River Park.

2.2.6.3 *Minor Commercial Nodes*

There are two existing minor commercial nodes within the city. They are minor or lower-order commercial and service centers in comparison to the commercial districts discussed above. These are smaller in scale and the goods and services available are less in variety. The markets that these centers serve are also limited to adjacent barangays or on a neighborhood scale, unlike the commercial districts which serve a wider regional market.

One such node is the junction formed by the commercial strips of Rizal Avenue, Rodriquez Avenue and Bayan-Bayanan Avenue. Another is a shopping node in Marikina Heights. These two nodes are in sharp contrast to one another as the former is a product of organic commercial strip development along main thoroughfares while the latter is a stand-alone shopping mall (Figure 2r). These minor commercial nodes are expected to play a bigger functional role in the next few years. According to the zoning plan of Marikina City, these commercial nodes will be allowed to expand to become medium-density commercial zones.

In addition to these minor nodes, a business and commercial strip is emerging on Tuazon St. in Barangay San Roque (Figure 2s). Tuazon St. physically connects Bonifacio Avenue (Marikina City) in the north and Marcos Highway (Pasig City) in the south. Marcos Highway, particularly at this junction with Tuazon St., is highly commercialized, with several modern shopping malls and cinema complexes, huge supermarkets, restaurants and fast food stores, and numerous retail shops. The emergent strip development along Tuazon St. seems to be a spillover effect of the aggressive commercial development on Marcos Highway. The city government of Marikina has perceived this situation as an opportunity to attract private investments and has therefore zoned Tuazon St. and its junction with Bonifacio Avenue as a high-density commercial zone.

Figure 2s. Emerging commercial strip along Tuazon St. in Barangay San Roque.

As of now, commercial development along Tuazon St. is patchy with some banks, restaurants, and retail shops side by side with residential areas. However, if present trends continue, Tuazon St. will eventually become a highly commercial area. Likewise, the vacant lands at the intersection of Tuazon and Bonifacio Avenue are planned to become sites of high-density and high-intensity commercial land uses (Figure 2t). This new business and commercial area would likely physically merge with the traditional commercial district of the city.

Figure 2t. The empty intersection of Tuazon St. and Bonifacio Avenue is expected to become a high-density commercial zone.

2.2.6.4 Residential Districts

Residential land use is the most predominant land use in the city and forms the matrix of the other land uses in the whole built-up area. The residential districts can be grouped in several categories: master planned residential subdivisions, resettlement sites, informal settlements, and, for lack of a better term, traditional neighborhoods.

2.2.6.4.1 Master planned Subdivisions

Master planned subdivisions are gated and guarded residential enclaves developed according to a particular site design and high building standards. Residential subdivisions cater to all income classes. For instance, there are subdivisions, which can only be afforded by the moneyed class such as the Loyola Grand Villas in Barangay Barangka, while SSS Village in Barangay Concepcion Dos is an

Figure 2u. An example of an upper-class residential subdivision in Marikina City (foreground).

example of a middle-class subdivision and Dela Costa Subdivision in Barangay Barangka. In such areas (Figure 2u), land use is purely residential; with very little commercial (e.g., a small convenience or retail (*sari-sari*) store at a corner) and perhaps institutional land uses (e.g., a chapel or small church). Common facilities such as basketball courts, community center, and parks and playgrounds are also present.

Figure 2v. Land uses in lower-class subdivisions exhibit a mixture of residential, commercial and business.

In lower-class subdivisions, however, site design and building standards are not as high (Figure 2v). In many cases too, commercial and business activities such as retail and wholesale stores, repair shops, beauty parlors, video and computer games rental shops, eateries, convenience shops, and even pre-schools are present in the residential space to augment the household income. Community facilities are also provided within such residential areas.

2.2.6.4.2 Socialized Housing and Resettlement Sites

Areas for socialized housing and resettlement are land set aside to accommodate the urban poor who reside in flood-prone areas such as along creeks and rivers and those who live in slums and squatter settlements who occupy either privately owned or public lands. Most of these communities had already been relocated to various resettlement sites in Barangays Concepcion Uno, Malanday, Parang, Nangka, and Marikina Heights.

The Marikina City government developed 106 hectares of privately owned lands into an Area for Priority Development where about 23,000 people have been resettled (1999 figures). Government lands were used to accommodate about 3,400 informal settlers in the Socialized Housing Zone within the city. Examples of these resettlement sites are the Libis and Tumana Resettlement Site in Barangay Concepcion Uno (Figure 2w). Water and electricity systems as well as alleys and inner roads were constructed for these high-density residential communities.

Figure 2w. High-density resettlement communities in Marikina City.

Squatter communities still exist in various parts of the city. In addition, there are also informal settlements that exhibit slum-like conditions such as blight, overcrowding, substandard structures, and a lack of sanitary facilities. Many of these are located in danger zones, i.e. steep slopes and flood-prone areas (Figure 2x). These communities have been marked as on-site priority development areas where basic infrastructures (i.e. access roads and alleys) and communal facilities (i.e. water pumps, community centers, and basketball courts) are being provided by the city government. These areas include UBB in Barangka, Olandes Bliss in IVC as well as the high-density residential communities in Marikina Heights and Parang.

Figure 2x. Informal settlements exist in various parts of the city, usually in hazardous sites such as river banks and flood-prone areas.

2.2.6.4.3 *Traditional Residential Neighborhoods*

Lastly, there are the traditional neighborhoods scattered all over the city (Figure 2y). These residential areas neither belong to the gated, master planned subdivisions nor to resettlement sites. The old residential district in Barangay Sta. Elena is an example of a traditional neighborhood, which surround the old *poblacion* or town center of Marikina. In this case, residential and commercial uses are found side by side to each other due to the commercialization of the area. Such neighborhoods are normally densely populated.

Figure 2y. Traditional neighborhoods are scattered all over the city.

2.2.6.5 *Industrial Zones*

Light, medium and heavy industries are located in several barangays, namely Barangays IVC, Kalumpang, Malanday, Jesus dela Pena, Concepcion Uno, Nangka, and Parang. There is, however, only one distinct industrial district that can be recognized, and this is located in Barangay Parang (Figure 2z). It has been labeled in the approved zoning plan of 2002 as a heavy industrial zone. Located in this zone are large manufacturing industries such as Fortune Tobacco, Tower Steel, Goodrich Tires, Goya, Armscorp, and Precision Foundry.

Figure 2z. The industrial district of Marikina City in Barangay Parang.

This area has also been designated as the Marikina Economic Zone under the Urban Redevelopment Program of the Board of Investments. Through this program, new industries are enticed to locate within the zone by offering them financial and tax incentives that are given only to industries, which choose to locate in special economic zones or industrial estates in the provinces.

Even if many industries in Metro Manila are choosing to relocate in many special economic and industrial zones just outside the metropolis to take advantage of investment incentives offered by the government, it is expected that existing industries will continue to operate in Marikina City. Moreover, in spite of high labor, property, and supply costs, industrial firms are likely to remain because of the current industry-friendly policy of the city and its efforts to provide the same financial incentives given to industries located in the government-supported special economic zones outside Metro Manila.

2.2.6.6 Institutional Zones

Institutional land uses are likewise found throughout the city, which include the city hall, barangay halls and community centers, police and fire stations, public and private hospitals, as well as public and private elementary and high schools and colleges. There are, however, noteworthy institutional zones such as the Marikina City Hall and vicinity, comprised of the city hall and several schools and colleges located in the city's traditional business district in Barangay Sta. Elena and the Boys' Town complex in Barangay Parang. The campuses of several large educational institutions such as Ateneo de Manila, Marist School, and St. Scholastica College also make up discrete institutional zones around the city.

2.2.6.7 Open Spaces

The city has about 62 hectares of open spaces, most of which are used as public pocket parks and recreational areas in residential communities and the mandatory green open spaces in exclusive subdivisions. Marikina River Park is the largest public recreational open space within the city with 220 hectares (2.2 sq. kms.). Some areas along the banks of the river are sometimes used for agricultural purposes.

CHAPTER 3

EVALUATING SEISMIC HAZARDS

To reduce potential damage from a future earthquake, it is necessary to understand the different seismic hazards in the area. The attributes of past earthquakes based on historical and instrumental seismic data inform the present about the possible characteristics of earthquakes that may occur in the future. Determining the parameters of a future probable earthquake such as location, probability of occurrence, depth of occurrence, magnitude, and severity of ground shaking is necessary to assess an area's seismic risk. These parameters then describe the scenario earthquake that will be used in analyzing urban vulnerability by estimating potential losses as a result of the scenario earthquake. Although a hypothetical earthquake could be used as the scenario earthquake, it is important that the hypothetical earthquake model is valid from a seismological point of view (Oyo Group, 2000).

Geologic or seismic studies need not be conducted in detail by a planner, especially if there are sources of information that provide the necessary data for hazard evaluation. Specialized government agencies and universities are usual places where knowledgeable people may be requested to provide information. Existing seismological maps and studies may offer reasonably complete information to be useful in land use planning for hazard mitigation. In this study, secondary data and existing scientific studies are utilized to provide an adequate assessment of the seismic hazards in the study area. Regional scale data oftentimes provide local seismic information.

This chapter describes the regional seismicity of Marikina City, the possible sources of future earthquakes, the parameters of the scenario earthquake based on the deterministic method, and the resulting intensity distribution of ground shaking as estimated by a simple computer software (RADIUS) used in the study.

3.1 Seismic Hazard Assessment: An Overview

Seismic hazard evaluation is an active field of research because of its importance in earthquake engineering and urban planning. Studies using macroseismic data are popular worldwide due to the absence of relevant strong ground motion data from actual earthquakes as well as from the simplicity of using existing databases of historical earthquakes (Gruenthal, 1999). Macroseismology is a branch of seismology that gathers and evaluates non-instrumental data on earthquakes based on the effects on people, objects, building structures, and nature by means of questionnaires and interviews. As historical data are very important in earthquake hazard studies, macroseismic methods have been very helpful in producing earthquake catalogues before the advent of seismological instruments at the turn of the twentieth century (Cecic and Musson, 2004). Macroseismic data are used by seismologists to derive earthquake parameters from such as epicenter, epicentral intensity, magnitude, and depth, which are then used to determine the future seismicity of an area.

Seismic hazard studies using macroseismic data abound in the literature. For instance, Zhang *et al*. (1994) performed a seismic hazard assessment for continental Asia (i.e. India, Nepal, Bangladesh, Bhutan, Myanmar, Thailand, Laos, Vietnam, Cambodia, China, Malaysia, Singapore, Sri Lanka, South Korea, North Korea, Mongolia, Japan, Kyrgyzstan, Kazakhstan, and Tajikistan) and produced a probabilistic seismic hazard map for the whole region covered by the study. The map depicts the ground shaking hazard that would have the largest effect on existing one- to two-story buildings, the most prevalent building class in Asia. This study showed that seismic hazard estimates in many countries in Asia, such as the Philippines, are not available. Probabilistic and deterministic analysis of seismic hazards usually at the regional or national level have been done for some countries or regions such as Kyrgyzstan (Abdrakhmatov *et al*., 2003), Algeria (Boughacha *et al*., 2004), Catalonia in Spain (Secanell *et al*., 2004), Lebanon (Harajli *et al*., 2002), for China, Romania and Ethiopia (Chen *et al*., 1998), and for Chile, Peru-Ecuador-South Columbia, Central America and Mexico (Tsapanos, 2003), to cite a few. For the Philippines, very few similar studies have only been recently conducted (e.g., Bautista, 2001; Bautista and Oike, 2000; Bautista, 1999; Daligdig and Besana, 1993). Most of these aimed at establishing earthquake parameters such as magnitude, intensity, peak ground acceleration, and probability of occurrence using macroseismic data, since instrumental seismic data are either sparse or non-existent.

Seismic hazard evaluation using paleoseismic methods, on the other hand, is a relatively new area of interest in the Philippines. An actual geological investigation through trench excavation surveys of a known active fault is a useful technique to characterize the seismic hazards of a "silent" area (Cinti *et al*., 2002). Trenching data can yield sufficient information on slip history, recurrence rate, unit displacement, and magnitude of earthquakes on that particular fault for which historical and instrumental records are far from complete. This method had not been popular in the Philippines (Pacific Consultants *et al*., 2002). It was only after the magnitude 7.8 1990 Luzon earthquake when interest in seismic hazard assessment using the trenching method was piqued (Nelson *et al*., 2003). The resulting fault scarps after the 1990 Luzon earthquake were excavated by a group of seismologists in order to establish the earthquake history on the Digdig segment of the Philippine Fault system, which caused the earthquake. During the previous two decades, only stratigraphic studies were conducted on sediments displaced by recent faulting to determine the magnitude and recurrence interval of past earthquakes on surface-rupturing faults which are located mostly in non-urban, non-built up areas, where results could not be used for maximum benefit (Nelson *et al.*, 2003).

In 1991, more trenching surveys were conducted by PHIVOLCS, this time on a potentially hazardous active fault in Metro Manila, the Valley Fault System. The PHIVOLCS excavated a trench across the East Valley Fault to prove recent lateral and thrust movements on the fault. Unfortunately, earthquake recurrence on the fault could not be determined, since no material suitable for 14 Carbon dating was found. The first detailed and most successful paleoseismic study was jointly carried out by PHIVOLCS and the United States Geological Society (USGS) from 1995 to 1996 on the West Valley Fault (WVF) in order to determine earthquake recurrence on the fault (Nelson *et al.*, 2003; Nelson *et al.*, 2000).

Damaging earthquakes can occur on any active fault and trench, although the timing and location cannot be precisely determined given the state of the art. Earthquake prediction remains no more than a hope for the future in spite of the Chinese success in predicting a major event at Haicheng in 1975 (Olson and Olson, 2001). Much was made of this, but in the following year, the terrible Tangshan earthquake was not foreseen. Additionally many false predictions of earthquakes have been made using the same methodology that predicted the Haicheng event (Key, 1995). The social and economic consequences of inaccurate predictions may be difficult for a society to accept, so that use of predictive methods is unlikely to be acceptable until it is proven and reliable. One spurious earthquake prediction happened in December 1990, when a large temblor was predicted on the New Madrid Fault in the heart of the United States of America (Nathe *et al*., 1999). Many people believed this false prediction and took actions accordingly. Predicting earthquake with precision is not likely to be achieved for many years, although this too is an active area of research (e.g., Ferraes, 2003; Papazachos, 2002; Contadakis and Asteriadis, 2001).

3.2 Regional Seismicity of Marikina City, Metro Manila

Records of both historical and recent earthquakes that affected the regional setting of Marikina City form the empirical basis of this hazards evaluation. Researches done particularly by Nelson *et al.* (2003), Bautista (2001), Bautista and Oike (2000), Daligdig and Besana (1993;

1992) along with the interviews of some experts from the Philippine Volcanology and Seismology Institute (PHIVOLCS) were very helpful in defining the parameters of the scenario earthquake that were later used in vulnerability assessment.

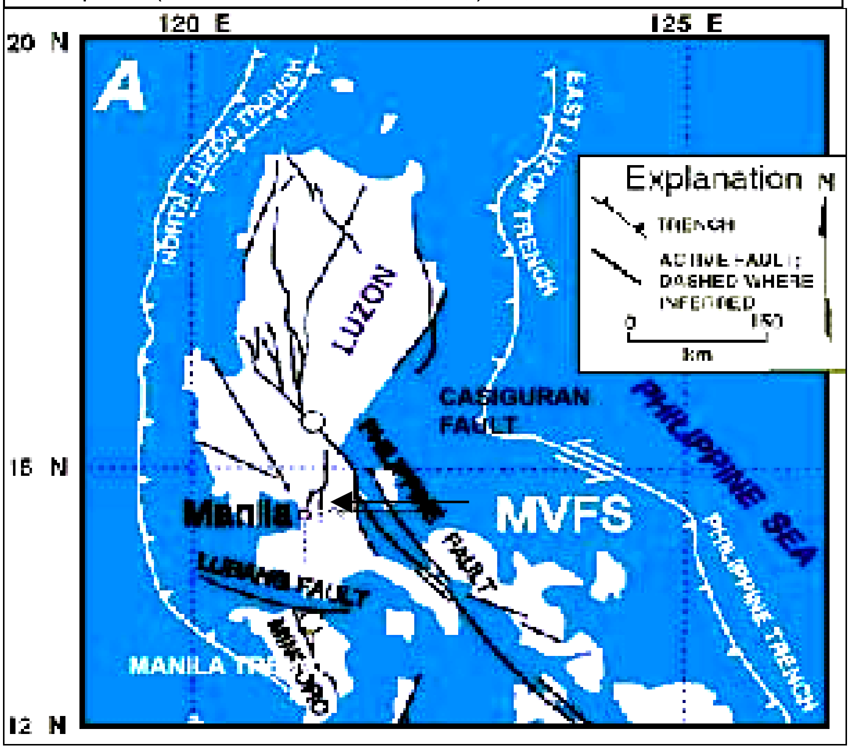
This section identifies and describes the source regions of historical and instrumental earthquakes that have significantly impacted Metro Manila throughout its history, from a Spanish colonial capital to the present-day megalopolis. Historical earthquake events that affected the old city of Manila and surroundings are also described. Historical or pre-instrumental earthquakes are those that are recorded in accounts of Spanish and other foreign missionaries and occurred prior to the instrumental period that began in the country in 1865.

3.2.1 Seismic Source Zones and Generators of Earthquakes

Based on historical and instrumental data, five earthquake zones or generators have been pinpointed as possible sources of major earthquakes shook Metro Manila in the past. These are, namely, the Valley Fault System (VFS), Philippine Fault Zone (PFZ), Casiguran Fault, Lubang Fault, and Manila Trench (see Map 3a).

One must bear in mind, though, that there is always a possibility that some unknown faults still remain undetected under thick recent sedimentary deposits. The PHIVOLCS have mapped previously identified inland faults based on remotely sensed data as well as on-site field surveys, techniques which are not effective in detecting hidden deep faults.

Map 3a. Sources of major earthquakes that have affected Metro Manila in the past. (Source: Nelson *et al.*, 2003)



Geophysical prospecting methods are more effective in searching for deep underground geologic structures, but only a few of such surveys have been undertaken so far in the Philippines (Pacific Consultants *et al.*, 2002).

3.2.1.1 Valley Fault System[1] (VFS)

Consisting of two almost parallel right-lateral faults trending north-northeast, the Valley Fault System is the most proximate source region to the study area of Marikina. The East Valley Fault (EVF) transects the neighboring provinces of Metro Manila, from the town of Angat, Province of Bulacan in the north going southwards to Cainta, Rizal Province where the fault trace disappears, as this area is too urbanized and built-up to detect any underlying structure buried deep in the ground.

The West Valley Fault (WVF) originates north of Metro Manila from the province of Bulacan, slices through the cities of Quezon, Marikina, Pasig, and Muntinlupa in the metropolitan area itself, and continues southwards in the province of Batangas, where the fault trace eventually vanishes. Between these two faults lies Marikina Valley, a graben downthrown by a previous movement of the two fault lines.

The WVF runs through some of the highly built-up areas in Metro Manila as well as some of the most expensive pieces of property in the country. Based on the mapping conducted by Daligdig *et al*. (1997), these include residential subdivisions in Quezon City such as Violago Homes, Filinvest, Capital Park; Loyola Grand Villas in Marikina City going south to St. Ignatius Village, White Plains, Green Meadows, and Valle Verde in Pasig City. These highly built up areas straddling the fault zone are directly exposed to surface rupture, the vertical or horizontal breaking of the ground or both along fault lines as a result of an earthquake.

As mentioned, this fault system has been classified as active, although no recent seismicity has been detected on both faults (Daligdig *et al*., 1997). Historical accounts, however, indicate that the 1599, 1601, 1771, and 1885 earthquakes could be attributed to movements along the VFS (Daligdig and Besana, 1993). Bautista (2000) also suggested that the EVF member of the VFS could have generated the 1658 and 1771 temblors. These were described as violent earthquakes, damaging many churches and stone buildings, and resulting to numerous injuries and deaths in old Manila as well as in the suburban town of Marikina and nearby Antipolo. A loud subterranean noise was heard in Marikina and surrounding towns.

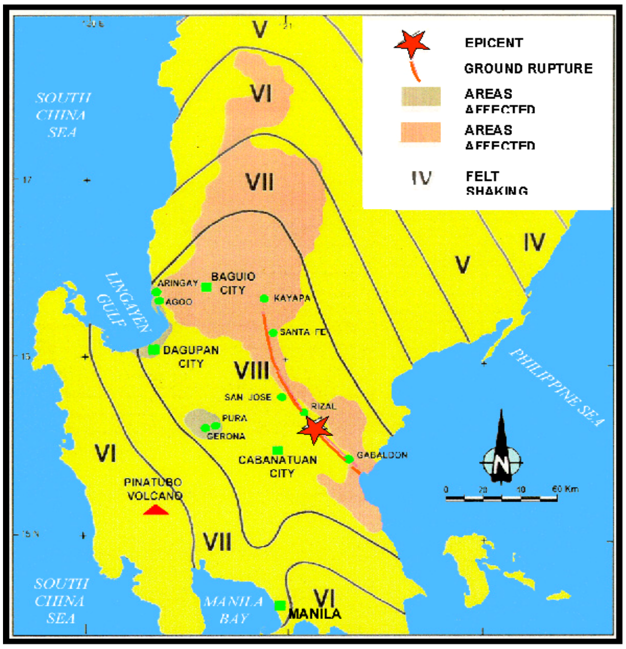
[1] Formerly known as the Marikina Valley Fault System, it was renamed as the Valley Fault System when a former mayor of Marikina City objected to appending the name of the city to the fault.

Given these historical earthquake events, it would seem that the VFS is experiencing a period of non-activity. According to the seismic gap theory, future earthquakes could occur along fault segments where strain energy is not being released. This means, slippage along the fault is so small that huge strains become locked in these fault segments. The segments where no movements have occurred for a long time could become the probable locations of sudden, violent earth movements in the future. Seismic gaps are therefore expected to become probable sites of future large earthquakes. As the WVF seems “silent“ for a long time, it can be considered as a seismic gap that poses a serious danger to the city of Marikina.

3.2.1.2 Philippine Fault Zone (PFZ)

More than 1,600 km long, this strike-slip fault has been the site of the most destructive and about a third of the large earthquakes in the country (Rimando, 1994). The fault zone is oriented north-northwest and cuts through Luzon Island continuing southward past the island of Mindanao. Sense of movement is left lateral with both vertical and horizontal components.

Movement along one segment of this fault, the Digdig fault, caused the recent and most devastating 7.8 magnitude 1990 Luzon earthquake (see Map 3b). This earthquake, though very destructive in and near the epicentral area (Intensity VIII), did not create so much physical damage in Metro Manila (Intensity VII in Manila and Intensity VI in Quezon City). Several old government buildings suffered cracks in Quezon City, for instance, had to be evacuated, and later condemned as unusable. Others were repaired. No casualties were reported in Metro Manila.



Map 3b. Isoseismal map of the 16 July 1990 North Luzon Earthquake M=7.8.
(Source: PHIVOLCS)

A spectacular geologic impact of the earthquake was the 125-km long surface rupture that caused the collapse of all structures straddling the fault due to lateral and vertical ground displacements (Punongbayan *et al.*, 1992) (Figure 3a). Another earthquake from the same Digdig segment that occurred in 1645 was more destructive, particularly in old Manila

(Intramuros or the Walled City) and in a suburb called Taguig.

The 1824 earthquake, which originated from the Alabat segment of the fault, caused some church towers in Manila and Antipolo, a suburban town, to collapse. Another earthquake, which occurred in 1880, could have originated from the Dingalan Bay segment, the branch of the fault nearest to Metro Manila (Bautista, 1999). This event caused widespread impacts in Manila and other provinces in Luzon.

The nature of the Philippine Fault Zone, e.g. segmentation and recurrence of earthquake along each segment, is not yet fully known, but recent seismic activities along the fault suggest that it will continue to be the locus of future earthquakes (Rimando, 1994). A future earthquake of M =7.5 from this source is highly possible, as the 1990 earthquake was 7.8. A seismic gap has also been identified on the PFZ. It is located 50 km east of the metropolis on the Quezon segment of the Philippine Fault Zone (Daligdig and Besana, 1993).

Figure 3a. Surface faulting near the epicentral area as a result of the July 1990 earthquake. (Source: PHIVOLCS website.)

3.2.1.3 Manila Trench

Located approximately 200 km west of Metro Manila, it extends about 1,100 km from Taiwan in the north down to the island of Mindoro, Philippines. Although active, the seismicity of this trench is not so intense (Bautista, 2001). Movements along this trench may have caused the 1677 earthquake, which triggered tsunamis (tidal waves) on the China Sea and ground fissuring in Manila (Daligdig and Besana, 1993). Damage to structures and casualties (2 persons died) were relatively minimal.

The 1863 earthquake appeared to have originated from Manila Trench based on historical accounts (Daligdig and Besana, 1992). The seismic event also produced a tsunami that rocked the ships anchored in Manila Bay. The destruction and deaths, however, were due to strong ground shaking. The earthquake wrought extensive damage in Manila as well as in the nearby provinces of Cavite, Bulacan, and Laguna. Around 400 persons died and 2,000 injured in Manila. More than 1,000 structures, including most churches in the old city of Manila, collapsed.

3.2.1.4 Lubang Fault

A submarine fault off the shore of Mindoro Island cutting east-west towards the smaller island of Lubang, Lubang Fault is located about 80 km southwest of the metropolis. Data from instrumental monitoring of the active fault suggest a high level of seismicity. This means that the stresses along the fault are periodically released; hence, there is lesser probability that large earthquakes would originate from here in the near future (Daligdig and Besana, 1992). Movements on this fault set off the 1852 and 1972 earthquakes. The 1972 event resulted to several heavily damaged buildings in Manila.

Bautista (2000) proposed that this submarine fault and other land-based faults comprise a source region, which she termed Mindoro Seismogenic Zone. A source region or seismogenetic source can be composed of different earthquake generating units, which are assumed to be governed by the same earthquake producing process (UNESCO, 1973).

3.2.1.5 Casiguran Fault

Although Casiguran Fault is the farthest among the earthquake generators previously discussed, about one-third of the most damaging earthquakes that impacted Metro Manila originated from it (Daligdig and Besana, 1993).

The series of earthquakes that happened in the 1970s (the 1970, 1972, and 1977 events) and one in 1968 originated from this fault. The 1968 earthquake (Ms = 7.3) was highly destructive in the old city of Manila (Intensity VII), although it was around 200 km away. It caused the total collapse of the multi-storey Ruby Tower in downtown Manila resulting to 268 deaths, 260 people injured, infrastructure damage, and structural damage to many buildings (see Figure 3b). Some of the damaged buildings were situated on the alluvial plains of the Pasig River. The Pasig River flows from Laguna de Bay, a freshwater lake east of Metro Manila, and drains westward to Manila Bay. Ground rupture, liquefaction, and sand fountains were reportedly observed around the town of Casiguran, the epicenter (Daligdig and Besana, 1992). Fissures ranged from 10 to 20 meters up to 400 to 500 meters in length in some areas were observed, while spaces between the cracks varied from five to 20 meters (PHIVOLCS Website). Casiguran Fault and the East Luzon Trench are proposed by Bautista to form another seismogenic source region.

Figure 3b. East side of the roof of Ruby Tower that collapsed toward the south. (Source: PHIVOLCS website.)

The 1968 Casiguran earthquake demonstrated that fault movements could cause considerable damage to areas far from the epicenter, if buildings and structures in seismic prone area were built without a thought to the kind of foundation. Structural damage was mainly concentrated in the areas underlain with deltaic deposits of the Pasig River. Soft, loose sediments have been known to amplify seismic waves.

The five earthquake generators discussed above are potential source zones of large earthquakes that could disastrously affect Metro Manila anytime in the future. In addition to these five loci, Bautista (2001;1999) identified three other faults, which were the likely sources of earthquakes that had impacted the metropolitan area in the past. East Laguna Fault is found southwest of Metro Manila in the adjacent province of Laguna and has a length of 50 km. Two earthquake events, the 1743 and 1937 quakes, are attributed to this fault. Another fault lying northwest of Metro Manila, with a length of 100 km, is believed to have generated the 1863 earthquake. Located below the southern tail of the East Luzon Trench is the transform submarine fault called E-W Transform Fault. The aftershocks of the April 1970 earthquake event were inferred to have originated from this fault.

Scientific knowledge on most of these seismic source zones is scant and further research is urgently needed. For instance, the VFS was only recently classified by government scientists as active (Punongbayan *et al.*, 1992; Daligidig *et al.*, 1997), although other geologists insisted otherwise. Known active crustal faults and lesser-known faults such as the East Laguna, East Zambales, and E-W Transform Faults need to be investigated more to unearth their earthquake history.

3.2.2 Seismic History of Metro Manila

Historical earthquakes that affected the old city of Manila and its environs are recorded in earthquake catalogues, where earthquake parameters such as epicenter, epicentral intensity, depth, and magnitude can be derived (Cecic and Musson, 2004). Earthquake events thereafter belong to the instrumental period where other parameters such as magnitude and focal depth location are also provided.

Macroseismic epicenters of historical earthquakes are defined as the centers of the most heavily shaken area or the area of maximum intensity (Karnik and Algermissen, 1978). The epicenter is the point on the earth's surface above the focus or origin of the earthquake. Epicentral areas of pre-1900 period indicated in the table below are approximations made by experts based on various assumptions. Determination of source zones is likewise judgment calls made by geologists and therefore sometimes vary. Table3a lists earthquake events with a cut-off intensity of Intensity VI on the Adapted Rossi-Forel Scale .

Table 3a. Earthquakes that Affected Manila Metropolitan Area, 1589-1999

DATE/ TIME	AFFECTED PLACES	INTENSITY IN MANILA AREA*	SOURCE ZONE/ GENERATOR	VISIBLE EFFECTS
1589 June	Manila			Many cracks appeared in La Guia Fort.
1599 June 21, 10:00 AM	Intramuros, Manila	Intensity VIII	VFS	Destroyed many buildings, a school, the stone vault of a church, wooden frame and walls of Sto. Domingo Church, which stood on adobe.
1601 Jan. 01, 12:00 AM	Intramuros, Manila	Intensity VIII	VFS	Almost flattened the city. Destroyed many structures such as stone houses, churches, stone vaults, the Manila Cathedral; killed/injured an unknown number of people.
1603	Intramuros, Manila			Damaged the Leprosarium, Royal Hospital and San Juan de Dios Hospital.
1635	Manila			Ruined several houses.
1645 Nov. 30, 8:30 PM	Intramuros, Binondo, Taguig, Manila; (Gapan, Nueva Ecija – epicenter)	Intensity IX	PFZ	Leveled the city to the ground. Demolished many churches including the Manila Cathedral, convents, hospitals, schools, colleges, and houses particularly along the Pasig River. A church collapsed in Binondo and Taguig. Killed around 3,000 people.

DATE/ TIME	AFFECTED PLACES	INTENSITY IN MANILA AREA*	SOURCE ZONE	VISIBLE EFFECTS
1658 Aug. 20, 3:00 PM	Manila; (Antipolo – epicenter)	Intensity IX	EVF	Shattered the Archbishop's House, scores of wooden houses and buildings, several churches, and one that was damaged in 1645 collapsed, killed and injured more than a few people.In Antipolo, tilted a 20-m high bell tower,cracked its walls and façade.
1664 July 19	Manila			Damaged a hospital and a small church.
1665 July 19	Manila			Destroyed a lot of buildings and a school hall.
1674	Manila			Ruined a church.
1677 Dec. 07, 7:30 PM	Manila; (off the western coast of Luzon Island – epicenter)	Intensity VII	Manila Trench	Produced a tsunami and flooded some coastal areas and wrecked boats. In Bauan, Batangas, ground ruptured in many places. In Manila, damaged old, unstable structures and the main chapel of Sto. Domingo Church, and killed two persons.
1684 August	Manila	Intensity VII		Injured many people but inflicted minor physical or structural damage.
1728 Nov. 28	Manila			Caused serious losses and destruction in the city.
1743 January	Manila	Intensity VII	PFZ (Daligdig and Besana, 1992); East Laguna Fault (Bautista, 2001)	
1767 Nov. 13, 3:25 PM	Manila	Intensity VII		Cracked walls and dislodged roof tiles.
1770 December between 9:00-11:00 PM	Manila	Intensity VII		Wrecked some houses.
1771 Feb. 01, Nighttime	Ermita, Manila; (Antipolo – epicenter)	Intensity VII	EVF	Shattered severely some churches in Ermita. Antipolo suffered serious damage.
1796 Nov. 05, 2:00 PM	Manila; (Pangasinan - epicenter)	Intensity VII	PFZ	One house collapsed. Damaged some churches, the Royal Palace, and barracks of the Royal Regiment. In Pangasinan, nine churches completely ruined.
1824 Oct. 26	Manila; (Lucban, Tayabas, now Quezon Province – epicenter)	Intensity VIII		Several churches and houses reduced to rubble along with military barracks and one bridge. Explosions heard along the Pasig River after which fishes seen floating dead on the river. Antipolo Church partially destroyed.

DATE/ TIME	AFFECTED PLACES	INTENSITY IN MANILA AREA*	SOURCE ZONE	VISIBLE EFFECTS
1828 Nov. 09, 6:30 PM	Manila	Intensity VII		Damaged some churches and bridges and cracked walls of many houses and a prison.
1829 Dec	Manila	Intensity VII		Damaged several buildings.
1830 Jan. 18, 5:15 PM	Manila; (Mauban, Quezon - epicenter)	Intensity VII		In Manila, new Customs building severely destroyed. In Mauban, a monastery collapsed. Walls and tower of one church built in 1600 fractured.
1833 Nov. 07, Evening	Manila	Intensity VII		Escolta bridge displaced by 10 cms. One person died.
1852 Sept. 16, 6:30 PM	Intramuros, Tondo, Pandacan, Samplaoc, Binondo, Manila; Paranaque and Las Pinas (now parts of MM); (Bataan - epicenter)	Intensity IX	Lubang Fault	Shattered many buildings, monasteries, churches, and houses. Fissured a lot of structures such as Fort Santiago, arches, facades, beams, vaults, gates, rectories, patios, cigar factory, and warehouses. Along the Pasig River, foundation of a cigarette factory displaced 5 cms. towards the river and damaged Malacanang Palace (Manila governor's vacation house) and rendered it uninhabitable. Destroyed churches of Tondo, Pandacan, Samplaoc, Paranaque and Las Pinas. Ruined an old cigar factory in Binondo. Killed 3 persons and 1 reported missing.
1862 Mar. 04, 5:30 PM	Manila; (Cavite – epicenter)	Intensity VII		Partially destroyed some houses and buildings.
1863 June 03, 7:25 PM	Intramuros, Tondo, Binondo, Santa Cruz, Quiapo, Pandacan, Santa Ana, Manila; Navotas; Pasig; Cainta; San Mateo; Antipolo; Tanay; Pililla; Taguig; (Manila Bay – epicenter)	Intensity IX	Manila Trench	Killed at least 500 and injured 400 persons. Produced a tsunami from the China Sea. Flattened the city by devastating more than 1,000 major private and public buildings, factories, hospitals, barracks, convents, monasteries, and great churches such as Manila Cathedral, Santa Isabel, Santo Domingo, San Agustin, San Juan de Dios, and Recoletos some of which had withstood past earthquakes. Many buildings in Tondo, Navotas, and Pasig destroyed and deemed condemned and a section of the Divisoria Market fell. Churches of Binondo, Santa Cruz, Quiapo, Pandacan, Pasig, Santa Ana, Cainta, San Mateo, Antipolo, Tanay, Pililla, and Taguig seriously damaged and bell towers collapsed.Resulted to extensive ground rupture and liquefaction.

DATE/ TIME	AFFECTED PLACES	INTENSITY IN MANILA AREA*	SOURCE ZONE	VISIBLE EFFECTS
1869 Oct. 01, 11:15 AM	Manila; (Malolos, Bulacan – epicenter)	Intensity VII	PFZ	Partially damaged several houses and buildings and the San Agustin Church. In Malolos, arch and tower of Barasoain Church collapsed as did some warehouses and stone houses in the province and neighboring towns in Cavite, Bulacan, Pampanga, and Batangas.
1880 July 18, 12:40 PM	Intramuros, Pandacan, Binondo, Tondo, Quiapo, Sampaloc, Paco, Malate, Manila; Mandaluyong Malabon; Marikina; Makati; Kalookan; Taguig; Paranaque; Las Pinas; Cainta; Pasig Pateros; (Infanta, Quezon - epicenter)	Intensity VIII	Casiguran Fault (Daligdig and Besana, 1993) Infanta Segment of the PFZ (Bautista, 2001)	Devastated Manila and suburbs. Collapse of almost all tile-roofed houses, buildings, churches, bell towers. Severely damaged the churches of Pandacan, Tondo, Sampaloc, Santa Ana, Malate, Malabon, Cainta, Pasig, Pateros, Paranaque, and Las Pinas and caused total collapse of Paco, Makati and Taguig Churches. Destroyed all masonry structures, houses, and buildings in Intramuros, Las Pinas, Cainta, Binondo, Quiapo, Santa Ana, Malabon, Marikina, and Kalookan. Displaced houses on Roque and Jolo streets in Binondo. Well-built structures near the Pasig River more damaged compared to those farther from the river and a wall of Malacanang Palace fell into a 2-cm ground rupture. Mud and sand ejected in Mandaluyong.
1885 November	Manila	Intensity VII	VFS	Minor damage. Loud underground noises heard in Marikina and other suburban towns.
1892 March 16, 8:58 PM	Manila; (Mangaldan, Pangasinan – epicenter)	Intensity VII	PFZ	Insignificant effects in Manila but very destructive in the epicentral area.
1937 Aug. 20, 7:59 PM	City of Manila; Pasig; (Alabat, Quezon – epicentral area)	Intensity VII	East Laguna Fault	Badly destroyed factories, office and commercial buildings, hotels, churches, schools and universities in various places in Manila. One building sank by 6 inches. Cracked many bridges. Downed, cut or burned telephone and electric lines and broke water pipes. Pasig Church damaged.
1942 April 09 12:41 AM	City of Manila			Cracked walls, windows, and floors of several buildings. Scarce reports probably due to WWII.

DATE/ TIME	AFFECTED PLACES	INTENSITY IN MANILA AREA*	SOURCE ZONE	VISIBLE EFFECTS
1968 Aug. 02, 4:19 AM	City of Manila; Quezon City; Makati; (Casiguran, Aurora – epicenter)	Intensity VII M= 7.3	Casiguran Fault	Caused the collapse of the 6-storey Ruby Tower. Heavily damaged and cracked government, office and commercial buildings, university buildings, hotels, and other structures. Slightly fractured three bridges. Ground subsidence occurred causing the collapse of one building. Buckled and fissured roads. Severe destruction observed on the north and south banks of Pasig River. In Quezon City, fractured a few buildings. In Makati, glass windows of buildings shattered. Property losses estimated to reach several million dollars.
1970 April 07, 1:34 PM	City of Manila; Quezon City; (Lubang Island – epicenter)	Intensity VII M= 7.3	Casiguran Fault	Seriously damaged office, government and commercial buildings, hotels, schools, and a cinema, some suffered structural damage. Caused roofs to cave in and shattered windowpanes. Cracked walls and destroyed the tower of Manila International Airport. Broke a 6-inch water pipe. The City Engineer of Manila recommended 6 buildings be condemned, 154 unsafe for occupancy, and 101 required repairs. One building in the University of the Philippines in Quezon City suffered structural damage. Telephone service temporarily disrupted. Killed 14 people and injured hundreds.
1972 April 26, 3:30 AM	City of Manila; (Lubang I. – epicenter)	Intensity VII	Lubang Fault	Partially ruined many hotels and office and commercial buildings including the Manila City Hall. City Library sustained heavy damage.
1972 May	City of Manila	Intensity VII	Casiguran Fault	Slightly damaged buildings located in central Manila and near Manila Bay.
1973 March 17, 4:31 PM	City of Manila; (Calauag, Quezon – epicenter)	Intensity VII M = 7.0	PFZ	Damaged buildings and high rises by cracking walls and ceilings and shattering windowpanes.
1974 Feb. 19, 11:30 AM	City of Manila; (Calauag, Quezon – epicenter)			Very minor damage.
1977 March 19, 5:43 AM	City of Manila (Palanan, Isabela – epicenter)	Intensity VII M= 7.0	Casiguran Fault	Cracked walls of 22 buildings, hotels, and schools.

DATE/ TIME	AFFECTED PLACES	INTENSITY IN MANILA AREA*	SOURCE ZONE	VISIBLE EFFECTS
1980 March	City of Manila	Intensity VI	Casiguran Fault	
1990 July 16, 4:26 PM	City of Manila; Pasay City	Intensity VII M = 7.8	Digdig Segment of the PFZ	Slightly damaged a college building, a high rise, a hospital, and buildings particularly those located in reclaimed areas in Binondo, Manila and Pasay City (i.e. PICC, Manila Film Center). Telephone and power service disrupted for 1 hour in Manila. Subsidence occurred in reclaimed areas.
1999 Dec. 12	City of Manila; Pasay City; (Masinloc, Zambales – epicenter)			Damaged buildings in Chinatown, Phil. General Hospital, San Sebastian College, one condominium, and houses in a residential subdivision in Manila. Damaged the PICC, Manila Film Center and Golden Bay Hotel in Pasay City.

Sources: Bautista, 2001; Bautista and Oike, 2000; Daligdig and Besana, 1993; Daligdig and Besana, 1992 and Repetti, 1949.

3.3 Seismic Hazard Assessment of Marikina City

3.3.1 Selecting the Scenario Earthquake

3.3.1.1 Earthquake Source and Maximum Magnitude

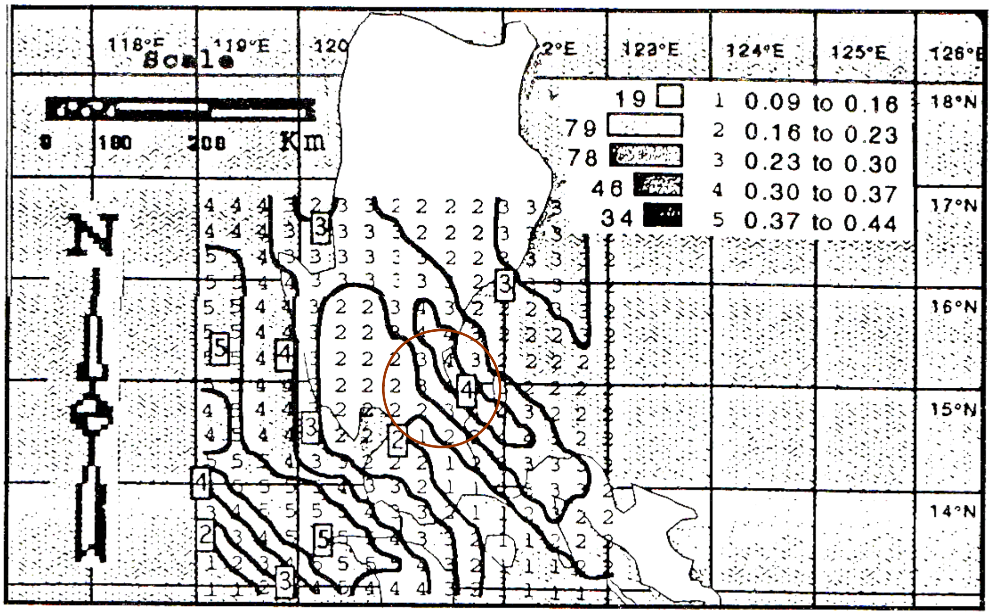
For the purposes of this study, a scenario earthquake must be adopted in order make an assessment of the vulnerability of the study area. The use of scenario earthquakes is the most common technique to assess potential earthquake damage or losses (Panel on Earthquake Loss Estimation Methodology, 1989). To be useful, the scenario earthquake must be defined in terms of several parameters such as location, epicenter, magnitude, intensity distribution, and depth.

No one can tell exactly when the next major earthquake would occur, where it would originate, and how big it would be. But one thing is certain: an earthquake could strike anytime in the future and devastate the city, if no mitigation strategy is implemented before it happens. In view of this, scientists have developed methods that allow them to estimate the probable size of a future earthquake, mostly measured in terms of ground shaking in a particular region of interest. There are two general methods used to select an earthquake scenario in seismic hazards analysis: probabilistic and deterministic. Both approaches contain elements of subjectivity and uncertainty (Kijko *et al.*, 1989).

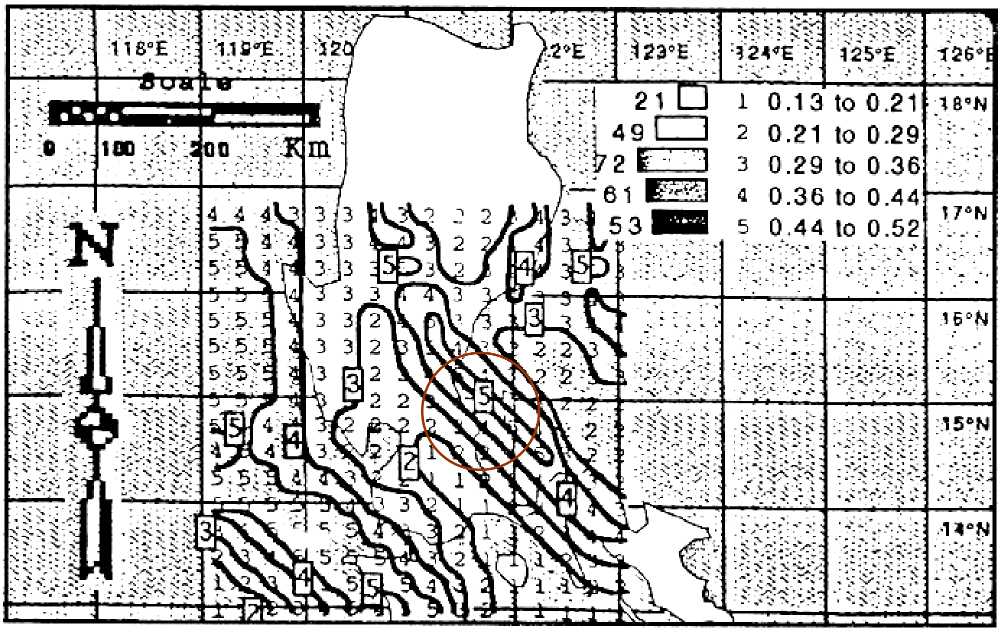
Probabilistic seismic hazard analysis takes into account all possible earthquake sources in a particular region and computes for the statistical probabilities for future earthquakes based on the frequency of historical earthquakes. In a nutshell, this approach estimates the recurrence interval of an earthquake of a particular magnitude and constructs a model of the expected ground motion from such an earthquake based on the attenuation characteristics of the area to account for the decrease in energy of the seismic waves as they travel from the origin through varying rock formations beneath the Earth's surface. One widely used probabilistic technique was pioneered by Cornell in 1968 (Holschneider *et al*., 2004; Karnik and Algermissen, 1978). The probable maximum ground shaking for a given area, usually expressed as a percentage of ground acceleration, is thus calculated and given a degree of probability, e.g., 10% probability of being exceeded in 50 years, which translates to a mean recurrence interval of 475 years. This type of seismic hazard analysis, however, is generally beyond the capability of local planning offices.

In the case of the Philippines, several studies have calculated the probable levels of ground shaking of Luzon Island where Marikina City lies using the probabilistic approach. The work of Bautista *et al*. (1992), Su (1988), and Hattori (1979) indicated on a regional scale the probable levels of ground shaking in terms of peak ground acceleration (PGA). Peak ground acceleration is expressed in terms of percent of gravity (i.e. 1.0g is equal to 32 feet/second/ second).

Bautista *et al*. (1992) produced ground motion hazard maps showing probable PGA values of 0.16g to 0.23g for a 50-year return period and for an earthquake with a 250-year return period, PGA values of 0.21g to 0.29g (Intensity VII to Intensity VIII) for the Metropolitan Manila area (see Map 3c and Map 3d). These values are comparable to the results of Su (1988), but are much higher than the PGA of 0.1g for 50- and 100-year return periods estimated by Hattori (1979). However, these models did not include the Valley Fault System as an earthquake generator, as the historical seismicity of the VFS was not yet established at this time. This is one disadvantage of the probabilistic technique. Probabilistic seismic hazard analysis requires as complete a history of earthquake in the area of interest as possible or the earthquake catalogue must at least have a large number of earthquake events to avoid problems of statistically inadequate data for evaluating earthquake parameters (Tsapanos, 2003; Zhang *et al*., 1994). Instrumental monitoring of the VFS began only in 1999 (Besana, April 2004, personal communication).



Map 3c. Seismicity of Metro Manila area, Luzon region (50-year return period). (Source: Bautista *et al.,* 1992.)

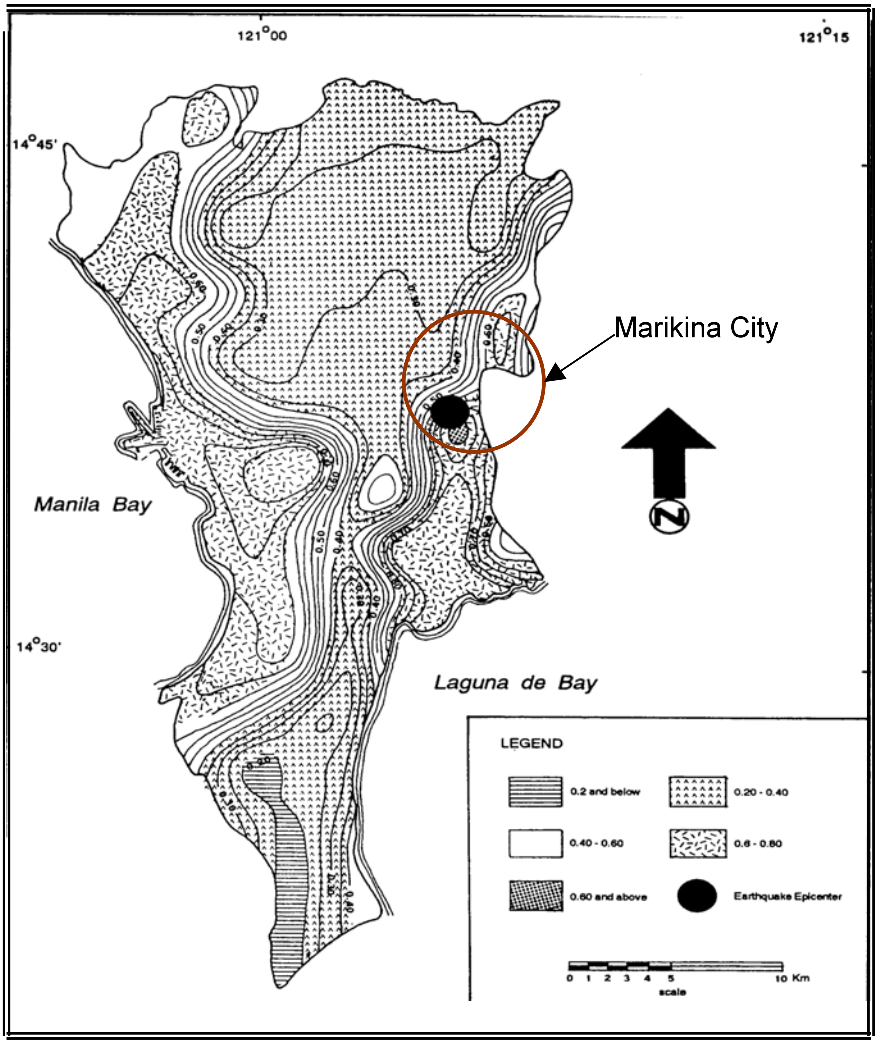


Map 3d. Seismicity of Metro Manila area, Luzon region (250-year return period). (Source: Bautista *et al*., 1992.)

Deterministic seismic hazard evaluation, on the other hand, does not require extensive strong ground motion data, which is not available for Metro Manila. The Philippines has had only a dedicated seismological network for the last five years. The deterministic approach starts with a user-chosen earthquake, known as the “worst case scenario,“ and without attaching any probability to the earthquake event (Kijko *et al*., 2003; Panel on Earthquake Loss Estimation Methodology, 1989). The expected ground motion is then calculated. Daligdig and Besana (1993) computed the expected PGAs for Metropolitan Manila using deterministic assumptions. They specified the probable loci of large earthquakes that have affected Metro Manila and assigned the maximum probable earthquake magnitude for each earthquake generator based on existing historical, instrumental, and empirical seismicity data. The epicentral distance from each seismic source was likewise specified. Also because of the lack of strong motion data, the attenuation equation used for Japan was applied to Metro Manila.

In this study, they came up with a ground shaking hazard map for Metro Manila (see Map 3e) showing the distribution of ground acceleration values for a magnitude 7.5 earthquake from the VFS, which “...possibly represents the worst case scenario for Metro Manila....“ (Daligdig and Besana, 1993). The scenario earthquake from the VFS was expected to produce ground accelerations of 0.20g in areas in the central plateau region to as high as 1.0g in the Marikina Valley. Another scenario earthquake was a magnitude 8 earthquake originating from a segment of the Philippine Fault. Using this scenario earthquake, Metro Manila would experience ground shaking levels of 0.4g in areas underlain by soft rocks to 0.15g in areas with hard rocks.

In an earlier work, Daligdig and Besana (1992) used the deterministic approach to evaluate the potential ground motion hazard in Metro Manila from five possible sources of earthquakes that may cause substantial damage to the metropolis. In the absence of ground motion attenuation relations for the Philippines, the attenuation equation developed by Fukushima and Tanaka (1990) for Japan was used to compute the acceleration values, since both countries have similar general tectonic setting. Hence, given the maximum magnitude and epicentral distance from each potential seismic source, the expected PGA values for Metro Manila for soft rock and hard rock foundations were estimated as shown in Table 3b.



Map 3e. Distribution of ground acceleration in Metro Manila from a probable magnitude 7.5 earthquake from the Valley Fault System. (Source: Daligdig and Besana, 1993)

Table 3b. Expected PGA Values for Metro Manila Using the Deterministic Approach

Earthquake Generator	Probable Magnitude	Epicentral Distance (km)	Peak Ground Acceleration (%g)		
			Soft Rock	Hard Rock	Mean
VFS	7.5	0	1.03	0.39	0.64
PFZ	8.0	50	0.38	0.15	0.24
Lubang Fault	7.5	80	0.18	0.07	0.11
Manila Trench	8.0	130	0.12	0.05	0.07
Casiguran Fault	8.0	200	0.05	0.02	0.03

Source: Daligdig and Besana, 1992.

The table shows the five potential seismic generators on which large earthquakes are anticipated. Of the five probable earthquake events, the maximum probable earthquake magnitude of 7.5 on the Valley Fault System (VFS) represents the worst case scenario not only for Marikina City but for the entire Metro Manila, with a possible mean PGA of 0.64g (Daligdig and Besana, 1992; Besana, 1992). Although the 7.5 magnitude earthquake originating from the VFS is lower compared to the scenario earthquakes from the PFZ, Manila Trench, and Casiguran Fault, the expected ground shaking levels in Metro Manila are higher. This is because of the factor of distance (distances in Table3b are hypothetical) between the source fault and the area. Generally, the site closer to the source faults will experience higher levels of ground motion. The intensity of ground shaking decreases or attenuates with distance from the earthquake generator. That is why an earthquake with an equal magnitude anticipated from another crustal fault, the Lubang Fault, located farther away from the site would produce considerably lower levels of ground shaking than the one from the VFS.

Many scientists agree that that the VFS will likely be a future source of the strongest levels of ground shaking in the metropolitan area (Punongbayan, Coburn, and Tayag, 1993; Nelson *et al.*, 2003). However, there are notable differences in the estimates of the maximum magnitude on the VFS. According to Zhang *et al.* (1994), if the area of interest is dominated by a single active fault or the earthquake catalogue for the area in question is not sufficient, the fault length can be used to estimate the maximum magnitude. Bautista (November 2001, personal communication) estimated that the maximum probable magnitude from the West Valley Fault of the VFS is 7.0, considering its mapped length of 100 km. Indeed, a mapped 40-km surface rupture on the WVF indicates that a future earthquake from the VFS could have a probable magnitude of 7, according to Daligdig and Besana (1993). But, since the entire length of the VFS has not been totally mapped, a 7.5 magnitude earthquake remains as a possible worst case scenario for the metropolitan area (Besana, 2001, personal communication; and Daligdig and Besana, 1993). This means, it is possible that the total length of the WVF is more than its mapped length of 100 km, which translates to the possibility of earthquakes of larger magnitudes.

Fault rupture lengths and displacements can also be used to estimate the magnitude of past earthquake events (Nelson *et al.*, 2003; Zhang *et al.*, 1994). Hence, turning to paleoseismology, historical earthquakes on the WVF could have reached magnitude 7 based on actual field observations of one- to two-meter lateral displacements in historical faulting events on a northern segment of the West Valley Fault (Nelson *et al.*, 2003). Presence of young, fault-related landforms prominent in the northern trace of the WVF that indicate an earthquake of this size were also noted. Still, Nelson *et al*. (2003) have not totally eliminated the possibility of a 7.5 magnitude historical earthquake on the WVF saying that "...there is a possibility that a much longer section of the fault ruptured during earthquakes as large as magnitude 7.5...", although supporting geologic evidence in the southern segment beyond Pasig River have yet to be identified and the nothern segments of the VFS have yet to be entirely mapped.

In an ongoing earthquake impact reduction study for Metro Manila or MMEIRS (Pacific Consultants *et al*., 2002), four scenario earthquakes from different seismic source zones, including two scenario earthquakes on the WVF, were chosen for an earthquake damage analysis of the whole metropolis, selected on the basis of high probability of occurrence as well as degree and extent of potential damage (see Table 3c). It is noteworthy that two scenario earthquakes from the WVF were used in the study with fault length as the variable. A magnitude 7.2 earthquake was adapted on the assumption that the WVF has a total length of 60 km. The other scenario earthquake sources considered were the PFZ, Lubang Fault, and Manila Trench.

Based on the foregoing, it is apparent that the VFS is represents a clear and present threat not only to Marikina City, but to the whole metropolitan region. Moreover, according to expert hazard analyses and opinions, the maximum probable earthquake magnitude that may originate from the VFS, specifically the WVF segment, range from 6 to 7.5.

Table 3c. Scenario Earthquakes Used in MMEIRS Study

Earthquake Source	Distance (km) *	Magnitude
West Valley Fault		
Length 1 = 30 km	3	6.8
Length 2 = 60 km	3	7.2
PFZ: Infanta Segment	62	7.6
Manila Trench	143	7.9
Lubang Fault	109	7.7
1863 Earthquake Event Manila Trench as possible source but still disputed	15	6.5

Source: Pacific Consultants *et al*., 2002.
* distance from center of Metropolitan Manila (14.56N, 121.02E)

For the purposes of this study, an earthquake of magnitude 7.5 originating from the WVF meets the criteria of being relatively probable and damaging. The historical maximum earthquake that has been known to occur from the WVF based on actual trenching of a northern segment of the WVF of Nelson *et al.* (2003; 2000) is equal or greater than magnitude 7, as they did not preclude the possibility of finding geological evidence of earthquakes as large as 7.5 in the southern portion of the WVF. There is likewise the crucial question of the total length of the WVF. Experts who were interviewed all agreed that the maximum magnitude could be higher than 7 if the total fault length of the West Valley Fault is longer than the actual mapped length (Bautista, M.L.P., February 2002, personal communication; Bautista, B.B. February 2002, personal communication; Besana, G., February 2002, personal communication; and Narag, I., February 2002, personal communication.)

Furthermore, a scenario earthquake originating from a local source, which lies directly beneath the city, represents the worst case scenario as the WVF transects the city of Marikina itself. In addition, in a public forum conducted by the researcher together with key local government officials and personnel, *barangay* officials, and representatives from community and non-government organizations on 7 March 2002 at the Marikina City Hall, the public showed interest in the VFS only and no concern was displayed regarding other earthquake generators.

Lastly, the deterministic approach has been found to be acceptable to governmental users of damage estimates as well as to the general public (Panel on Earthquake Loss Estimation Methodology, 1989). It is particularly useful when the consequences of a scenario event are needed for rapid damage estimation, information monitoring, and decision support (King et al., 1997). The deterministic method has been applied in several risk estimation studies of urban areas (e.g., Rashidov T.R. and Khakimov Sh.A., 2000; RADIUS Zigong Workgroup, 2000; King *et al.*, 1997).

The maximum probable earthquake magnitude of 7.5 on the Richter Scale (Annex 1) from the West Valley Fault was used as an input in the RADIUS computer program. The RADIUS program is an Excel-based tool that simplifies the process of seismic hazard and vulnerability assessment. It is most helpful in cases where there is no instrumental record on the distribution of ground shaking intensities from historical earthquakes and thus an attenuation relationship must be used to calculate this distribution, as in the case of Marikina City. The software calculates the intensity distribution and displays the information on a grid map. This is discussed in more detail in the section on Intensity Distribution.

3.3.1.2 Mean Return Period and Probability of Occurrence

The mean return period refers to the recurrence interval of an earthquake of the same size or magnitude. As mentioned, there is no instrumental historical record of the seismicity of VFS. However, a paleoseismic study from 1995 to 1996 was conducted jointly by a team from the United States Geological Survey (USGS) and PHIVOLCS at a site on the West Valley Fault of the VFS. Trenches and stream bank exposures yielded stratigraphic, soil and 14 Carbon data that prove that a northeastern splay of the WVF has generated at least four large, surface rupturing earthquakes since AD 600 (Nelson *et al*., 2003). Initial results of the study hinted only at least two or perhaps four large earthquakes with a recurrence interval of less than 500 years (Nelson *et al*., 2000).

The latest results however suggest a shorter range of 200 to 400 years as recurrence interval for future large earthquakes on the Valley Fault System or an average recurrence interval of 310 years (Nelson *et al.*, 2003). This estimate was based on 14C dating, the required period of time for argillic soils to develop, and estimates of historic faulting events made by the researchers since the exact time of each faulting event, including the most recent event, could not still be determined. Geologic evidence observed by the team, however, indicates that the last (the fourth) faulting event is historical, probably dating from 200 years ago.

Although the deterministic approach is used in this study, it is still desirable to provide a rough indication of probability of occurrence, if only to convey a likelihood of such an earthquake occurring. Following Kovach (1995), the probability of occurrence of the scenario earthquake within a 50-year time interval given the average return period is 15 percent. This means that there is a 15 percent probability that the scenario earthquake will occur within the specified time interval ($t + \Delta t$), provided that it has not occurred in the elapsed time ($t = 204$) since the last large earthquake ($T_1 \approx$ ca. 1800). This translates to an annual probability of 0.003, which is within the range of 0.001 and 0.005, the range of annual probabilities considered reasonable for disaster mitigation planning (Panel on Earthquake Loss Estimation Methodology, 1989).

This is not a prediction since there is no guarantee that there will be a 310-year interval between each earthquake event. The return period is simply a best estimate of an earthquake's frequency of occurrence. One or more earthquakes could occur in a shorter-than-average period. Seismologists go by one rule of thumb in the recurrence of large earthquakes: “The further you are from the last one, the closer you are to the next one.” Given the present knowledge and state-of-the-art technology, there is no other alternative but to assume that a significant earthquake will likely occur at any time and to take appropriate action.

3.3.1.3 Focal Depth

The focal depth of the earthquake is also an important parameter as epicentral intensity can be strongly affected by it (Cecic and Musson, 2004). Hence, it is also a required data input in the RADIUS damage estimation program. The focus is defined as the origin or point source of the earthquake. Many of the disastrous earthquakes that occurred in the Philippines were shallow-seated with depths ranging from 7 to 42 km. A shallow earthquake is defined by the NEIC and USGS as earthquakes occurring within 35 km of the Earth's surface (NEIC, 2003). As most of the significant earthquakes in the Philippines were shallow based on this definition, the scenario earthquake will be assigned with an arbitrary focal depth of 10 km.

Based on past experiences, shallow earthquakes cause more damage than intermediate and deep-seated temblors (between 70 and 300 km) as the energy generated by shallow earthquakes is released closer to the surface and therefore generates stronger ground shaking (NEIC, 2003). An example of what the difference in focal depths of earthquakes can make is the 25 March 2003 Hindu Kush earthquake in Afghanistan (M=6.1; depth= 8 km). It had about 95 times less energy than the event on 3 March 2003 (M=7.4; depth=256 km), but it caused much more damage (NEIC, 2003). In the 25 March earthquake, at least 1,000 people were killed, hundreds injured, and 1,500 houses destroyed or damaged. In comparison, the 3 March earthquake caused all in all about 166 deaths, several injured, and 700 houses destroyed.

3.3.1.4 Parameters of the Scenario Earthquake

The parameters of the scenario earthquake chosen as representative of a damaging seismic event expected in Marikina City are listed in Table 3d. These parameters of the scenario earthquake were applied in the RADIUS computer program to determine the levels and geographic distribution of ground shaking in Marikina City.

Table 3d. Parameters of the Scenario Earthquake

Magnitude	7.5
Location/Origin	West Valley Fault of the Valley Fault System
Depth	8 km
Epicenter	Barangay Barangka, Marikina City
Day and Time of Occurrence	Monday, 10.05 hours
Mean Return Period	310 years
Probability of Occurrence - in a 50-year time interval - annual probability	 0.15 0.003

3.3.1.5 Determination of the Intensity Distribution using RADIUS

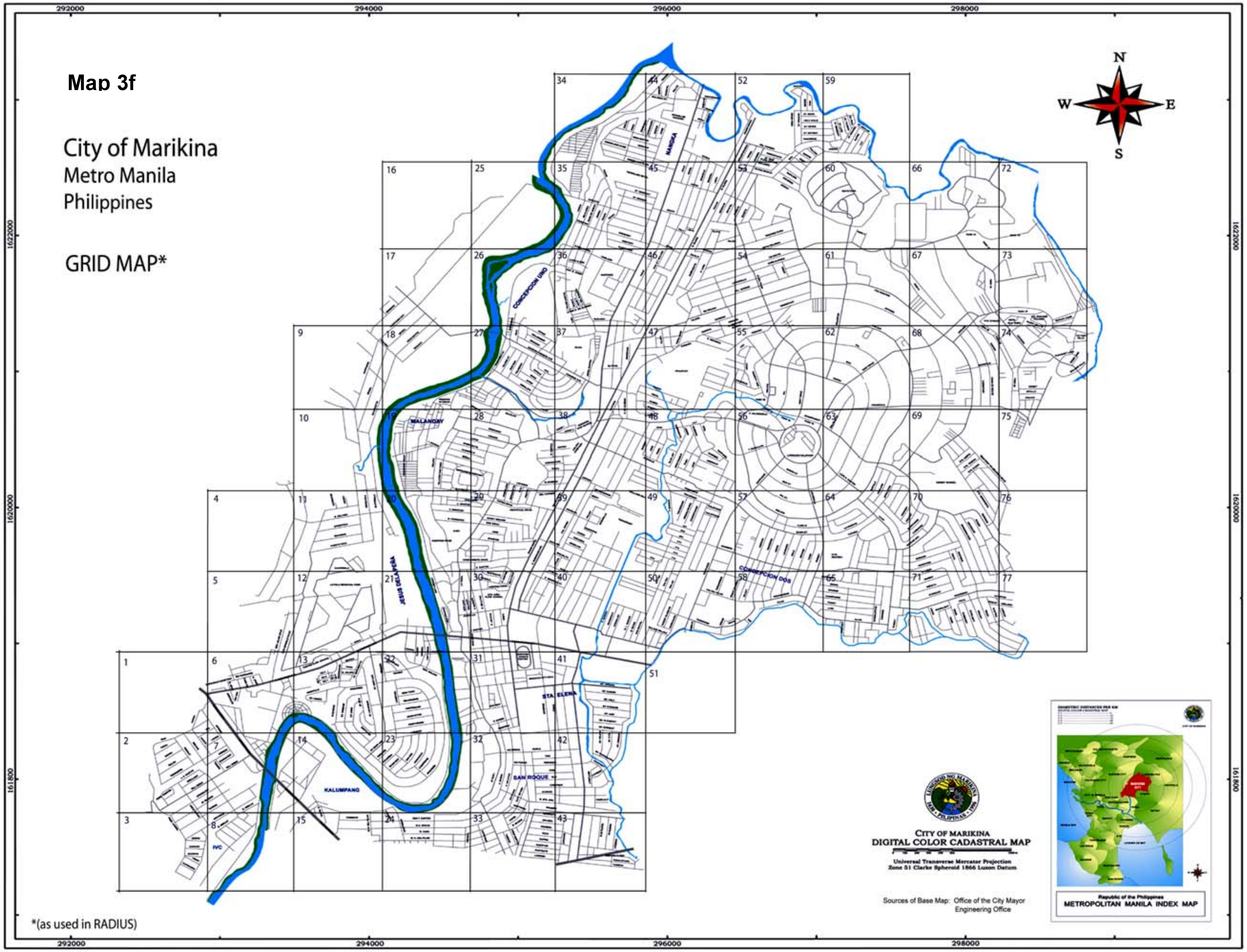
In order to complete the parameters of the scenario earthquake, the probable levels of ground shaking and their geographic distribution within the city must be determined. The intensity of ground shaking is influenced by several geologic factors:

1. Magnitude of the earthquake – The bigger the earthquake, the higher the intensity of ground shaking. This means a greater likelihood for death and damage.
2. Distance from the epicenter – The relationship between distance and damage is directly related: the nearer to the epicenter, the greater the intensity of ground shaking, the greater are the potential losses.
3. Local site conditions – Ground conditions can affect the characteristics of ground motion as different types of rocks or soils react differently to seismic waves. Generally, high danger zones for ground shaking are areas underlain by thick deposits of water-saturated soft sediment, while less dangerous areas are underlain by hard, indurated materials with thin unconsolidated overburden.

Thus, potential ground shaking can be estimated from the parameters of the scenario earthquake and ground conditions. The software used in this study is called RADIUS. It is a simple earthquake damage estimation tool developed with the support of the UN International Decade for Natural Disaster Reduction (UN-IDNDR). The computer program was developed from the experiences of nine cities in various developing countries that were used as case studies as part of the UN-IDNDR initiative called Risk Assessment Tools for Diagnosis of Urban Areas Against Seismic Disasters or RADIUS (Kaneko and Sun, 2000). The RADIUS software is not a Geographic Information System (GIS) type of program. It runs on Microsoft Excel 97 with simplified methodologies to make it user-friendly and faster.

In this study, intensities of ground shaking are estimated from the parameters of the scenario earthquake (refer to Table 3d) together with information on local geology using the RADIUS tool. The user needs to feed following information into the program for ground shaking levels to be calculated: shape of study area by meshes, ground condition or soil type, and choice of scenario earthquake and its parameters.

Firstly, the study area of Marikina City was divided into 77 grids or meshes, with each grid having a dimension of approximately 0.62 km x 0.62 km or an area of 0.3844 square kilometers (Map 3f – Grid Map). This is more detailed than the program's recommendation of 1 to 5 km. Each grid was given an Area ID and Area Name. The Mesh ID was automatically assigned by the computer program.



Map 3f
City of Marikina
Metro Manila
Philippines
GRID MAP*
*(as used in RADIUS)
N
W
E
S
292000
294000
296000
298000
1622000
1620000
161800
NANGKA
CONCEPCION UNO
MALANDAY
JESUS DELA PEÑA
CONCEPCION DOS
STA. ELENA
SAN ROQUE
KALUMPANG
IVC
CITY OF MARIKINA
DIGITAL COLOR CADASTRAL MAP
Universal Transverse Mercator Projection
Zone 51 Clarke Spheroid 1866 Luzon Datum
Sources of Base Map: Office of the City Mayor
Engineering Office
Republic of the Philippines
METROPOLITAN MANILA INDEX MAP

The subdivided units of the city must be zoned according to existing ground conditions, because ground conditions vary in different parts of the city. The surface geology map of Marikina City was used in this regard. In the RADIUS tool, the variations in local ground conditions are accounted for by inputting the predominant type of rock or soil present in each grid using a four-fold soil classification with corresponding amplification factors, to wit:

0 = Unknown, if data on ground condition is not available. Amplification factor used for unknown ground condition is set at 1.00 (standard amplification factor).

1 = Hard Rock, corresponds to volcanic rocks and pre-Tertiary sedimentary rocks. Amplification factor is 0.55.

2 = Soft Rock, refers to Tertiary sedimentary rocks. Amplification factor is 0.70.

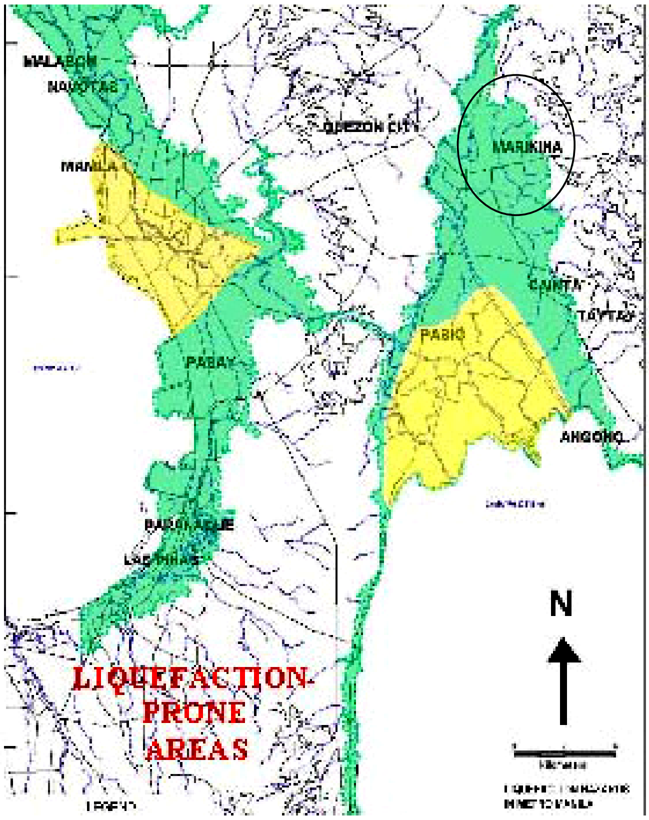
3 = Medium Soil, refers to diluvial and stiff alluvial soils (not liquefiable). This class is used as the standard and the amplification factor is thus set at 1.00.

4 = Soft Soil, corresponds to soft, alluvial soil, reclaimed land, landfill, etc. (liquefiable). Amplification factor is set at 1.30.

Local ground conditions must be accounted for as site effects may result to amplification of ground shaking (Abbott, 1996; Punongbayan *et al.*, 1993; EERI, 1986; UNDRO, 1977). Loose, uncompacted sediments and soft soil layers have been observed to amplify the intensity of ground shaking (Dolce *et al.*, 2003; Havenith *et al.*, 2003; Oliveira, 2003). The phenomenon of ground amplification in soft soil environments such as bay shore and lakeshore areas reclaimed with artificial fill on soft mud has also been widely observed in previous earthquakes such as the 1985 Mexico, 1989 Loma Prieta, and 1995 Kobe earthquakes (Lomnitz, 1997).

Particular site conditions may also result to liquefaction. Ground-shaking induced liquefaction is a process in which soil loses strength and behaves like a viscous liquid. In some cases, soil deformation as a result of liquefaction may be large enough to lead to ground failures and thus damage structures atop the ground (Greene *et al.*, 1994). Liquefaction occurs only in environments characterized by recently deposited loose sediments and high-water table such as river channels, flood plains, deltas, and poorly compacted artificial fills. The damaging effects of liquefaction have been shown by the 1964 Niigata, Japan, 1964 Alaska, 1989 Loma Prieta, California, 1999 Kocaeli, Turkey, and 1999 Chi-Chi, Taiwan earthquakes (Luccioni *et al.*, 2000; Scawthorn, 2000; Erdik, 2000; O'Rourke, 1999; Kayen and Mitchell, 1997;). Liquefaction during the 1990 Luzon, Philippines earthquake also caused many buildings to settle and tip in the deltaic area of Dagupan City.

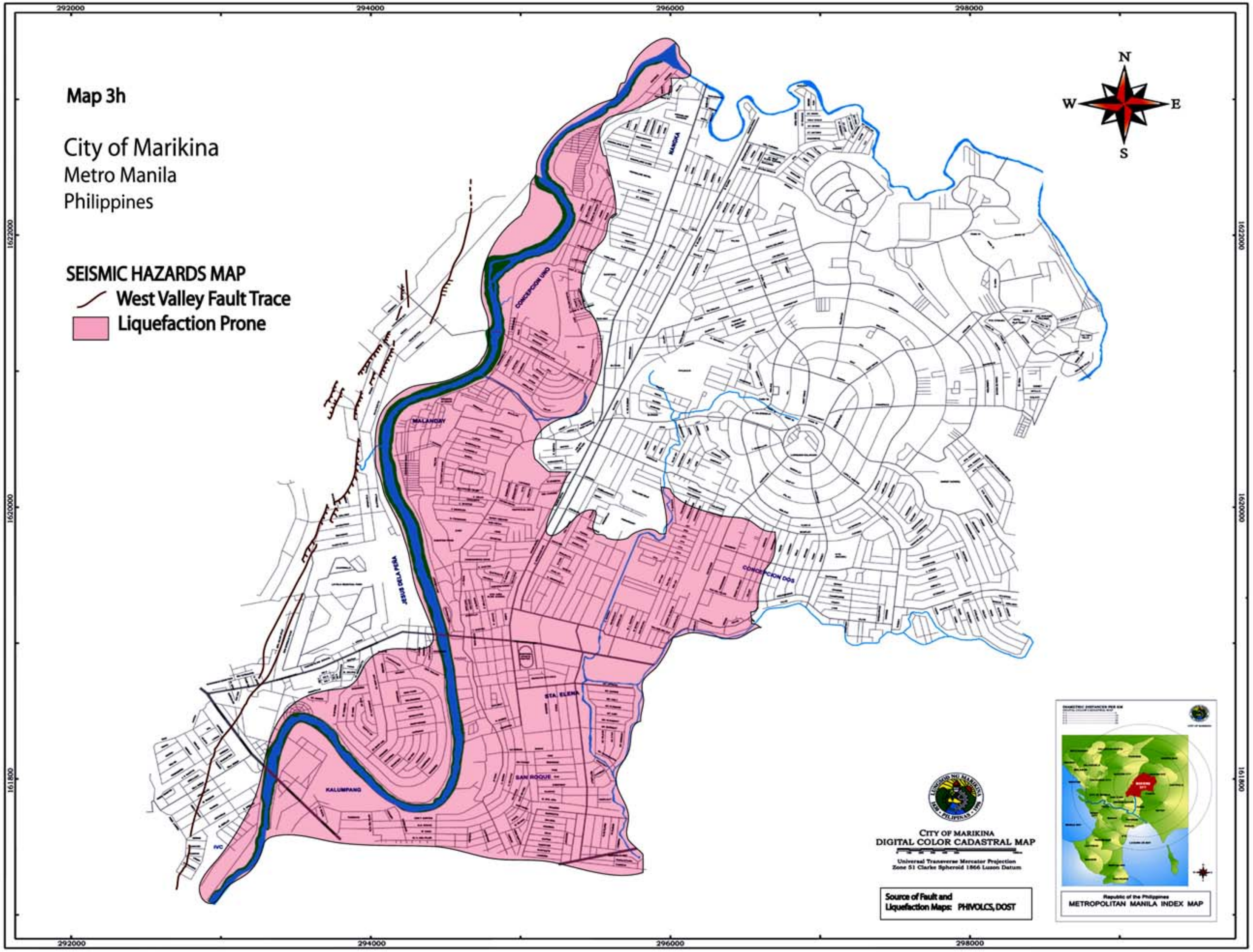
In Marikina City, the presence of soft, Quaternary alluvium in the valley is noted to be concentrated in the graben, where Marikina River passes through. This is the natural depositional environment for alluvial deposits. To account for the presence of liquefiable soils, located particularly in the river floodplain, the Liquefaction Potential Map of Metro Manila (Map 3g) obtained from PHIVOLCS was used as a source of information. The spatial distribution of liquefiable soils in Marikina City is patterned after the areas delineated as moderately susceptible to liquefaction on the Liquefaction Hazards Map of Metro Manila prepared by PHIVOLCS. As the map encompasses the whole metropolitan area, the liquefiable areas within the city of Marikina was manually traced from the original Liquefaction Hazards Map at a 1:10,000 scale onto the base map used by the study. This liquefaction susceptible area is then shown on the Seismic Hazards Map of Marikina City (Map 3g), which also indicates the fault trace of the West Valley Fault. The eastern splay of the Valley Fault System does not pass through the city itself; hence, it is not indicated on the map.



Map 3g. Liquefaction Potential Map of Metro Manila Map (Source: PHIVOLCS)

The area within Marikina City that is encompassed by the liquefaction susceptible area is classified as “Soft Soil (liquefiable).” This soil underlies the flat-lying central part of the city of Marikina. The rest of the Quaternary alluvium outside the area of liquefaction susceptibility is classified as “Medium Soil“ using the soil classification of RADIUS.

Tuff and tuffaceous sediments are classified under “Soft Rock“. These deposits are mostly concentrated at the foothills of a part of the Sierra Madre mountain range on the western side of the city, in the direction of the neighboring mountainous city of Antipolo in Rizal Province. A thin slice of this lithologic unit is also found on the eastern shoulder of the city.


Map 3h
City of Marikina
Metro Manila
Philippines
SEISMIC HAZARDS MAP
West Valley Fault Trace
Liquefaction Prone
N
W
E
S
292000
294000
296000
298000
1622000
1620000
161800
MANGKA
CONCEPCION UNO
MALANDAY
JESUS DELA PEÑA
CONCEPCION DOS
STA. ELENA
SAN ROQUE
KALUMPANG
IVC
CITY OF MARIKINA
DIGITAL COLOR CADASTRAL MAP
Universal Transverse Mercator Projection
Zone 51 Clarke Spheroid 1866 Luzon Datum
Source of Fault and
Liquefaction Maps: PHIVOLCS, DOST
Republic of the Philippines
METROPOLITAN MANILA INDEX MAP

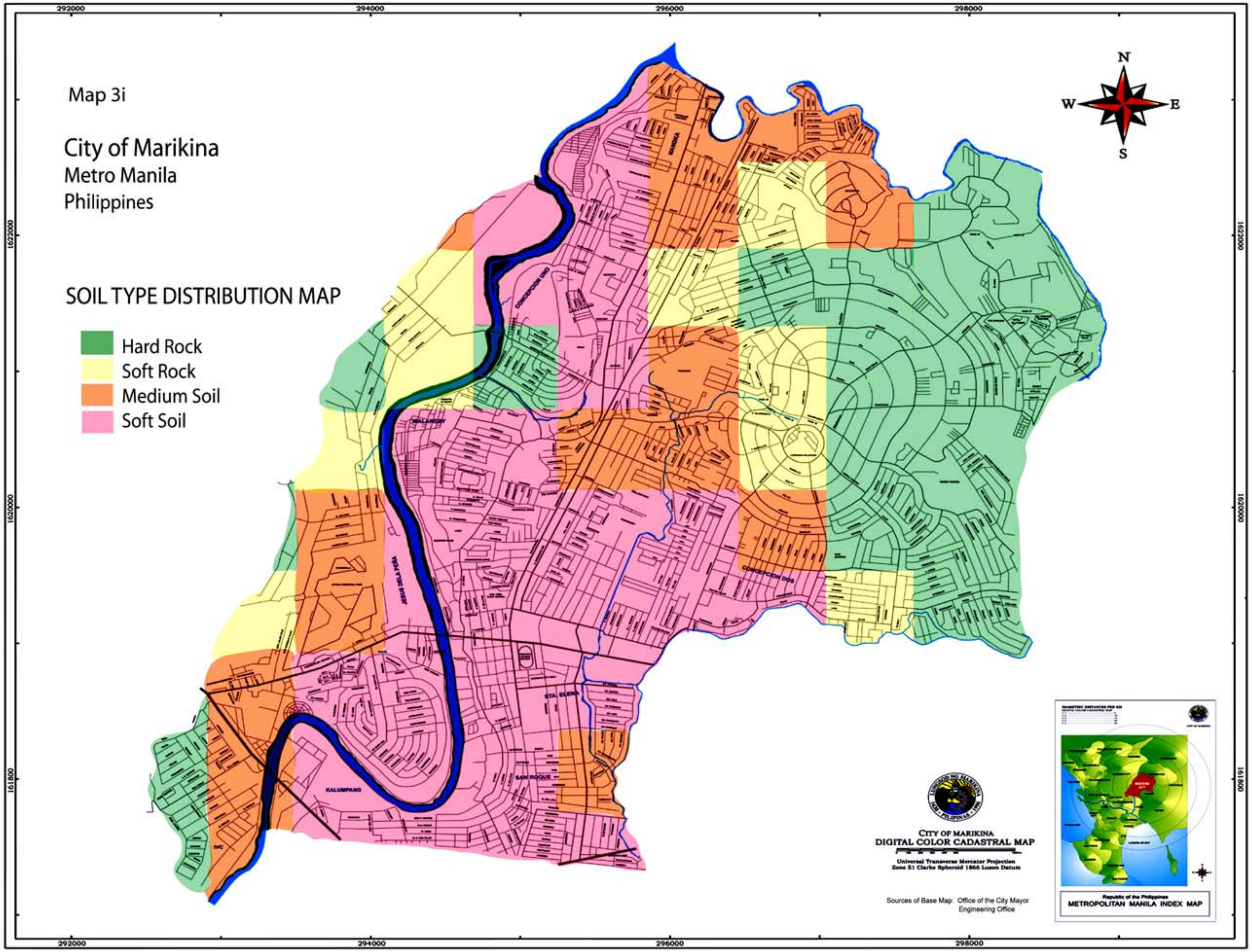
Lastly, the basement complex and pyroclastic flow deposits/adobe are categorized as "Hard Rock" in the RADIUS program. The basement rock unit is found only in the hilly part of the city going westward towards the Sierra Madre mountain range. Pyroclastic flow deposits and adobe are concentrated on the eastern edge of the city, in the direction of the neighboring city of Quezon. In sum, the ground types underlying Marikina City are categorized as follows:

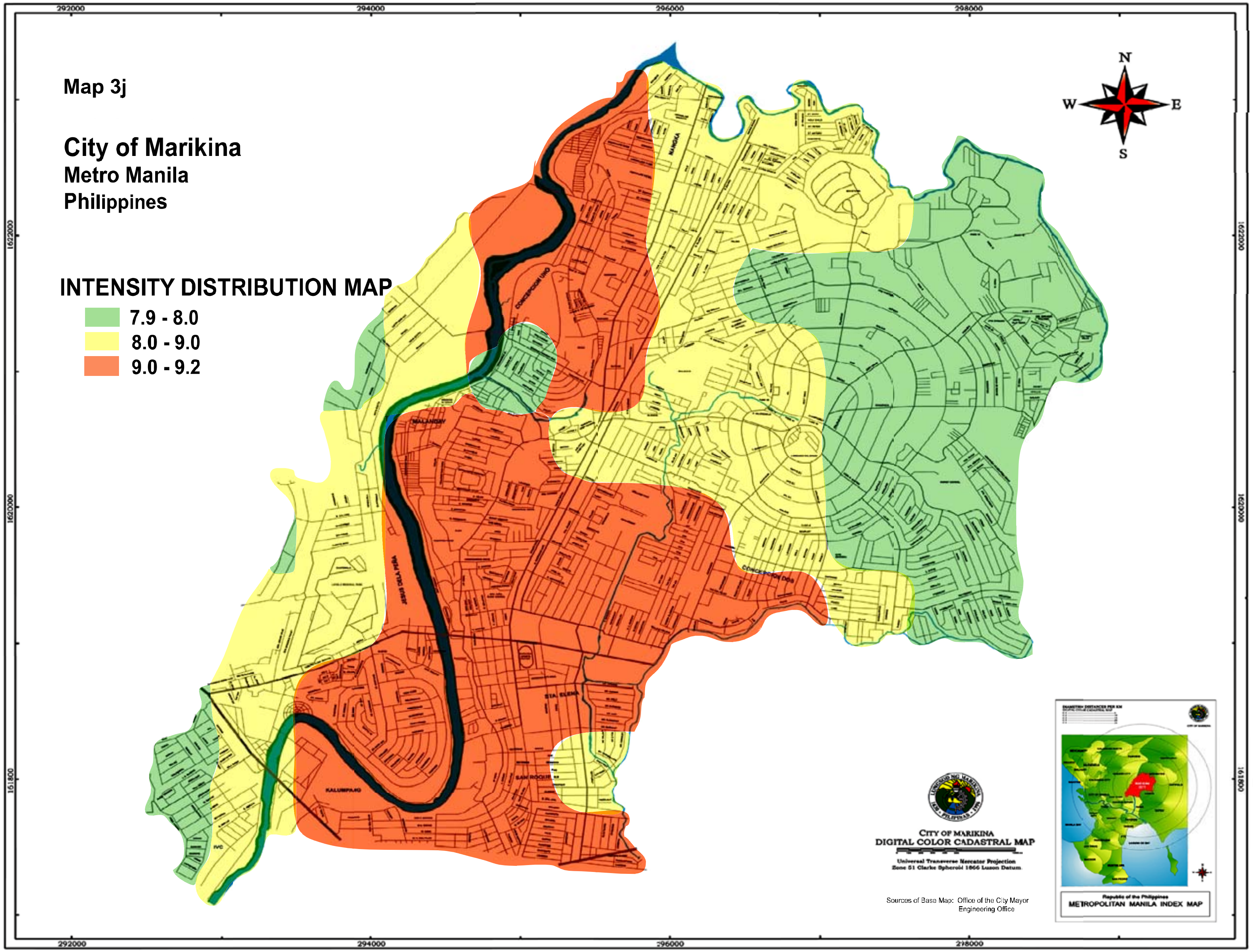
- Basement complex/Pyroclastic flow deposits/Adobe – Hard Rock (1)
- Tuff and Tuffaceous sediments – Soft Rock (2)
- Quaternary alluvium (not liquefiable) – Medium Soil (3)
- Quaternary alluvium (liquefiable) – Soft Soil (4)

The resulting Soil Type Distribution using the RADIUS microzoning system is appended as Annex 2. Map 3i shows the Soil Type Distribution Map overlaid on the planimetric map of Marikina City. Based on this map, it can be seen that about 38 percent are underlain by soft, liquefiable soils, while 21 percent of the land area have stiff, alluvial soils. Areas underlain by soft rocks account for 12 percent, while the remaining 30 percent of the city are underlain by hard rocks.

Given this distribution of soil types within the city as well as the scenario earthquake parameters, the intensity distribution can be calculated by the program. Seismic intensity scales and PGA are popular measures. The program calculates the PGA by using one of three available attenuation formulas: Joyner & Boore (1981), Campbell (1981), or Fukushima & Tanaka (1990). The attenuation equation selected in this study is that of Fukushima and Tanaka (1990). The PGA values were converted to MMI using the empirical formula of Trifunac & Brady (1975) as intensity scales are the most familiar index to indicate the strength of ground shaking in terms of effects visible to and felt by humans. Several types of intensity scales exist and different types are used throughout the world (see Annex 3). The Modified Mercalli Intensity scale is the intensity scale used in RADIUS.

Results of the intensity calculations made by RADIUS are shown on Map 3j (Intensity Distribution Map). The raw results produced are appended as Annex 4. The Intensity Distribution Map shows that Marikina City is expected to experience MMI levels ranging from 7.9 to 9.2, or an average intensity of 8.57. The equivalent ground accelerations are 0.2g to 0.6g or an average of 0.4g.


Map 3i
City of Marikina
Metro Manila
Philippines
SOIL TYPE DISTRIBUTION MAP
Hard Rock
Soft Rock
Medium Soil
Soft Soil
N
W
E
S
CITY OF MARIKINA
DIGITAL COLOR CADASTRAL MAP
Universal Transverse Mercator Projection
Zone 51 Clarke Spheroid 1866 Luzon Datum
Sources of Base Map: Office of the City Mayor
Engineering Office
Republic of the Philippines
METROPOLITAN MANILA INDEX MAP
292000
294000
296000
298000
1622000
1620000
161800
JESUS DELA PEÑA
CONCEPCION UNO
CONCEPCION DOS
MALANDAY
MARIKINA
STA. ELENA
SAN ROQUE
KALUMPANG
IVC


Map 3j
City of Marikina
Metro Manila
Philippines
INTENSITY DISTRIBUTION MAP
7.9 - 8.0
8.0 - 9.0
9.0 - 9.2
N
W
E
S
292000
294000
296000
298000
1622000
1620000
161800
CONCEPCION UNO
CONCEPCION DOS
MALANDAY
JESUS DELA PEÑA
STA. ELENA
SAN ROQUE
KALUMPANG
IVC
CITY OF MARIKINA
DIGITAL COLOR CADASTRAL MAP
Universal Transverse Mercator Projection
Zone 51 Clarke Spheroid 1866 Luzon Datum
Sources of Base Map: Office of the City Mayor
Engineering Office
Republic of the Philippines
METROPOLITAN MANILA INDEX MAP

Based on the Intensity Distribution Map, a large part of the city (38 percent), including the downtown area where the major thoroughfares of Bonifacio Avenue, Shoe Avenue and Rizal Avenue converge, will experience the strongest ground shaking of at least MMI=9. Downtown Marikina plays a vital function in the working of the city. This is where major commercial and business activities are offered to the populace as well as administrative services as the Marikina City Hall is also situated in this district.

The area that will experience ground shaking of MMI=8 to 9 (32 percent) is predominantly residential in terms of land use. Commercial land uses are also here due to the presence of modern large shopping centers (Riverbanks Center and Marikina Heights Shopping Mall). Riverbanks Center is composed of several freestanding commercial buildings offering a wide-variety of products and services such as a shopping mall, hotel, conference hall, restaurants, and amusement centers. It is Marikina's modern commercial district and is also a regional commercial and shopping node as it attracts residents from neighboring cities. Marikina Heights Shopping Mall, on the other hand, is a neighborhood shopping center, with a smaller catchment area compared to the Riverbanks Center. As this area is underlain by non-liquefiable alluvium, tuff, and tuffaceous sediments.

In this moderate intensity shaking region, the pre-existing fault trace of the western splay of the Valley Fault System is found. It is overlain mostly by low- to medium- density residential land uses.

The area of the least shaking intensity or MMI=7 to 8 is found in the western and eastern edges of the city (30 percent), This shaking region is characterized by medium to heavy industrial land uses. Residential land uses, characterized by planned residential subdivisions for the upper and middle strata of the society typify the western edges.

3.3.2 Collateral Seismic Hazards

The assessment made by this study is mainly focused on the severity of ground shaking hazard that could result from the scenario earthquake. Ground shaking is the primary seismic hazard. Liquefaction potential is already incorporated as a contributory factor to the severity of ground shaking through the soil classification used in RADIUS. This last section discusses the collateral hazards of ground shaking.

3.3.2.1 Surface Faulting

Breaking and moving of the ground surface as a result of faulting is another collateral hazard. Surface faulting is normally associated with shallow (less than 20 kilometers deep) earthquakes of magnitude of at least 7 (Ikeda, 2002). It is thus expected to occur given the parameters of the scenario earthquake. As a result of surface faulting, the ground may be displaced horizontally, vertically, or both. A surface rupture involving several feet of movement will cause heavy damage to almost all structures straddling the fault. The area of impact of this particular hazard, however, is confined mainly within the zone of the pre-existing fault.

The West Valley Fault is found in the Intensity 8 shaking area. According to Daligdig and Besana (1992), an earthquake of magnitude 7.5 from the WVF could result to a maximum right-lateral displacement of two to four meters, large displacements which will destroy any building on the fault no matter how well built it is. In addition, a misalignment of roads and fences may occur.

It is evident that the West Valley Fault zone is already built-up in some places, although much of the land in the upper part of the fault is still vacant. This area is characterized by low-density planned residential estate (Loyola Heights) for the well off. The southern trace of the WVF, however, traverses a medium-density residential area (Montevista). Property damage due to surface rupture usually accounts for only a small fraction of total losses in a seismic disaster and can be predicted with satisfactory accuracy once the fault line is defined (Panel on Earthquake Loss Estimation Methodology, 1989). Unfortunately, PHIVOLCS has not precisely delineated the West Valley Fault line on the ground.

3.3.2.2 Landslides and Tsunamis

Landslides, another collateral hazard that could be triggered by strong ground shaking, are considered negligible in the study area. Based on the hazard evaluation of Daligdig and Besana (1993), the city is slightly prone to landslides due to flat-lying, moderately weathered tuff bedrock. They recommended that detailed stability studies and mapping be conducted to identify areas where discrete or localized slope failures may occur. Landslide risk assessment, on its own, is a highly specialized discipline (e.g. Leiba *et al.*, 2003). Landslides are therefore not treated in this study.

Tsunamis are seismic sea waves generated by underwater faulting, movements along trenches, submarine landslides as well as submarine volcanic eruptions. Therefore, tsunamis are not expected to occur in the scenario earthquake for Marikina City. Based on historical earthquake events, it is Manila Trench that could be tsunamigenic. However, the narrow mouth of Manila Bay and presence of Corregidor Island act as barriers that protect the inland areas of the metropolis (Daligdig and Besana, 1993), although the coastal zone of Metro Manila fronting Manila Bay may be susceptible to tsunamis, as evidenced by the 1677 and 1863 earthquakes.

CHAPTER 4

ASSESSING EARTHQUAKE VULNERABILITY

How much loss might it suffer from a future earthquake? How many will die or be injured? How much will be the damaging effect on the city's buildings? How big a disaster will a seismically challenged city face? These are some key questions that earthquake prone cities should ask. A forecast of the adverse consequences of a hypothetical or scenario earthquake is called a damage estimate (Panel on Earthquake Loss Estimation Methodology, 1989). Damage estimation is a difficult undertaking but necessary to construct a seismic risk scenario. It is of growing importance in planning seismic risk reduction strategies and disaster preparedness, particularly in high-risk areas (Spence *et al.*, 2003; Oyo Group, 2000; Bolton *et al.*, 1986). Earthquake damage estimation is thus imperative to identify especially vulnerable or high-risk areas in the city, anticipate the probable extent of physical damage and, by extension, how many people could be adversely affected, pinpoint critical facilities that are particularly at risk, and stimulate and provide a logical basis for seismic disaster mitigation planning.

This chapter will discuss the seismic vulnerability of Marikina City through the estimation of potential damage from a scenario earthquake. In the last chapter, a scenario earthquake has been chosen and its parameters elaborated. As a user-selected earthquake, it is known as the "worst case scenario" earthquake. Loss estimates in this study are considered deterministic in the sense that they are based on a single scenario earthquake, although a range of the expected losses is provided as well.

4.1 Estimating Potential Earthquake Damage

After evaluating the seismic hazards, seismic risk analysis proceeds to the assessment of the adverse consequences that these hazards might bear upon the society. The most influential method of damage assessment was developed by the Applied Technology Council commonly known as ATC-13 (Kijko *et al.*, 2003). The ATC-13 proposed a loss estimation model for seven levels of earthquake intensity against potential percent physical damage for 78 facility types and 36 building classes existing in California in order to estimate the economic impact of a future large earthquake (ATC, 1985). Damage in this model is expressed in terms of monetary losses, specifically, the ratio of (US) dollar loss to replacement value, otherwise known as the damage factor. The mean damage factor can then be calculated for a group of similar structures.

Traditionally, vulnerability asssement seeks to ascertain the relationship between ground motion and expected damage to different classes of buildings (Kijko *et al*., 2003; Oliveira, 2003; Kappos, 1998; Chen *et al*., 1997; Panel on Earthquake Loss Estimation Methodology, 1989). This necessitates the development of a building inventory (e.g., Dolce *et al*., 2003; King *et al*., 1997; McCormack and Rad, 1997; ATC, 1985). Complete inventory collection is the most costly and time-consuming phase of this method of vulnerability analysis. Data on existing building stock are collected (e.g., types, heights, design levels, occupancies, age, etc.) and structures are then classified according to structural type, occupancy, number of stories, construction materials, age, and other criteria. Building typologies are therefore established for a specific area of interest. More strenuous criteria may result in a more detailed building classification scheme depending on the needs of the user. Damage estimation usually covers only large groups of similar structures and not individual buildings. However, damage estimation studies can be conducted on an individual structure basis as well (see Rojahn *et al*., 1997).

Motion-damage relationships for a variety of building classes are established through the use of engineering judgment or damage data from past earthquakes where construction types are compatible, or both. In practical situations, a survey of experts (i.e. a combination of experienced specialists such as engineers, architects, and building officials) is normally conducted to form an expert opinion on the potential damage most likely to be observed for each building class, as pertinent data are seldom available, even in highly developed countries (Kappos *et al*., 1998; ATC, 1985). The relationship between ground shaking and damage is commonly represented by a vulnerability curve or a damage probability matrix. A vulnerability curve describes the damage ratio of a particular building class at various intensity levels, while a damage probability matrix, constructed for each building class, indicates the probability that a particular building class would suffer a certain damage state at certain quake intensity. The difference between the two is that the latter incorporates the probabilistic nature of the loss phenomenon (Kircher *et al*., 1997). The total earthquake loss estimate is the aggregate or the sum of losses in each construction class. Such loss estimates are useful in assessing potential building damage, cost of repairing damage, direct economic losses, and for application in the insurance industry.

With the advent of Geographic Information System, or GIS, vulnerability studies have been fast tracked with the use of digital maps and electronic files of building inventories. Vulnerability to different natural hazards can now be mapped to a scale and level of detail that was barely possible before the 1990s (King, 2001). One example of a computer program that uses GIS as a platform is HAZUS. HAZUS is implemented through PC-based GIS software (an original MapInfo version and an ArcView version for East, West, and Central regions of the United States) and is used as a standardized methodology in the United States for loss estimation arising from natural hazards (FEMA, 2002). First developed in 1994 to assess the impact of earthquakes, it has been expanded to include models of flooding (riverine and coastal) and wind (hurricanes, thunderstorms, tornadoes, extra tropical cyclones and hail) hazards. It provides three levels of analysis to suit the level of effort and expertise of the user. Hence, one can improve the accuracy of HAZUS loss estimates by providing more detailed data about an area's geology or building stock. An extra feature of the program is a module on inventory data collection to provide guidance to planners, local officials, and emergency managers in gathering inventory data required for regional multi-hazard loss estimation (NIBS, 2004).

Another computation tool using GIS and artificial intelligence techniques is the European project SERGISAI. The SERGISAI procedure for seismic risk assessment has been developed to estimate expected earthquake damage at three geographical scales (e.g., regional, sub-regional, and local) and intended for use in civil defense and land use planning (Zonno *et al.*, 2003). The prototype has been applied in Toscana, Italy and Barcelona, Spain.

In spite of these technological advances, the problem of building inventory collection still exists. Different government agencies and private offices have different pieces of necessary information. Not one source has the complete data set, if the data exist at all. Even if collecting all the information from various sources is possible, the data set is often incomplete. Most of the time, available data have many gaps and holes. Also, combining the information is difficult because the data are usually not uniform, are in different formats, and have different levels of aggregation. This problem is more severe in developing countries where priority is not given to creating databases of the built environment. In such situations, generating a building census then becomes a requirement.

Because of the pervasive problem of lack of or inadequate building inventory and the cost of conducting a building census, alternative techniques that expedite building classification have been tried such as the use of census information, which results in a coarse earthquake damage assessment (Oliveira, 2003). Other means involved aerial photography and random sampling of buildings (Khudeira and Mohammadi, 2000). Another method that circumvents the procedure of establishing a building inventory makes use of macroeconomic indicators to estimate earthquake losses (e.g., Yong et al., 2001;Chen *et al.*, 1997). It bypasses the building inventory problem by using regional GDP to represent total social wealth and prorating it with population distribution as a proxy indicator of an area's building stock. Potential physical damage to buildings is thus computed as losses in the area's social wealth as a whole.

4.2 Study Methodology

4.2.1 RADIUS: Tool for Earthquake Damage Estimation

The computer program used in this study for earthquake damage estimation was RADIUS, which stands for Risk Assessment Tools for Diagnosis of Urban Areas Against Seismic Disasters. This freeware can be used to calculate seismic intensity distribution (as in Chapter 3) as well as building damage, number of casualties, and lifeline damage. The user does not need to attend a special training unlike for computer programs that use GIS as a platform. It runs on the widely available spreadsheet program, Microsoft Excel. The RADIUS tool is user-friendly with its help and instruction documents and requires no expensive hardware. It provides visual outputs in the form of tables and grids that give a spatial dimension to damage calculations. Although its functions and accuracy are limited, RADIUS is suitable for the purpose of assessing vulnerability on a citywide scale (Oyo Group, 2000).

4.2.1.1 Building Classification and Vulnerability Functions in RADIUS

Utilizing RADIUS means applying the default building classification scheme and damage functions for the city of Marikina. Building classification is generally based on a number of parameters such as use or occupancy type and structural system or building type. As earthquake damage is predicted based on the building type, the structural system is considered as a key factor in assessing building performance and casualties (Kirchner *et al.*, 1997). There are four building categories in RADIUS based on the function or occupancy of the building, i.e. residential, commercial, institutional (educational and health), and industrial. These major categories are further refined into several building subclasses based on the kind of construction materials used (reinforced concrete, unreinforced masonry, or composite construction), mode of construction (engineered or non-engineered/informal construction), code application, and number of stories (Table 4a). The simple classification scheme, largely derived from the RADIUS case studies of nine cities, considers that the tool will be mainly used in developing countries (OYO Group, 2000). The user is thus expected to enter data for building inventory that closely match the building classes in the program.

Table 4a. Building Classification Used in RADIUS Program

Classification	Description
RES1	Informal construction: mainly slums, row housing, etc. made from unfired bricks, mud mortar, loosely tied walls and roof.
RES2	Unreinforced masonry (URM) – reinforced concrete (RC) composite construction: substandard construction, not complying with the local building code provisions, with height of up to 3 stories.
RES3	URM-RC composite construction: old, deteriorated construction, not complying with the latest building code provisions, with height of 4 to 6 stories
RES4	Engineered RC construction: newly constructed multi-story buildings for residential and commercial purposes
EDU1	School buildings up to 2 stories: generally, the percentage of this type of buildings should be very low
EDU2	School buildings greater than 2 stories: office buildings should also be included in this class; generally, the percentage of this type of buildings should be very low
MED1	Low to medium rise hospitals: generally, the percentage of this type of buildings should be very low
MED2	High rise hospitals: generally, the percentage of this type of buildings should be very low
COM	Shopping centers
IND	Industrial facilities: both low and high risk

Earthquakes are complex phenomena to model. Any detailed earthquake damage estimation exercise typically conducted in developed countries is just as complex and requires extensive data and skilled personnel. In the RADIUS program, vulnerability functions are determined as the function of MMI/acceleration as shown in the building damage curve (Figure 4a). A simplified engineering model is adopted by the program in order to make data collection straightforward, speed up the calculations, and make it easy to use for local decision makers and planners in developing countries (Oyo Group, 2000).

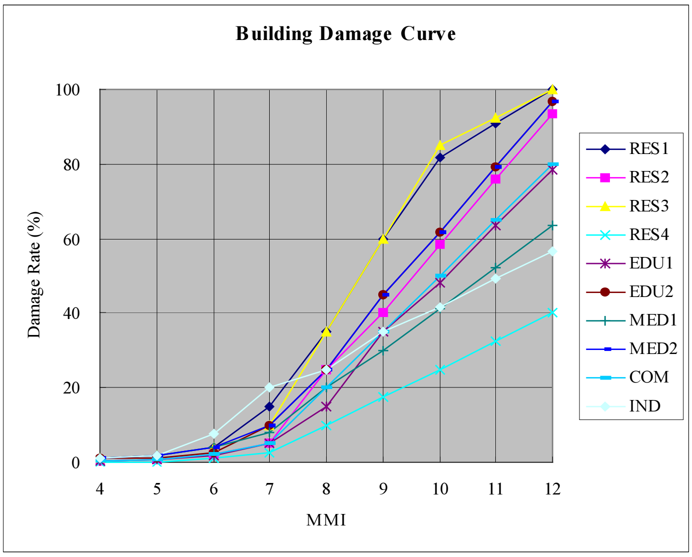


Figure 4a. Building Damage Curve

Like in other damage estimation studies, the vulnerability curves applied in RADIUS are based on damage data observed from past earthquake events. One caveat though: damage estimation results using RADIUS must be treated as preliminary estimations only. Further validation and more detailed studies could be conducted, if more accurate damage estimates are needed.

4.2.1.2 Other Constant Data Used in RADIUS

Constant data used for damage analysis in the RADIUS program are mesh weight rates, vulnerability values for casualty estimation, the difference between daytime and nighttime populations for each building class, and definitions of daytime and nighttime.

The user is required to input the mesh weight (relative density of building counts) of each grid. Mesh weight rates range from "Very High", “High", “Medium", or "Low," with the corresponding weight factors of 3.0, 2.0, 1.0, and 0.5, respectively. The user also has to enter the total number of buildings in the study area and the percentages of building classes present in each mesh.

Since building damage is a major cause of casualties during earthquakes, casualty counts in terms of the number of deaths and the injured are estimated by using default building class coefficients and number of damaged buildings. As the number of people indoors during the day is not the same as the number of people indoors at nighttime, the time of occurrence for the scenario earthquake must also be specified. Casualty estimations largely depend on the time of occurrence of the quake. For instance, schools and offices are fully occupied during the day, while these are deserted at night.

Damage estimation of essential facilities including lifelines is another complex task. The program calculates only the total damage for the whole area under study, not for individual meshes. Lifelines for which earthquake damage can be estimated are roads (local and highway), bridges, tunnels, electrical and telecommunication supply (towers and sub-stations), water supply and sewage (trunk and distribution lines, pumping stations, and treatment plants), reservoirs, dams and tanks, and gasoline stations.

4.2.2 Applying a Land Use Approach to Building Classification

Earthquake damage is usually estimated for every subdivision or zone of the area of interest; hence, it is also known as seismic microzoning. This damage estimation method is used in RADIUS in the form of mesh zoning. As mentioned previously, the study area was subdivided into 77 meshes or grids. In order to estimate potential building damage, the different classes of buildings present in each grid and the corresponding percentage of each class must be entered in the program.

As there is a lack of an electronic database of building inventory in Marikina City, an alternative methodology was developed as part of this research to produce a building inventory on a mesh basis. The approach is based on existing land use types identified in each grid, rather than on individual structures. The method employed a combination of remotely sensed data in the form of an aerial photo, updated land use map, land use survey through foot and windshield surveys, and interviews with resource persons, i.e. the Building Official and City Engineer. In short, the study made the best possible use of already existing information as well as of local expertise and their familiarity with the city.

Firstly, windshield and foot surveys were conducted from January to March 2003 to compare and contrast on the ground the 2002 land use map and the 1997 aerial photo obtained from the Engineering Department and City Planning and Development Office of Marikina City to see if there were changes in the land use pattern of the city during the intervening years. Based on the surveys, there were very minimal changes in the land use portrayed by the aerial photo when compared to the updated 2002 land use map of the city. Hence, the aerial photo was deemed usable for the purpose of identifying land uses within the city, while counterchecking with the 2002 land use map at the same time.

Secondly, the aerial photo was subdivided into the same 77 grids as previously done with the base map used in the study. Land uses present in each grid were identified with the assistance of resource persons, carefully taking note of the slight changes that were observed on the 2002 land use map and during the land use surveys. For questionable areas on the aerial photo or areas where land use was difficult to ascertain, a validation was conducted by ground truthing.

In order to identify the types of buildings typical in the major land use categories in Marikina City, a rapid survey of buildings was conducted. Four grids were selected to represent different urban matrices so that different land uses would be captured for analysis: medium density residential land use (Grid 7), low-density residential land use (Grid 11), commercial land use (Grid 31), and industrial/high-density residential land uses (Grid 67). The size of the sample was 10 percent of the total number of buildings in each chosen grid as counted from the aerial photo. Systematic sampling of structures with a random start was performed. The rapid building survey also provided empirical data, which served to verify if the building classification system of RADIUS was indeed applicable in the study area. The interview schedule used in the building survey is attached as Appendix 8.

Survey data were coded, processed, and analyzed using SPSS 10.0 for Windows. Land use classes identified in the grids were taken to mean as occupancy types. As mentioned, the RADIUS program uses four major classes of buildings based on occupancy type, i.e. residential, commercial, institutional, and industrial. Residential and institutional categories are further refined into several building classes. Based on several criteria such as the mode of construction, code compliance, construction materials used, and number of stories, several subclasses of residential use are employed in RADIUS, e.g. RES1, RES2, RES3, and RES4 as well as several subclasses of institutional use, e.g. EDU1, EDU2, MED1, and MED2. Major commercial shopping centers and industrial buildings are simply classified into COM and IND, respectively, without further refinement.

To determine the proportions of residential subclasses, cross-tabulation of different variables were performed, e.g. cross-tabulation of major occupancy types with types of structure (single house, multi-family dwellings, buildings, factories, etc.), and structure types with mode of construction (whether engineered or non-engineered, which suggests if the structures complied with the building codes or not), type of walling material (reinforced concrete, unreinforced masonry, wood/timber, mixed/composite construction, etc.) and number of stories.

Critical institutional facilities such as schools and hospitals were, on the other hand, easily pinpointed in each grid with the help of the resource person, while major commercial shopping centers and industrial plants were readily identifiable on the aerial photo.

The percentages of building classes in each grid were then estimated and entered in the computer program. For grids characterized by an amorphous mix of commercial and various subclasses of residential structures, the proportions gathered from Grid 31 were applied. This was done, as it was difficult to ascertain the percentages of the different types of residential structures, particularly to differentiate on the aerial photo the RES4 structures from RES 1 and RES 2, which were also observed to be present in such grids during the land use and building surveys. Therefore, it was assumed that an equal percentage of RES 1, RES 2, and RES 4 structures were present in those grids.

Housing census data of 2000 were likewise used as a basic guide in the determination of construction types present in the study area. The problem with the census data was that the basic unit of analysis is not buildings but households. In the Philippines, it is normal to find two or more households sharing one residential dwelling. Hence, utilizing the available housing census data for damage assessment was not possible.

4.3 Results of the Rapid Building Survey

A brief discussion of the general characteristics of the building stock as well as the profile of land uses in each surveyed grid is given below. The results of the survey are then generalized to establish the typical building classes found in the different land use types in Marikina City.

4.3.1 Grid 7, Medium-Density Residential Matrix

This grid is located in the southern area of the city. The larger portion belongs to Barangay IVC, while the rest lies within *Barangays* Barangka and Kalumpang. Grid 7 (Figure 4b) was assumed to represent a matrix of typical middle-income residential area, e.g., Industrial Valley Subdivision and Montevista Subdivision.

Based on the land use and building survey done within the grid, the area was predominantly residential (94 percent). Two types of residential land use were noted: a large typical middle-income, medium-density residential area (Figure 4c) and two small sections composed of low-income, high-density residential land use, UBB in the north and Olandes in the south (Figure 4d). These different land uses are clearly identifiable on the aerial photo as well. The existence of industrial land use (2 percent) near residential neighborhoods is not uncommon in many Philippine cities. Structures for residential with commercial use (6 percent) are predominantly residential structures whose first story is partly occupied by minor commercial activities, which are generally retail sales or personal services, e.g., convenience stores, canteens, bakeries. This land use is highly ubiquitous and can be found perhaps in all cities throughout the Philippines.

Conversely, a building is classified as commercial with residential use when the entire first story is occupied by commercial activity, usually of retail, wholesale, or personal and business service nature. This land use type accounted for two percent. Table 4b shows the frequencies of the types of land uses/building occupancy based on the survey of Grid 7.

Figure 4b. Grid 7

Table 4b. Types of Land Use/Occupancy, Grid 7

Land Use/ Occupancy Type	Frequency	Percent	Cumulative Percent
Residential	36	73.5	73.5
Commercial	3	6.1	79.6
Industrial/ Manufacturing	1	2.0	81.6
Residential with commercial use	3	6.1	87.8
Commercial with residential use	1	2.0	89.8
Institutional	5	10.2	100.0
Total	49	100.0	

Cross-tabulation results shown in Table 4c indicate that residential land uses were made up mostly of single houses (94 percent). Of the single houses, the most common were one-story (54 percent) and two-story single, detached dwellings (41 percent). Three-story houses were seldom (5 percent). The rest were multi-unit residential dwellings (6 percent), e.g., duplexes, townhouses, apartments, with one to three stories.

Table 4c. Type of Land Use/Occupancy per Type of Structure, Grid 7

Type of Land Use/ Occupancy		Single house	Duplex/ Townhouse/ Apartment	Building	Factory	Ware-house Type	Total
Residential	% within Use	94.4%	5.6%				100.0%
	% within Structure	87.2%	100.0%				73.5%
Commercial	% within Use			66.7%		33.3%	100.0%
	% within Structure			40.0%		50.0%	6.1%
Industrial	% within Use				100.0%		100.0%
	% within Structure				100.0%		2.0%
Residential with commercial	% within Use	100.0%					100.0%
	% within Structure	7.7%					6.1%
Commercial with residential	% within Use			100.0%			100.0%
	% within Structure			20.0%			2.0%
Institutional	% within Use	40.0%		40.0%		20.0%	100.0%
	% within Structure	5.1%		40.0%		50.0%	10.2%
Total	% within Use	79.6%	4.1%	10.2%	2.0%	4.1%	100.0%
	% within Structure	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Figure 4c. Typical reinforced concrete low-rise single house (left) and an ordinary neighborhood (right) in a medium-density middle-class subdivision.

Figure 4d. Substandard reinforced concrete residential houses packed in a high-density residential area (left) and an example of a self-built single house (right). Note the warehouse type of structure (without walls) in the left photo used as a multi-purpose hall.

Commercial land uses were manifested in terms of multi-story buildings (from one to three floors) (67 percent) and warehouses (33 percent). Institutional land uses were present in the form of single houses (40 percent), e.g., used as pre-/nursery schools, and multi-story buildings (40 percent) and warehouse type structures (20 percent), e.g. multi-purpose halls (Figure 4d). As Table 4d indicates, the most common type of building in this grid was the single house, accounting for almost 80 percent of the area's building stock. The most predominant building use was for residential (74 percent).

Based on the cross-tabulation between occupancy types and kind of walling materials (Table 4d), 69 percent of structures for residential purpose were made of reinforced concrete walls. Generally defined, reinforced concrete buildings are structures with vertical and horizontal steel reinforcing within concrete masonry walls (FEMA, 1998). Reinforced concrete walls are "assumed to resist load through resistance of the masonry in compression and the reinforcing steel in tension or compression" (ATC, 1997). Most commercial (67 percent) and institutional (80 percent) buildings and all industrial structures (100 percent) were also made of RC walls.

A curious observation is the presence of structures built of both wood and masonry (e.g., concrete, brick, or stone), which comprised more than 14 percent of the building stock in the grid (Figure 4e). Masonry-cum-wood structures in this area were primarily used for residential purpose (including those used partly for commercial activity) (100 percent). The lower story is usually built of masonry walls, while the second floor is made of wood. Masonry walls of this particular building type may or may not be reinforced. This type of mixed construction started to become popular in the 1970s (Pacific Consultants International *et al*., 2002). It is the third most prevalent walling material used for buildings in Metro Manila (Sarausad, 1993). The first choice for construction material is concrete/brick/stone followed by wood.

Figure 4e. An example of a non-engineered composite construction of masonry (first floor) and wood (second floor). The first story is partly used as a small neighborhood retail store.

Table 4d. Occupancy Type per Walling Material, Grid 7

Occupancy Type		RC	C/B/S	Wood/ Timber	Part C/B/S / Part Wood	No walls	Total
Residential	% within Occupancy	69.4%	8.3%	8.3%	13.9%		100.0%
	% within wall	73.5%	100.0%	100.0%	71.4%		73.5%
Commercial	% within Occupancy	66.7%				33.3%	100.0%
	% within wall	5.9%				50.0%	6.1%
Industrial	% within Occupancy	100.0%					100.0%
	% within wall	2.9%					2.0%
Residential with commercial	% within Occupancy	33.3%			66.7%		100.0%
	% within wall	2.9%			28.6%		6.1%
Commercial with residential	% within Occupancy	100.0%					100.0%
	% within wall	2.9%					2.0%
Institutional	% within Occupancy	80.0%				20.0%	100.0%
	% within wall	11.8%				50.0%	10.2%
Total	% within Occupancy	69.4%	6.1%	6.1%	14.3%	4.1%	100.0%
	% within wall	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: RC – Reinforced Concrete; CHB – Concrete hollow blocks;
C/B/S – Concrete/Brick/Stone.

Wooden walls comprised about eight percent of residential structures, while URM houses composed the remaining eight percent. Unreinforced masonry (URM) structures are generally defined as buildings with walls made of CHB, bricks, or stones without reinforcing steel bars. URM walls withstand gravity and lateral loads through the resistance of the masonry materials alone (ATC, 1997).

Looking further into occupancy types and their mode of construction, Table 4e shows that only about 58 percent of residences (e.g., single houses and duplexes/townhouses) and 67 percent of commercial buildings were engineered. An alarming 42 and 33 percent were self-built houses and commercial buildings, respectively. Other structures used for residential with minor commercial, commercial with residential, industrial, and institutional were all engineered (100 percent). As a whole, only 67 percent of the building stock in this grid were engineered and a substantial 33 percent were self-built.

Table 4e. Occupancy Type and Mode of Construction, Grid 7

Type of Occupancy		Engineered	Non-Engineered	Total
Residential	% within Occupancy Type	58.3%	41.7%	100.0%
	% within ENGG	63.6%	93.8%	73.5%
Commercial	% within Occupancy Type	66.7%	33.3%	100.0%
	% within ENGG	6.1%	6.3%	6.1%
Industrial	% within Occupancy Type	100.0%		100.0%
	% within ENGG	3.0%		2.0%
Residential with commercial	% within Occupancy Type	100.0%		100.0%
	% within ENGG	9.1%		6.1%
Commercial with residential	% within Occupancy Type	100.0%		100.0%
	% within ENGG	3.0%		2.0%
Institutional	% within Occupancy Type	100.0%		100.0%
	% within ENGG	15.2%		10.2%
Total	% within Occupancy Type	67.3%	32.7%	100.0%
	% within ENGG	100.0%	100.0%	100.0%

Engineered buildings are designed by and constructed under the supervision of a registered architect and/or engineer; while non-engineered structures are self-built structures without the benefit of planning and design inputs from a licensed professional and therefore compromise safety, quality, and integrity of the structure, mainly in exchange for lower costs. Engineered structures follow at least the minimum technical specifications of existing design codes, e.g. building code, structural code, and fire code, especially structures built after 1972 (74 percent). Modern safety standards such as the National Structural Code for Buildings and National Building Code (Presidential Decree 1096) were first issued in 1972 and 1977, respectively. These codes have undergone several revisions and updates since then.

Focusing on the non-engineered structures, Table 4e reveals that the bulk of self-built structures was mostly used for residential purposes (94 percent). Now looking closer at the survey results on residential structures alone, all URM shelter (made of concrete hollow block, brick, or stone) was non-engineered (Table 4f). Most URM residential housing was concentrated in depressed or low-income areas in *Barangay* Barangka. A substantial proportion of wooden shelter was likewise self-built (67 percent). This means that informal settlers use both masonry and wooden materials for shelter construction up to the present.

There were also considerable single-family residential RC structures (36 percent) that were non-engineered. This means, even among buildings of RC construction, substandard construction quality may be found which do not conform to the minimum requirements set forth in the modern codes (Espiritu, February 2004, personal communication). This point to a problem in enforcing building and structural codes, particularly in depressed areas where people would simply build houses without bothering to secure a building permit. There could be many reasons for this situation. According to Espiritu (2004, personal communication), one primary reason for most informal settlers and squatters not to apply for a building permit is the requirement to submit a legal title to the land, which they do not possess. Therefore, they ignore the legal procedure and build their houses anyway. In the process, building construction is of substandard quality as there is no quality control from the Engineering Office and the city government loses revenues from building permit fees.

Table 4f. Residential Structures, Walling Material per Mode of Construction, Grid 7

Type of Walling Material		Engineered	Non-Engineered	Total
RC	% within Wall	64.0%	36.0%	100.0%
	% within ENGG	76.2%	60.0%	69.4%
CHB/Brick/Stone	% within Wall		100.0%	100.0%
	% within ENGG		20.0%	8.3%
Wood/Timber	% within Wall	33.3%	66.7%	100.0%
	% within ENGG	4.8%	13.3%	8.3%
Part C/B/S / Part Wood	% within Wall	80.0%	20.0%	100.0%
	%within ENGG	19.0%	6.7%	13.9%
Total	% within Wall	58.3%	41.7%	100.0%
	% within ENGG	100.0%	100.0%	100.0%

Note: RC – Reinforced Concrete, CHB – Concrete hollow block,
C/B/S – Concrete/Brick/Stone

Engineered, single-family houses and duplexes/townhouses (64 percent), on the other hand, were typically found in formal residential subdivisions. Composite construction of wood and concrete were found in both formal and informal settlements, although majority of this type of structures here was engineered (80 percent).

Figure 4f. This photo shows the diversity in the types of single-family residential houses in Marikina City. This row of houses is fronting a major thoroughfare in a traditional, non-subdivision neighborhood. Substandard structures such as one-story non-engineered unreinforced masonry (extreme left) and masonry-cum-wood houses (extreme right) and non-engineered two-story RC houses are commonly seen in similar quarters around the city. Take note again the use of residential space for petty commercial activity (building second from right).

In general, 24 percent of the building stock in this grid were built prior to the issuance of modern codes, particularly from 1950 to 1971. Most of the single houses were built in the 1970s and 1980s. The mean age of the buildings in the grid was 21 years old using the time of the survey as base year (2003). Concerning ownership, 86 percent were private properties and 10 percent were rented and used for residential and commercial purposes. The rest were either owned by the city government or undetermined.

4.3.2 Grid 11, Low-Density Residential Matrix

Another grid was surveyed due to its matrix of low-density residential land use. This high-end, exclusive residential subdivision is located in *Barangay* Tanong. Low-density residential land use is highly identifiable on the aerial photo (Figure 4g). As shown in Table 4g, the area was predominantly residential. The other land uses, found in the southern part of the grid namely, industrial land use and cemetery, were disregarded as the former was considered as part of Grid 20, while the cemetery contained no significant structures.

Figure 4g. Grid 11

Table 4g. Types of Land Use/Occupancy, Grid 11

Land Use/ Occupancy Type	Frequency	Percent	Cumulative Percent
Residential	29	96.7	96.7
Residential with commercial use	1	3.3	100.0
Total	30	100.0	

Residential land uses in the grid were manifested by single detached houses (93 percent) and duplexes and townhouses (7 percent) (Table 4h). Residential land use mixed with commercial took place in multi-family residential dwellings (100 percent). Residences in this grid, whether single- or multi-family dwellings, had either one (63 percent) or two stories (37 percent), as shown in Figures 4h and 4i.

Table 4h. Type of Land Use/Occupancy per Type of Structure, Grid 11

Type of Land Use/Occupancy		Single house	Duplex/Townhouse/ Apartment	Total
Residential	% within Occupancy Type	93.1%	6.9%	100.0%
	% within Type of Structure	100.0%	66.7%	96.7%
Residential with commercial use	% within Occupancy Type		100.0%	100.0%
	% within Type of Structure		33.3%	3.3%
Total	% within Occupancy Type	90.0%	10.0%	100.0%
	% within Type of Structure	100.0%	100.0%	100.0%

Total floor areas of these residences ranged from 122 sq. m. to about 900 sq. m. Lot areas varied in size from a modest 108 sq. m. to an astounding 1,699 sq. m. Average floor area and lot area was 376 sq. m. and 718 sq. m., respectively, fairly large floor and lot sizes considering the prohibitive prices of real estate in Metro Manila.

Lastly, 100 percent of the building stock in this grid were made of engineered reinforced concrete structures. They were also of relatively recent vintage—the oldest surveyed building was built in 1991. The mean age of structures was 10 years old reckoned from the time of the building survey (2003). In terms of ownership, 100 percent of the residences here were privately property.

Figure 4h. Typical single, detached (left) and multi-unit (right) residential shelter found in modern residential estates such as this one. Bungalows, sitting on large lot parcels, and townhouses are commonly seen structures.

Figure 4i. A two-story reinforced concrete house is under construction across the street from a row of townhouses (left) and an example of a two-story residence in a low-density residential area.

4.3.3 Grid 31, Commercial Matrix

Grid 31 (Figure 4j) is the most complicated grid in the survey in terms of land use. It covers a portion of the downtown core in *Barangay* Sta. Elena, the old heart of the city. It is where business and commercial activities are concentrated, including the New Marikina Public Market or People's Mall. It is also the site of Marikina City Hall, Sports Complex, and several educational institutions.

Looking at the different types of land uses present inside the grid (Table 4i), the two major land uses were commercial land use (including commercial with residential use) and residential land use (including residential with commercial use) comprising 51 and 41 percent, respectively.

The map depicts that a large part of the city (38 percent), including the downtown area where the major thoroughfares of Bonifacio Avenue, Shoe Avenue and Rizal Avenue converge, would experience the strongest ground shaking or MMI=9 to 9.2. This area is highly residential, but the traditional commercial and business district of the city is located here as well.

As discussed in Chapter 2, the traditional commercial district of Marikina is characterized by an amorphous mixture of commercial, residential, and institutional land uses. These land uses are found in the high-density commercial strips along Bonifacio Avenue and Rizal Avenue. Residential land use is intermingled within this commercial zone in a random fashion. Commercial land use includes wholesale and retail shops, shops offering personal, social, and business services, cafes and restaurants, and the wet and dry Public Market. Institutional land uses, on the other hand, are concentrated along Shoe Avenue where Marikina City Hall and several educational establishments are found.

In short, this area of expected highest MMI is also the area of high-density and high-intensity land uses where most of the socio-economic activities and business transactions of the city take place and high concentrations of people are found during the day. A large chunk of the residential land use of the city in the form of planned residential developments and subdivisions will also experience at least MMI=9. The Tumana Resettlement Site is also located in this high intensity area. As this area is underlain by soft, liquefiable Quaternary alluvial soils, ground failures due to may occur such as lateral spreading, settlement, and sand boils may occur.

The area that will experience ground shaking of MMI=8 to 9 (32 percent) is predominantly residential in terms of land use. Commercial land uses are also here due to the presence of modern large shopping centers (Riverbanks Center and Marikina Heights Shopping Mall). Riverbanks Center is composed of several freestanding commercial buildings offering a wide-variety of products and services such as a shopping mall, hotel, conference hall, restaurants, and amusement centers. It is Marikina's modern commercial district and is also a regional commercial and shopping node as it attracts residents from neighboring cities. Marikina Heights Shopping Mall, on the other hand, is a neighborhood shopping center, with a smaller catchment area compared to the Riverbanks Center. This area is underlain by non-liquefiable alluvium, tuff, and tuffaceous sediments.

The area of the least intensity or MMI=7 to 8 is found in the western and eastern edges of the city (30 percent), which is founded on hard, basement rocks. It is characterized by the presence of medium to heavy industrial land uses. Residential land uses, characterized by planned residential subdivisions for the middle class and informal resettlement sites near factories and along creeks typify this area as well.

Figure 4j. Grid 31

Table 4i. Types of Land Use/Occupancy, Grid 31

Land Use/ Occupancy Type	Frequency	Percent	Cumulative Percent
Residential	19	32.2	32.2
Commercial	12	20.3	52.5
Industrial/ Manufacturing	2	3.4	55.9
Transportation/ Storage/Utilities/ Communication	1	1.7	57.6
Residential with commercial use	5	8.5	66.1
Commercial with residential use	18	30.5	96.6
Institutional	2	3.4	100.0
Total	59	100.0	

The presence of mixed commercial and residential land uses (residential areas with commercial account for 9 percent and commercial areas with residential account for 31 percent) support the observation made in Chapter 2 about the amorphousness of land use in this district and the widespread conversion of residential into commercial areas, specifically in the city's traditional commercial center. As discussed previously, residential land use along a major thoroughfare or in a predominantly commercial district has the propensity to be either partly or completely converted into commercial use to take advantage of business opportunities offered by a commercially strategic location (Figure 4k). For the same reasons, the ground floor of buildings fronting a main street tends to be used for commercial purposes while the upper floors are utilized for living space. In this manner, commercial development of the area continues to take place.

Figure 4k. An archetypal masonry and wood commercial structure fronting Rizal Avenue. The ground floor is normally used for business purposes. A furniture shop occupies the ground floor in this photo, while the upper floor is used mainly as living space. Such shop houses are similarly found in the older parts of the city such as in the traditional commercial district and commercial strip on Rizal Avenue.

Scrutinizing the types of structures corresponding to the different land uses (Table 4j), statistics reveal that residential land uses (including that mixed with commercial use) were manifested by single houses (100 percent). On the other hand, commercial land uses (including commercial with residential use) exhibited more diverse structural types. In the case of purely commercial land use, structures took the form of multi-story buildings (58 percent) and warehouse type (structures without partition walls and are also used for storage) (42 percent), while commercial mixed residential land use was evident in single houses (50 percent), buildings (33 percent), and multi-unit structures such as duplexes and townhouses (17 percent). This diversity in classes of commercial structures further verifies the amorphous combination of commercial and residential land uses in the traditional commercial district of the city, which furnishes it with a unique urban fabric and differentiates it from surrounding land use districts (Figures 4l and 4m).

Table 4j. Type of Occupancy per Type of Structure, Grid 31

Occupancy Type		Single house	Duplex/ Townhouse /Apartment	Building	Factory	Ware-house Type	Others	Total
Residential	% within Occu.	100.0%						100.0%
	% within Struc.	57.6%						32.2%
Commercial	% within Occu.			58.3%		41.7%		100.0%
	% within Struc.			43.8%		100.0%		20.3%
Industrial	% within Occu.			50.0%	50.0%			100.0%
	% within Struc.			6.3%	100.0%			3.4%
Utilities/ Communication	% within Occu.						100.0%	100.0%
	% within Struc.						100.0%	1.7%
Residential with commercial	% within Occu.	100.0%						100.0%
	% within Struc.	15.2%						8.5%
Commercial with residential	% within Occu.	50.0%	16.7%	33.3%				100.0%
	% within Struc.	27.3%	100.0%	37.5%				30.5%
Institutional	% within Occu.			100.0%				100.0%
	% within Struc.			12.5%				3.4%
Total	% within Occu.	55.9%	5.1%	27.1%	1.7%	8.5%	1.7%	100.0%
	% within Struc.	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Understandably, institutional land use was made up of multi-story buildings, while manufacturing activities were housed in factories (50 percent) and multi-story buildings (50 percent). “Utilities/Communication” refers to electric supply sub-stations, transmitters, cell phone relay towers, etc.; hence the structure type was labeled as “Others.”

Table 4j likewise reveals that, in this grid, the most prominent type of structure was the single house (56 percent) as in the case of Grids 7 and 11, but the most predominant building use was for commercial (includes commercial with residential use) (51 percent).

Figure 4l. Low-rise (1 to 3 stories) reinforced concrete buildings used for commercial and business activities line both sides of Rodriguez Avenue (left) and Bonifacio Avenue (right), two major thoroughfares forming part of the traditional commercial areas of Marikina City.

Figure 4m. The traditional commercial district of Marikina City possesses a variety of structures ranging from masonry-cum-wood shop houses, low-rise commercial buildings, reinforced concrete multi-story buildings (more than 3 floors) (above) to masonry-cum-wood residences (right). The two-story residential structure has been extended outward to make space for a retail store. Behind the shop is the ground floor of the house. Such residential houses with minor commercial use are very common within the “superblock” in the traditional commercial district.

Cross-tabulating occupancy types with kinds of walling material (Table 4k), results indicate that majority of residential structures were built of mixed masonry and wood (58 percent). In addition, 60 percent of residential with minor commercial use were also housed in this composite construction type (Figure 4m). Furthermore, almost 40 percent of buildings for commercial with residential use were likewise built of combined masonry and wood. Commercial structures, on the other hand, were only 67 percent reinforced concrete.

In general, structures that were part masonry and part wood comprised 36 percent of the building stock in this grid and reinforced concrete accounted only for 49 percent. Thus, aside from its mixed commercial and residential land use, the substantial presence of masonry-cum-wood structures is another distinctive characteristic of Marikina City's downtown.

Structures used for industrial and institutional activities were all made of reinforced concrete (both 100 percent) (Figure 4n).

Table 4k. Type of Occupancy per Walling Material, Grid 31

Occupancy Type		RC	CHB/B/S	Wood/ Timber	Part C/B/S /Part Wood	No walls	Total
Residential	% within Occu.	36.8%		5.3%	57.9%		100.0%
	% within wall	24.1%		25.0%	52.4%		32.2%
Commercial	% within Occu.	66.7%	8.3%	8.3%		16.7%	100.0%
	% within wall	27.6%	50.0%	25.0%		100.0%	20.3%
Industrial	% within Occu.	100.0%					100.0%
	% within wall	6.9%					3.4%
Utilities/ Communication	% within Occu.					100.0%	100.0%
	% within wall					100.0%	1.7%
Residential with commercial	% within Occu.	40.0%			60.0%		100.0%
	% within wall	6.9%			14.3%		8.5%
Commercial with residential	% within Occu.	44.4%	5.6%	11.1%	38.9%		100.0%
	% within wall	27.6%	50.0%	50.0%	33.3%		30.5%
Institutional	% within Occu.	100.0%					100.0%
	% within wall	6.9%					3.4%
Total	% within Occu.	49.2%	3.4%	6.8%	35.6%	5.1%	100.0%
	% within wall	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: RC – Reinforced Concrete; CHB – Concrete hollow block;
C/B/S – Concrete/Brick/Stone.

Figure 4n. Institutional buildings such as the Marikina Public Library (left) and the City Hall (right) are located in the traditional commercial district.

Cross-tabulating the occupancy type with the mode of construction (Table 4l), the figures indicate that a significant number of structures used for residential (37 percent), residential with minor commercial (20 percent), and commercial with residential (33 percent) fell under the non-engineered category. In terms of the total building stock, almost 75 percent were designed and constructed under professional supervision, while the rest (25 percent) were self-built.

Table 4l. Occupancy Type and Mode of Construction, Grid 31

Occupancy Type		Engineered	Non-Engineered	Total
Residential	% within Occupancy Type	63.2%	36.8%	100.0%
	% within ENGG	27.3%	46.7%	32.2%
Commercial	% within Occupancy Type	91.7%	8.3%	100.0%
	% within ENGG	25.0%	6.7%	20.3%
Industrial	% within Occupancy Type	100.0%		100.0%
	% within ENGG	4.5%		3.4%
Utilities/ Communication	% within Occupancy Type	100.0%		100.0%
	% within ENGG	2.3%		1.7%
Residential with commercial	% within Occupancy Type	80.0%	20.0%	100.0%
	% within ENGG	9.1%	6.7%	8.5%
Commercial with residential	% within Occupancy Type	66.7%	33.3%	100.0%
	% within ENGG	27.3%	40.0%	30.5%
Institutional	% within Occupancy Type	100.0%		100.0%
	% within ENGG	4.5%		3.4%
Total	% within Occupancy Type	74.6%	25.4%	100.0%
	% within ENGG	100.0%	100.0%	100.0%

Non-engineered structures were found to be used for two major purposes, namely, residential and commercial. Thus, cross-tabulating occupancy type and walling material for non-engineered structures only (Table 4m), numbers reveal that majority (75 percent) of non-engineered residential structures (including residential with commercial use) were of masonry-cum-wood construction type. Moreover, a substantial proportion (25 percent) of RC residences were non-engineered as well.

Table 4m. Non-Engineered Structures, Occupancy Type per Walling Material, Grid 31

Occupancy Type		RC	Wood/ Timber	Part C/B/S/ Part Wood	Total
Residential	% within Occupancy	25.0%		75.0%	100.0%
	% within wall	66.7%		66.7%	53.3%
Commercial	% within Occupancy	14.3%	42.9%	42.9%	100.0%
	% within wall	33.3%	100.0%	33.3%	46.7%
Total	% within Occupancy	20.0%	20.0%	60.0%	100.0%
	% within wall	100.0%	100.0%	100.0%	100.0%

This situation is also true for non-engineered commercial structures (including commercial with residential use) as 14 percent were made of RC walls. Wooden (43 percent) and masonry and wood (43 percent) structures accounted for a significant number of non-engineered commercial buildings.

As a whole, non-engineered structures consisted of 20 percent RC buildings. This demonstrates once again that not all RC structures are engineered. It is possible that RC buildings can be of substandard construction and may not comply with modern safety standards. This situation is also true in Grid 7. Of the remaining 80 percent of the building stock in this grid, 20 percent were self-built wooden structures and 60 percent were masonry-cum-wood structures.

Furthermore, since Grid 31 is the older part of the city, the age of the buildings is another factor that can partly explain the presence of non-engineered RC structures in this area, particularly the preponderance of masonry and wood composite construction. As this grid is not only in the middle of Marikina's traditional downtown but also a part of the old *pueblo* or town, many buildings in this particular district of the city are older compared to the rest of the city. About 57 percent of all structures were built prior to the adoption of modern codes in 1972, with some structures dating back as far as 1898. The mean age of the building stock in this grid was 39 years old reckoned from the time of the survey in 2003. As discussed in Chapter 2, the more recent residential land use in the city consists of master planned subdivisions, resettlement and socialized housing sites, and informal settlements mostly located in flood-prone areas.

4.3.4 Grid 67, Industrial Matrix with High-Density Residential Land Use

An area with a predominantly industrial matrix was necessary in order to characterize existing structures used for manufacturing activities. Grid 67 is located in the highly industrialized *Barangay* Parang in the northeastern corner of the city. This area has been declared as the Marikina Economic Zone where new industries are being attracted to locate through economic incentives. Because of the strict security in manufacturing compounds, the researcher was not allowed entry. Observations were done from the sidewalk or from places where an unobstructed view of the industrial buildings were available.

Although Grid 67 was surveyed because of the preponderance of industrial buildings in the area, it is however composed of a variety of land uses (Figure 4o). In terms of the number of buildings, it is predominantly residential (84 percent) (Table 4n). Industrial land use accounted only for about 13 percent. However, on closer inspection, it is clear that in terms of land area, industrial land use is more predominant. What is notable in this grid is that it illustrates the prevalent situation in most highly urbanized areas in the Philippines where industrial land use is surrounded by high-density residential land use. Highly packed, informal settlements mushroom around industrial compounds, because factory workers and employees, who mostly earn only the minimum daily wage, build makeshift houses as near as possible to the factories where they work to save on transportation costs.

Figure 4o. Grid 67

Table 4n. Types of Land Use/Occupancy, Grid 67

Land Use/ Occoupancy Type	Frequency	Percent	Cumulative Percent
Residential	64	81.0	81.0
Industrial/ Manufacturing	10	12.7	93.7
Residential with Commercial	5	6.3	100.0
Total	79	100.0	

The ubiquitous mixed residential and commercial land use was also present, accounting for around four percent of the land use in this particular grid. Commercial use in this case was petty, mostly small neighborhood stores selling common household items on retail such as canned goods, ice, oil, noodles, soft drinks, beer, cigarettes, and candies. The meager income from such undertaking probably helps to augment the household budget no matter how small.

Cross-tabulating the type of land use/occupancy with structure types gives more in-depth information about the urban fabric of the area (Table 4o). Residential land use in general was manifested by single houses (100 percent). As in the other grids, the most prominent structure here was the single house (87 percent).

Table 4o. Type of Land Use/Occupancy per Type of Structure, Grid 67

Type of Land Use/Occupancy		Single house	Factory	Total
Residential	% within Occupancy Type	100.0%		100.0%
	% within Type of Structure	92.8%		81.0%
Industrial/ Manufacturing	% within Occupancy Type		100.0%	100.0%
	% within Type of Structure		100.0%	12.7%
Residential with commercial	% within Occupancy Type	100.0%		100.0%
	% within Type of Structure	7.2%		6.3%
Total	% within Occupancy Type	87.3%	12.7%	100.0%
	% within Type of Structure	100.0%	100.0%	100.0%

Manufacturing activities were conducted in factories and industrial plants (100 percent) made of reinforced concrete (100 percent) (Table 4p). Although the residential areas around industries were mostly low-cost housing and informal settlements, with only a small presence of medium-density housing that is easily distinguishable on the aerial photo, majority of structures used for residential (74 percent) and residential with commercial (80 percent) were built of reinforced concrete walls as shown in Table 4p.

However, looking at their mode of construction (Table 4q), the bulk of the residences (67 percent and 100 percent) were found to be self-built. Industrial buildings, in contrast, were all engineered (100 percent).

Table 4p. Occupancy Type and Walling Material, Grid 67

Occupancy Type		RC	CHB/B/S	Wood/ Timber	Part C/B/S /Part Wood	Total
Residential	% within Occupancy	73.4%	12.5%	4.7%	9.4%	100.0%
	% within wall	77.0%	100.0%	100.0%	85.7%	81.0%
Industrial	% within Occupancy	100.0%				100.0%
	% within wall	16.4%				12.7%
Residential with commercial	% within Occupancy	80.0%			20.0%	100.0%
	% within wall	6.6%			14.3%	6.3%
Total	% within Occupancy	77.2%	10.1%	3.8%	8.9%	100.0%
	% within wall	100.0%	100.0%	100.0%	100.0%	100.0%

Note: RC – Reinforced Concrete; CHB – Concrete hollow block;
C/B/S – Concrete/Brick/Stone.

Table 4q. Occupancy Type and Mode of Construction, Grid 67

Occupancy Type		Engineered	Non-Engineered	Total
Residential	% within Occupancy	32.8%	67.2%	100.0%
	% within ENGG	67.7%	89.6%	81.0%
Industrial	% within Occupancy	100.0%		100.0%
	% within ENGG	32.3%		12.7%
Residential with commercial	% within Occupancy		100.0%	100.0%
	% within ENGG		10.4%	6.3%
Total	% within Occupancy	39.2%	60.8%	100.0%
	% within ENGG	100.0%	100.0%	100.0%

Figure 4p. Manufacturing compounds in the industrial district of Marikina City.

Drawing from Table 4o, residential land uses (including residential with commercial) were 100 percent composed of single houses. Hence, cross-tabulating the kind of walling material of single houses alone and their mode of construction, 65 percent of RC structures were built by the homeowners themselves, without professional engineering input (Table 4r). Not surprisingly, the bulk of wooden (100 percent), unreinforced masonry (88 percent), and masonry-cum-wood structures (71 percent) was likewise non-engineered. These substandard structures were concentrated in the informal settlements and resettlement sites located around the industrial plants.

Table 4r. Single houses, Type of Walling Material, Engineered or Non-Engineered, Grid 67

Type of Walling Material		Engineered	Non-Engineered	Total
RC	% within wall	35.3%	64.7%	100.0%
	% within ENGG	85.7%	68.8%	73.9%
C/B/S	% within wall	12.5%	87.5%	100.0%
	% within ENGG	4.8%	14.6%	11.6%
Wood/Timber	% within wall		100.0%	100.0%
	% within ENGG		6.3%	4.3%
Part C/B/S/ Part Wood	% within wall	28.6%	71.4%	100.0%
	% within ENGG	9.5%	10.4%	10.1%
Total	% within wall	30.4%	69.6%	100.0%
	% within ENGG	100.0%	100.0%	100.0%

Figure 4q. A high-density residential neighborhood (left) displays a variety of single houses—non-engineered wooden/makeshift, unreinforced masonry, and reinforced concrete structures stand side by side along a road, while informal settlements composed of makeshift, densely packed houses as in the right photo are commonly seen around industrial areas.

Moreover, some of these self-built houses were multi-story (25 percent), although three quarters of the non-engineered single houses (75 percent) had only one floor (Table 4s). However, in terms of total floor area (sum of the area of all floors) , self-built shelter had as little as 19 sq. m. of space. The biggest total floor area in this category was 96 sq. m. Engineered single houses had slightly larger total floor areas, ranging from a low of 25 to a modest 120 sq. m. The average total floor area of single residences in this grid was 41 sq. m.

Table 4s. Single Houses, Mode of Construction per Number of Stories, Grid 67

Mode of Construction		1.00	2.00	3.00	Total
Engineered	% within ENGG	71.4%	28.6%		100.0%
	% within STORIES	29.4%	35.3%		30.4%
Non-Engineered	% within ENGG	75.0%	22.9%	2.1%	100.0%
	% within STORIES	70.6%	64.7%	100.0%	69.6%
Total	% within ENGG	73.9%	24.6%	1.4%	100.0%
	% within STORIES	100.0%	100.0%	100.0%	100.0%

These houses, whether engineered or non-engineered, were built relatively recent, beginning from the 1970s. It was during this decade when manufacturing industries started to invest in Marikina as a response of the business sector to the industrial location policy of the government at that time, which encouraged the manufacturing sector to locate outside Manila. The mean age of the building stock in this grid was 15 years old reckoned from the time of the building survey.

4.3.5 Land Uses and Building Classes in Marikina City

Results of the land use and building surveys reveal that the building stock of Marikina City is highly heterogeneous. Buildings vary in terms of construction materials, occupancy, mode of construction, age, maintenance conditions, and design. Exposure to ground motion hazard of the building stock, moreover, is very high. Marikina City had a total of 56,089 buildings in 2003 and a total population of 389,765 in year 2000.

The classification of Marikina's building stock is not a straightforward task due to its heterogeneity. Nevertheless, drawing from the results of the survey, some generalizations can be made. The most predominant building use is residential, making up about 75 percent of the building stock. Commercial buildings account for about 16 percent while six percent are industrial plants and factories. Institutional and other miscellaneous structures (e.g., transmitters, mobile phone towers, electric power sub-stations) comprise the remaining four percent of the building stock.

The most common type of building is the low-rise single-family residence (77 percent). Single houses are built of different types of walling material. The most commonly used is reinforced concrete (68 percent) followed by the composite construction of masonry (first floor) and wood (second floor) (20 percent). Unreinforced masonry and wooden single houses account for 12 percent of single-family living units. Single, detached dwellings usually have one to three stories.

Multi-family residences such as duplexes and townhouses compose four percent. Such multi-family dwelling units are usually made of reinforced concrete (88 percent). The rest are of masonry-cum-wood construction. These low-rise buildings generally have one to three floors.

Buildings, mainly used for business and institutional purposes and industrial activities in some cases, are chiefly made up of reinforced concrete as well (10 percent). A great majority (86 percent) is composed of low-rise structures with one to three stories, though there are mid-rise buildings with four or more floors that appear to be geographically limited to the downtown area and along Rizal Avenue. There is no building height limitation in Marikina City. The remaining fourteen percent are made up of composite masonry and wood construction.

Factories (six percent), structures used for manufacturing purposes, are made of reinforced concrete. Because of their large floor areas, they are typically one-story structures.

Warehouses (three percent) mostly have no walls. They are basically open structures with only columns (either reinforced concrete or steel) and roof (57 percent). Those with reinforced concrete walls account for about 29 percent, while wooden warehouses claim 14 percent of the total. Warehouses are used for commercial (e.g., wholesale stores, covered parking/used car lot, public wet and dry market), storage of wholesale stores, and institutional purposes (e.g., multi-purpose hall, public service center).

There are vertical structures in the city that cannot be classified under the preceding structural types such as transmitters, mobile phone towers, and electric power sub-stations. These constitute 0.5 percent of the building stock. Such structures are not included in this earthquake damage estimation study.

In terms of construction material, reinforced concrete (RC) structures with one to two stories (73 percent) are predominant. These structures practically compose the built up area of the city, particularly the numerous residential subdivisions. Three or more stories of RC frame buildings can be seen in the subdivisions and in the city's downtown or traditional commercial center.

It must be noted, however, that there are RC structures that are non-engineered (30 percent). Furthermore, of the 70 percent of engineered RC structures, 11 percent were built prior to the adoption of modern building codes (pre-1971). Therefore, only a small portion (59 percent) of all RC structures can be safely assumed to have been built to modern safety standards. In general, potential damage to engineered RC structures built before 1971 can be assumed to be higher than engineered buildings erected after modern building codes had been introduced in 1972. Yet, there is still the question of whether engineered RC structures in Marikina City were designed and built according to seismic criteria, although the National Structural Code for Buildings was issued in 1972 and has been thrice updated, in 1981, 1986, and 1992. The last edition was a response to the 1990 Luzon earthquake (M=7.8). Usually, only major projects can afford to follow seismic design standard (Booth and Martinez-Rueda, 1995).

Most RC structures began to be constructed in Marikina City in the 1950s, after World War II. Reconstruction of Manila was initiated and Manila's suburbs, including Marikina, thus experienced rapid population growth and urban development. Reinforced concrete was introduced to the Philippines in 1905 by the U.S. government when it adopted concrete block for its hospitals and barracks in the country (ATC, 1997). The widespread use of RC and concrete hollow blocks (CHB) and associated construction practice are influences of the U.S. (Booth and Martinez-Rueda, 1995). At present, most buildings in the Philippines make use of RC and CHB, be it a humble abode or a skyscraper, perhaps also as a result of the dwindling supply and rising cost of timber.

Adequately reinforced concrete buildings are ductile structures that can absorb more force and therefore stands up to strong ground shaking. In past earthquakes such as in the 18 August 1980 earthquake in Guayaquil, Ecuador, RC buildings performed well, sustaining only non-structural damage (Argudo, 1999). Of the damaged RC buildings, most had more than three stories.

In the case of the August 1999 Duzce and November 1999 Kocaeli, Turkey (M=7.4) earthquakes, however, engineered RC residential apartment buildings that compromised on the quality of construction materials and workmanship suffered the consequences of ground shaking (Figure 4r) (Erdik, 2000). Moreover, there was a significant inventory of non-ductile concrete buildings in these urban areas. Non-ductile buildings are those built of concrete structurally reinforced with steel, but the quantity of steel (especially hoop or spiral steel and steel at connections) is too low to strengthen the building against lateral forces produced during an earthquake (O'Rourke, 1999).

Figure 4r. Poorly built medium-rise RC apartment blocks pancaked during the August 1999 Duzce (left) and November 1999 Kocaeli earthquakes (17,000 people killed) (right) in Turkey. (Source: Erdik, 2000.)

Hence, these buildings are prone to catastrophic fracturing of the concrete, with lethal consequences for the occupants. The Turkey earthquakes prove that RC structures could become death traps as a great number of people could be killed, when poorly designed and constructed RC buildings do collapse, as in the January 1999 Armenia, Colombia (M=6.2) and August 1999 Athens, Greece (M=5.9 (Figure 4s). Non-ductile concrete structures pose a serious problem for many cities around the world.

Another building class that forms part of the building inventory in Marikina City is the old composite two-story construction type of masonry and wood. This class comprises 16 percent of the total and can be found scattered all over the city, whether in the formal residential subdivisions, in the downtown area (the older part of the city), in resettlement sites, or in informal settlements. A significant number of such buildings (43 percent) are non-engineered.

Figure 4s. These RC structures did not withstand earthquake forces during the January 1999 Armenia, Colombia and August 1999 Athens, Greece tremblors. (Source: Scawthorn, 2000.)

Lastly, unreinforced masonry (URM) and wooden structures make up six percent and five percent of the building stock, respectively. These low-rise buildings typically stand in informal settlements and resettlement sites and are mostly non-engineered (72 percent). Of very simple plan, they are likewise light and fragile. They are made of inferior quality materials, of substandard construction, and not well maintained. Therefore, URM and wooden buildings in Marikina City generally lack any seismic-resistant feature and are more vulnerable to ground shaking hazard. Earthquake such as the 1972 Managua and the 1976 Guatemala earthquakes illustrate this point (Figure 4t).

Figure 4t. Downtown Managua City, Nicaragua after the 1972 Managua earthquake (left). The total collapse of URM and adobe buildings left 5000 people dead because of falling masonry walls and roofs supported by these walls. Complete collapse of an unreinforced brick masonry church during the 1976 Guatemala Earthquake (right). (Source: Bertero, 1985)

Of all construction materials, masonry is the oldest and dates back more than several million years in ancient cultures around the world. Buildings made of URM, however, have been observed to perform poorly in earthquakes such as in the 1933 Long Beach earthquake, after which unreinforced masonry was banned in California (ATC, 1997). Unreinforced masonry buildings are highly vulnerable to earthquake forces as URM walls tend to fall down easily, while the roof and the floor tend to break away from the walls as they are non-ductile (Khudeira and Mohammadi, 2000; O'Rourke, 1999; BSSC, 1995b). Hence, the possibility of brittle failure of URM structures, which in the case of Marikina City are mostly non-engineered or self-built, is very high such as what happened during the 2002 Hindu Kush earthquake in Afghanistan (Figure 4u).

Figure 4u. Traditional mud brick houses in Afghanistan easily collapsed and left thousands homeless as a result of the 7.4 magnitude earthquake in 2002.

In spite of the heterogeneity of the building stock of Marikina City, one can still see some repetitive patterns in the city's urban fabric such as the constant presence of non-engineered residential shelter made of wood as well as URM in the different resettlement sites and informal settlements within the city. Or the ubiquitous existence of real estate developments all over the city. Such residential subdivisions are essentially covered with low-rise single-family detached dwellings made of RC.

4.3.5.1 Summary of Building Classes in Marikina City

Drawing from the foregoing analyses, the types of land uses in Marikina City were found to be convertible to the building classes used in RADIUS. The different land use types observed in Marikina City fell into several major categories. These major land use categories are based on the zoning classification used in the Philippines. These are listed on the left-hand column of Table 4t. The common building types corresponding to each land use category are identified and described on the right-hand column of the table.

Table 4t. Types of Land Uses and Common Building Classes in Marikina City, 2002

Type of Land Use/Zone	Typical Building Types
R-1 or Low Density Residential Zone	Composed of predominantly single, detached residential dwellings of modern, engineered RC construction, usually having 1 to 2 stories. Engineered RC multi-family dwellings such as duplexes and townhouses also present. Residential dwellings used for commercial purpose vary from minimal to nil.
R-2 or Medium Density Residential Zone	Consists of predominantly single, detached residential shelter of modern, engineered RC construction, typically having 1 to 2 stories. Notable presence of multi-unit residential dwellings with 1 to 2 stories. Minor presence of 3-story single and multi-family dwellings. Minimal presence of non-engineered composite masonry and wood structures and wooden structures. Residential buildings in many cases also used for other purposes (i.e. convenience stores, pre-school). In some commercial buildings, upper floor is used for residential purpose. Presence of engineered, RC commercial and institutional buildings of up to 3 stories noted.
R-3 or High Density Residential Zone	All resettlement sites are classified as R-3 zones. Other R-3 areas located around factories and along creeks. Composed of a variety of structures such as non-engineered RC, URM, and wooden buildings as well as composite structures of masonry and wood not complying with local building codes. Most dwellings are 1-story single, detached structures although built very close to each other. Few structures have 2 to 3 stories.
Low to Medium Density Commercial Zone/ Minor Commercial Zone	Mostly as commercial strips found along major thoroughfares and the downtown area of the city interspersed with residential, industrial and institutional land uses. Composed of engineered, RC multi-story buildings, although majority are up to only 3 stories tall. Strong presence of non-engineered low-rise masonry-cum-wood commercial buildings or shop houses, where the upper floor is used for living purposes. Masonry and wood residential structures also present. Warehouses and factories notable.
High Density Commercial Zone/ Major Commercial Zone	Major shopping centers in the form of shopping malls and arcades made of modern, RC structures.
Industrial Land Uses	Include low- and high-risk industries. Composed of engineered, RC structures usually having 1 story with large floor areas.
Institutional Land Uses	Composed of local and national government office buildings, public and private school, and public and private hospitals. Mostly of engineered, RC low-rise structures, some cases of more than 3 stories.

Based on the results of the rapid building survey and in accordance with the RADIUS building classification scheme, the building types are grouped based on occupancy, walling materials used, mode of construction, and numbers of stories. Hence, land uses are converted into equivalent building classes as employed in the RADIUS program as follows (Table 4u):

Table 4u. Land Use Types Converted to Building Classes

Land Use Types/Zones	Equivalent Building Classes in RADIUS
Low Density Residential Zone (R-1)	RES4 (percentages based on Grid 11)
Medium Density Residential Zone (R-2)	RES4 with possible presence of RES2 and RES1 (percentages based on Grid 7)
High Density Residential Zone (R-3)	RES2 and RES1 with some RES4 (percentages based on Grid 67)
Minor Commercial Zone (C-1 and C-2)	RES4, RES2, and RES 1 with possible presence of IND, EDU1, EDU2, MED1, and MED2 (percentages based on Grid 31)
Major Commercial Zone (C-3)	COM (as identified from land use map and aerial photo)
Industrial Land Uses (I-1 and I-2)	IND (as identified on the land use map and aerial photo)
Institutional Land Uses	EDU1, EDU2, MED1, MED2 (as identified on the land use map and aerial photo)

4.3.6. Other Modifying Factors of Building Behavior During Earthquakes

There are other factors that affect the seismic performance of buildings during earthquakes. In the RADIUS program, the seismic factors accounted for are the building's construction type (based on construction materials used and whether they are engineered or non-engineered), height (which determines the period of the building), building condition (well-maintained or deteriorated), and code compliance (design, construction quality and workmanship that meet the provisions of modern building codes). These important building characteristics, in conjunction with the level of intensity, affect their performance in an earthquake and may spell the difference between sustaining minor damages or total collapse.

Still, there are other factors that may influence the outcome of a building in an earthquake, whether it survives or collapses. Buildings are subject to the downward pull of gravity (33 feet per second per second). Portions of a building that resist gravity and earthquake load are called structural components and include columns, load-bearing walls, beams, braces, and foundations (Wiss, 1994). In an earthquake, buildings are pushed by ground motion in all directions, up and down, but most of all, sideways. As structures are subject to more pronounced lateral forces, building components tend to be pulled apart or distorted, which can result in severe damage or collapse. Hence, the concern in designing seismic-resistant buildings lies in the capacity of the structural components of a building to handle the horizontal ground movements due to ground shaking (FEMA, 1998). Important factors, which are called “performance modifiers”—building design features that affect the overall seismic vulnerability of a structure regardless of whether it is engineered or non-engineered as well as structures with and without earthquake resistant design—affect the behavior of buildings during an earthquake (McCormack and Rad, 1997; BSSC, 1995a; ATC, 1985; Bertero, 1985). These include vertical irregularity, plan irregularity, soft story, short columns, and pounding.

Building configuration (i.e., shape and size) plays a big role in the seismic performance of a structure. A regular building configuration, that is, a simple rectangle form, is more likely to suffer less damage compared to an irregular building, no matter what construction material or structural system had been used (BSSC, 1995a).

A vertical irregularity or asymmetry in elevation results in a discontinuity of strength, stiffness, geometry, or mass in one story with respect to adjacent stories, while plan irregularity or asymmetry in the horizontal lay-out of a building are due to complexities of design such as E-, T-, X-, U, H, and L-shaped configurations (ATC, 1997). Building irregularities in plan and elevation result in stress concentration in a single or few elements or connections, which may then fail and bring down the whole building. Plan irregularities may also result in the twisting of the buildings or torsion due to forces that are difficult to control and may then tear the building apart. For instance, during the 1980 Guayaquil earthquake, most of the destroyed structures displayed an asymmetric design in both elevation and plan, possessed glass facades or “curtain walls”, and cantilever balconies (Argudo, 1999). Both vertical and plan irregularities have been cited as the main cause for collapse of many buildings in past earthquakes (Dimitriu *et al.*, 2000; Erdik, 2000; Whittaker *et al.*, 1997).

Soft story is the most serious condition of vertical irregularity. A soft story is one where there are no bracings and shear walls to transmit seismic loads to the ground. Shear walls can resist horizontal forces and transmit them back to the ground, while bracing made of ductile material gives seismic strength to a structure by resisting vertical and horizontal movements of the ground (BSSC, 1995a). A soft or weak story is usually the first story in which there are fewer or taller columns. This makes the story weaker or more flexible than the stories above, resulting in an undue proportion of forces at the second floor connections and, when the forces become unmanageable, eventually in building collapse. Large openings in the lower floors such as a garage, hotel lobbies, and a first floor used for parking in a multi-story building creates a soft story. Many building failures due to ground shaking around the world involved buildings with soft stories such as in the 1971 earthquake in San Fernando, California and in the 1994 Northridge, California earthquake where many residential apartments collapsed due to ground floor parking (BSSC, 1995b) as well as in the 1999 Athens earthquake (Dimitriu *et al*., 2000) (Figure 4v).

Figure 4v. Soft ground story collapse of Olive View Hospital in the 1971 San Fernando earthquake (left) and (pilotis) collapse of a poorly constructed four-story RC apartment in the 1999 Athens earthquake (right). Pounding could have occurred as evidenced by heavy damage on the right side of the taller building. (Sources: BSSC, 1995b; Dimitriu, 2000.)

The short column problem is often created inadvertently when space between columns is filled in by walls that do not reach the floor above, say, to allow high windows. Short columns are stiffer than longer columns. Because earthquake forces are attracted to stiffer elements, short columns tend to become locations of stress concentration.

Buildings of different heights that do not have sufficient spacing between them may sway at different vibration frequencies and smash into one another during an earthquake (Abbott, 1996). This effect is called pounding or "hammer effect." Pounding may occur between adjacent buildings and result to one building collapsing into another causing the total destruction of the other. Apparent vertical irregularity can also occur due to an interaction between a tall building and an adjacent shorter building due to the pounding of the roof of the smaller building against the columns of the taller one. This was the case of many partial building collapse in the 1985 Mexico City earthquake (ATC, 1997; Moehle and Mahin, 1991).

Such building features have been observed in many structures within the city of Marikina. For instance, many public school buildings have irregularities in plan. They usually have a U- or L-shape configuration in order to make efficient use of limited land. The inner space is used as a courtyard where sports, games, and other school programs take place. Soft stories are also common, especially in single, detached homes and townhouses where part of the ground floor is used as parking space for cars. There is as well the possibility of pounding to occur particularly along the major commercial thoroughfares (e.g., Rizal Avenue, Bonifacio Avenue, and Shoe Avenue), where commercial and residential RC buildings of varying heights are built too close to each other.

Booth and Martinez-Rueda (1995) conducted a survey of Philippine engineers, which revealed that, based on expert opinion, the causes of building vulnerability to past earthquakes were mainly a result of inappropriate design and construction practices. Explicitly, building failures connected to design were due to soft stories, inadequate lateral stiffness, and deficient detailing of structural members and their connections. With respect to construction practice, buildings were seismically vulnerable due to low quality of construction materials, poor workmanship or insufficient site supervision, non-compliance with building standards, and lack of structural analysis. Faulty design and construction malpractices were also cited as main causes of building damage during the 1999 earthquake series, i.e. August 1999 Duzcek (Turkey), September 1999 Athens, September 1999 Chichi (Taiwan), and November 1999 Kocaeli (Turkey) earthquakes (see Dimitriu *et al.*, 2000; Erdik, 2000; Scawthorn, 2000).

In addition, Booth and Martinez-Rueza also mentioned that during the 1990 Luzon earthquake, most of the buildings in the affected region survived with minor damage. Still, many buildings collapsed or were severely damaged due to the abovementioned building vulnerabilities. Damage to most residential houses include displacement of second story due to a soft ground story, collapse of exterior walls, and tilting due to liquefaction in coastal areas, and settlement and collapse due to loss of foundation support.

Damage to non-structural components of buildings (i.e., every part of the building and all its contents with the exception of the structure) is also of great concern, because it can also result in injuries or death due to falling non-structural items and great property (i.e., building content can be costly such as in hospitals and museums) (Wiss, 1994). In most modern buildings, the non-structural components make up 60 to 80 percent of the value of the building (BSSC, 1995b). Non-structural damage, however, is not covered in this study.

“It is buildings that kill people, not earthquakes” sounds like a cliché, but it is true. A large number of quake-related deaths and injuries in urban areas are caused by the collapse of buildings and other infrastructures such as roads and bridges (Figure 4w) due to ground shaking, as shown by numerous earthquakes in the past.

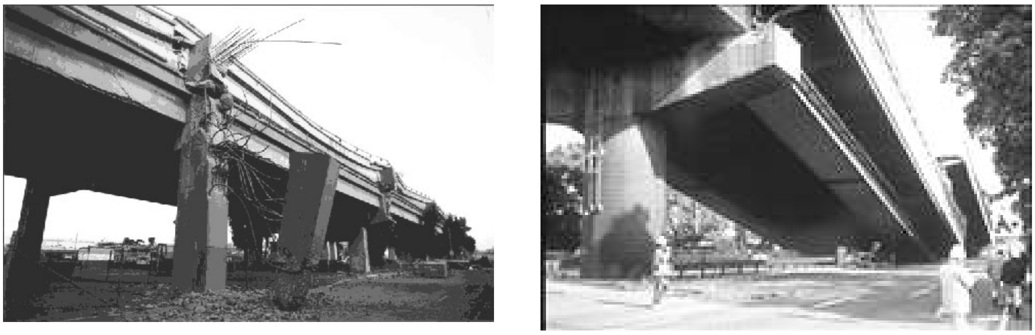


Figure 4w. An expressway in Oakland, California buckled during the 1989 Loma Prieta, California earthquake (left) while an approach span collapsed during the 1995 Kobe, Japan earthquake. (Sources: O'Rourke, 1999; Bertero, 1985.)

Collateral hazards such as liquefaction, in some cases, also caused significant property damage such as in the 1964 Niigata (Bertero, 1985) and 1995 Kobe earthquakes (Figure 4x) (Scawthorn, 2000).

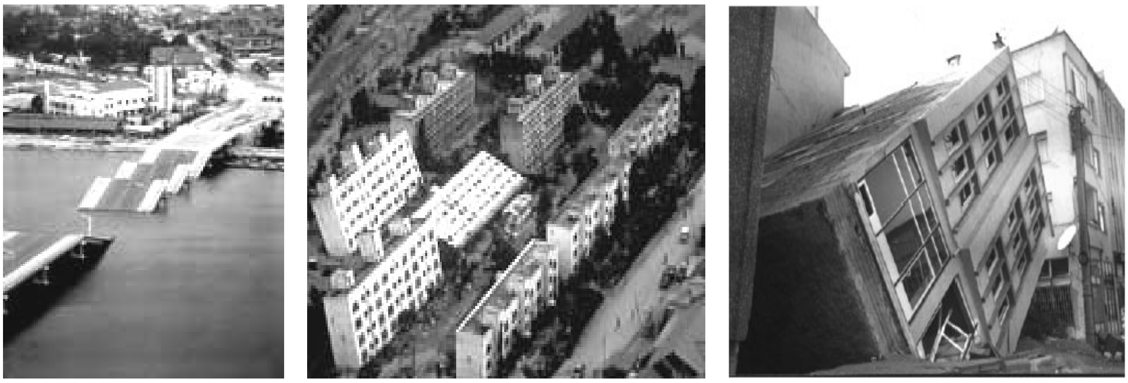


Figure 4x. Effects of liquefaction show in the collapse of the Showa Bridge by falling off its piers (left) and in the tilting of apartment buildings (center) in Japan after the M=7.5 1964 Niigata earthquake and in Adapazari after the 1999 Kocaeli earthquake in Turkey (right). (Sources: Bertero, 1985; Erdik, 2000.)

Surface faulting may likewise contribute substantially to property damage, especially if the fault directly lies below a densely built up area such as in the case of the 1971 San Fernando, August 1999 Kocaeli, and September 1999 Chichi, Taiwan earthquakes (Figure 4y). It can also cause loss of life as in the Taiwan earthquake, where surface faulting in a naval facility intersected and collapsed a military building, killing many high-ranking commanders (O'Rourke, 1999).

Figure 4y. Damaged to a building in Sylmar during the 1971 San Fernando earthquake (left) and vertically displaced structures along the fault caused by the 1999 Chichi, Taiwan earthquake (right). (Sources: Bertero, 1985; O'Rourke, 1999.)

4.4 Results of Earthquake Damage Estimation

After inputting the required data on the building stock of the city in the computer program, estimates of physical damage to the building stock and social losses are provided by RADIUS. Damage to the existing building stock is given by damaged building counts and mean damage ratio, while social losses are given in terms of loss of life and number of moderately and seriously injured. These estimates are provided by the program on a grid basis. A number of vulnerability maps depicting the different types of losses (i.e. building/physical damage, deaths, and injuries) are also produced. Damage and casualty estimates were made for a 7.5 earthquake occurring on the West Valley Fault of the Marikina Valley Fault System.

One limitation of the RADIUS damage assessment program is that it considers only the effects of ground shaking hazard on the built environment. Estimation of potential damage arising from collateral hazards such as surface faulting and liquefaction is therefore not included. Areas underlain by liquefiable soils can only be generally defined but possible damage associated to liquefaction and surface faulting is not estimated. Brief descriptions of the damage assessment are given in the next subsections.

4.4.1 Physical Vulnerability

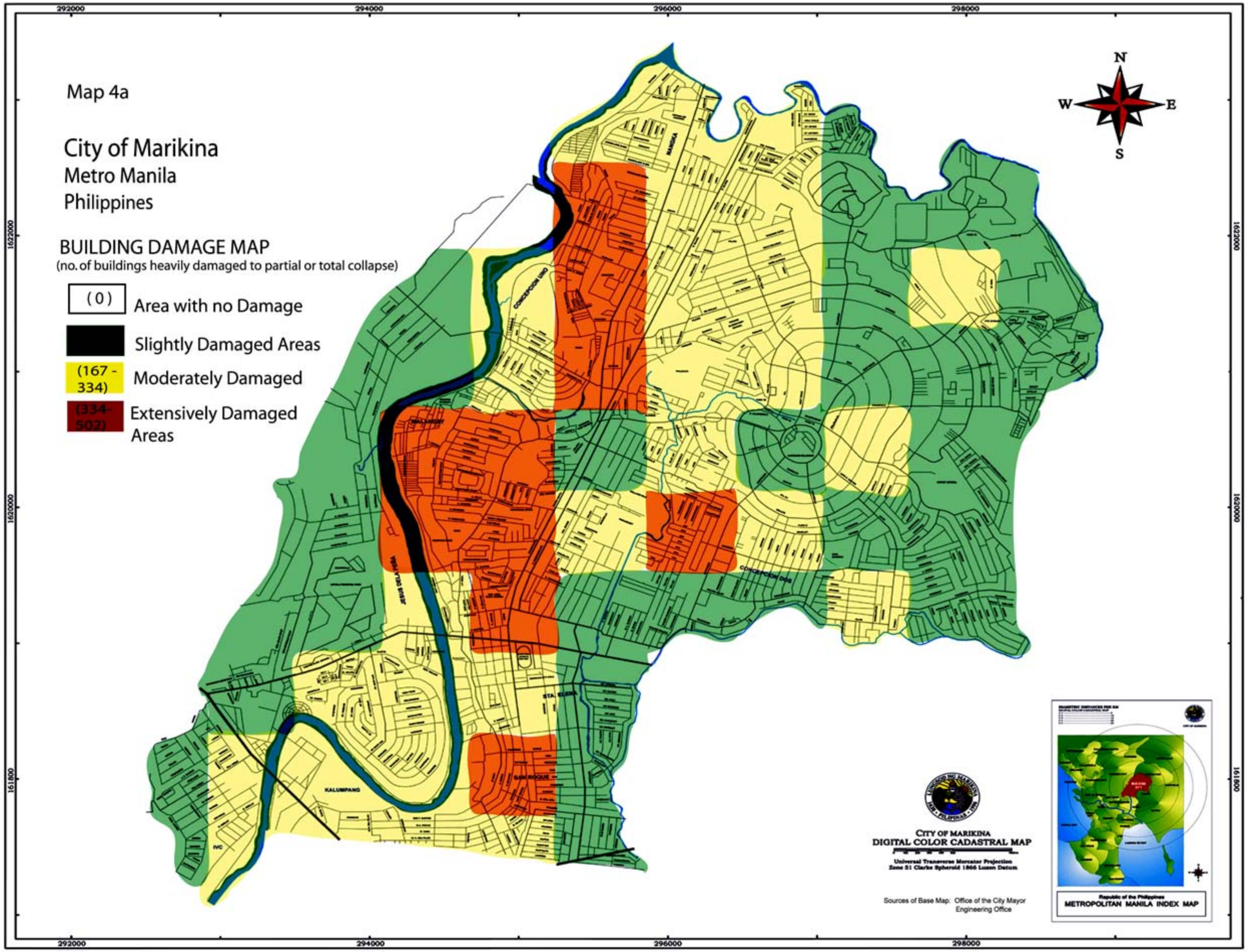
The Building Damage Distribution Map (Map 4a) graphically shows the geographic distribution of damaged buildings as a result of the scenario earthquake. Raw RADIUS building damage results are appended as Appendix 9 (RADIUS Table 3: Building Inventory Partitioned to Meshes), Appendix 10 (RADIUS Table 5: Number of Buildings Damaged by Earthquake) and Appendix 11 (RADIUS Damaged Building Distribution).

Losses are predicted by the RADIUS program using the building stock as tabulated in Appendix 9. A more accurate and refined survey of structures would provide a more precise estimate of damage. Although a more exact analysis could be done in each case with additional effort, the uncertainties of a practical study like this one are unavoidable. In addition, the computer program only considers two damage levels considered: heavy damage and collapse. Light building damage is therefore not considered.

As the physical exposure of the city is not equal across space, physical vulnerability also varies geographically. The physical exposure of the city is described by the number of buildings exposed to ground shaking hazard, while the number of damaged buildings indicates the vulnerability of the different building classes. The total physical exposure of Marikina City is 56,089 buildings.

Physical vulnerability is a function of the response of existing buildings to the intensity of ground shaking. In this regard, the Building Damage Distribution Map (Map 4a) shows the relative physical vulnerability of the different locations within the city of Marikina caused by the scenario earthquake in terms of the count of damaged buildings for each grid. The city is hence divided into several damage areas in terms of the number of damaged buildings (not damage states): no damage, slightly damaged, moderately damaged, and extensively damaged.

The Extensively Damaged Areas (EDAs) fall within the zone of strongest ground shaking (MMI = 9.0 to 9.2) and are found in *Barangays* Malanday, Santo Nino, San Roque Nangka, and Concepcion 1. In Malanday, the EDAs are characterized by high-density residential neighborhoods and informal settlements. The major commercial strips along Bonifacio, Rizal and Rodriquez Avenues in Santo Nino, San Roque, and Concepcion 1 are likewise expected to sustain heavy building damage on a wide scale. In this near earthquake scenario, the amplification of seismic waves may not have a substantial impact on the tall buildings in the downtown commercial areas, the zone with soft soils. Still, structural and particularly non-structural damage would probably affect most buildings in the area.


Map 4a
City of Marikina
Metro Manila
Philippines
BUILDING DAMAGE MAP
(no. of buildings heavily damaged to partial or total collapse)
(0) Area with no Damage
Slightly Damaged Areas
(167 - 334) Moderately Damaged
(334-502) Extensively Damaged Areas
N
S
W
E
292000
294000
296000
298000
1622000
1620000
161800
CONCEPCION UNO
CONCEPCION DOS
JESUS DELA PEÑA
NANGKA
STA. ELENA
SAN ROQUE
KALUMPANG
IVC
CITY OF MARIKINA
DIGITAL COLOR CADASTRAL MAP
Universal Transverse Mercator Projection
Zone 51 Clarke Spheroid 1866 Luzon Datum
Sources of Base Map: Office of the City Mayor
Engineering Office
Republic of the Philippines
METROPOLITAN MANILA INDEX MAP

The EDAs have a total building exposure of about 12,540 based on RADIUS calculations, of which 4,087 would suffer heavy damage or a mean damage ratio of 33 percent. This means that in the EDAs, about 310 buildings are expected to be damaged for every 1000 structures. In terms of the damaged buildings, almost half (48.5 percent) would be accounted for by RES2 structures, 28 percent by RES4, and 19.5 percent are RES1 buildings. About 1.5 percent is made up of critically damaged industrial structures. Educational facilities are likewise severely affected, with EDU1 and EDU2 building classes respectively accounting for 0.6 percent and 2.7 percent of building damage in the EDAs.

The Moderately Damaged Areas (MDAs) are located both within the zone of MMI levels of 8 to 9, specifically in *Barangays* Kalumpang, San Roque, Santa Elena, Jesus de la Pena, Tanong, Santo Nino, Concepcion 1, Concepcion 2, Nangka, and Parang. The MDAs have a total physical exposure of 25,410 structures. Of these, 6300 buildings are likely to sustain severe structural damage, giving a mean damage ratio of 25 percent or 250 damaged structures per 1000 buildings. The damage pattern among the different building classes in the MDAs is the same as in the EDAs, where RES2 structures sustain the most number of damage in its rank, followed by RES4 and RES1 buildings.

The MDAs can be described as mostly zones of medium-density residential neighborhoods scattered in the abovementioned *barangays* as well as some high-density residential areas. The traditional commercial and business center of the city or the downtown area in *Barangay* Santa Elena as well as segments of the minor commercial zone along Bonifacio and Rizal Avenues are also expected to be moderately damaged by the scenario earthquake.

The Slightly Damaged Areas (SDAs) have a total exposure of about 18,150 buildings of which about 3,171 will probably be damaged. This translates to a mean damage ratio of 17.5 percent. The damage pattern is also the same as in the EDAs and MDAs where RES2 buildings suffer the most extensive damage in terms of absolute number.

Table 4v reveals that the physical exposure as well as the physical vulnerability of the city based on the different building classes for each shaking region. The expected mean damage ratio for the whole city is 24.5 percent or 245 buildings for every 1000 structures. This also means that about a quarter of the city's building stock will suffer heavy structural damage to partial or total collapse. The remaining 75 percent of the city's structures will remain intact or suffer light to moderate structural and/or non-structural damage.

Table 4v. Damaged Building Count

Building Type	MMI 7.9 to 8.0		MMI 8.0 to 9.0		MMI 9.0 to 9.2		Total No. of Damaged Buildings	Percent to Total No. of Buildings
	Building Count	No. of Damaged Buildings	Building Count	No. of Damaged Buildings	Building Count	No. of Damaged Buildings		
RES1	1428	467	1605	762	2053	1289	2518	4.5%
RES2	4936	1118	5060	1654	7266	3078	5850	10.4%
RES4	7365	670	10097	1432	14211	2623	4725	8.4%
EDU1	114	17	123	31	94	34	82	0.15%
EDU2	143	32	140	56	330	157	245	0.45%
MED2	0	0	10	4	0	0	4	0.007%
COM	0	0	7	2	0	0	2	0.004%
IND	536	131	119	36	452	163	330	0.6%
Total	**14,522**	**2,435 (17.70%)**	**17,161**	**3,977 (28.91%)**	**24,406**	**7,344 (53.39%)**	**13,756 (100%)**	**24.5%**

The region that will experience the strongest ground shaking (MMI=9 to 9.2) also has the highest physical exposure (24,406 buildings). This region will also experience the most building damage (53 percent of the total damaged buildings) by the scenario earthquake. The MMI=8 to 9 shaking region has a physical exposure of more than 17,000 structures and will likely suffer about 29 percent of the total building damage. Lastly, the region with the relatively lower shaking intensity (MMI=7.9 to 8.0) likewise has a lower physical exposure (14,522 buildings) and will experience lesser building damage (18 percent of the total building damage).

As the last column of Table 4v reveals, a relatively small fraction of the buildings (23 percent) do most of the damage (95 percent). In this case, the maxim of “10 to 20 percent of buildings do 80 to 90 percent of the damage” (McCormack and Rad, 1997) seems to be valid.

Table 4w also summarizes the calculations made by the RADIUS program in terms of building class. It suggests that the class with the highest damage ratio is RES1, with almost 50 percent or a ratio of 495 damaged buildings for every 1000 standing structures, which confirms the high vulnerability of unreinforced masonry (URM) structures to ground shaking.

The next vulnerable building types are EDU2 (school and office buildings higher than two stories) and MED2 (high rise hospitals) with a damage ratio of 40 percent, followed by RES2 (single-family residential structures of non-engineered reinforced concrete (RC)/masonry and wood composite construction) with 34 percent. The least vulnerable buildings are RES4 structures (mostly single-family RC houses, townhouses, and modern commercial buildings) with a relatively low damage ratio of 15 percent. Although such buildings are engineered, as mentioned earlier, only buildings constructed after the adoption of modern building codes in 1971 can be assumed to have some degree of protection against earthquakes.

Table 4w. Building Count and Number of Buildings Damaged by the Scenario Earthquake

Building Class	Building Count	Number of Damaged Buildings	Damage Ratio (%)	Cumulative Percent of Damaged Buildings
RES1	5,086	2,518	49.5	0%
RES2	17,262	5,850	34.0	18.30%
RES4	31,673	4,725	15.0	60.82%
EDU1	331	82	24.7	95.17%
EDU2	613	245	40.0	95.77%
MED1	0	0	0	97.57%
MED2	10	4	40.0	97.57%
COM	7	2	28.6	97.64%
IND	1,107	330	29.8	97.65%
TOTAL	56,089	13,756	24.5	100.00%

Table 4w also suggests the highly likely post-disaster problem of homelessness. Based on the table, about 24 percent of the residential dwellings would likely suffer serious damage due to ground shaking. However, how severe the state of structural damage these buildings would suffer, cannot be known at this point. Given that the damaged area encompasses the whole city and the total population in 2000 was almost 400,000, an assumption of 10 percent homelessness as a direct result of the earthquake would yield 40,000 people looking for accommodation after the earthquake event.

It is also safe to assume that there would be some damage due to fire caused by ignition of liquefied petroleum gas (LPG). This is the most commonly used fuel for cooking in Philippine households, as this is cheaper than electricity. Hence, fire breakouts may also add to the problem of homelessness after an earthquake.

4.4.2 Human Vulnerability

Estimation of casualties in terms of human life and injuries is usually performed in seismic loss estimation studies as a function of the building inventory and population data (Whitman *et al.*, 1997). In the RADIUS program, this is likewise the case. The main cause of death and injury during an earthquake is heavy structural damage or partial and total building collapse. Injuries considered by RADIUS are only the moderate and severe injuries. Slight injuries, injuries that do not require hospitalization, are not considered. In addition, the time of day when the earthquake strikes is also an influencing factor. Casualties caused by secondary effects, such as heart attacks, are not included. The uncertainty associated with the loss of life and injury is very high. The results are therefore preliminary and based on a simplified model used by the RADIUS program and should be treated as such.

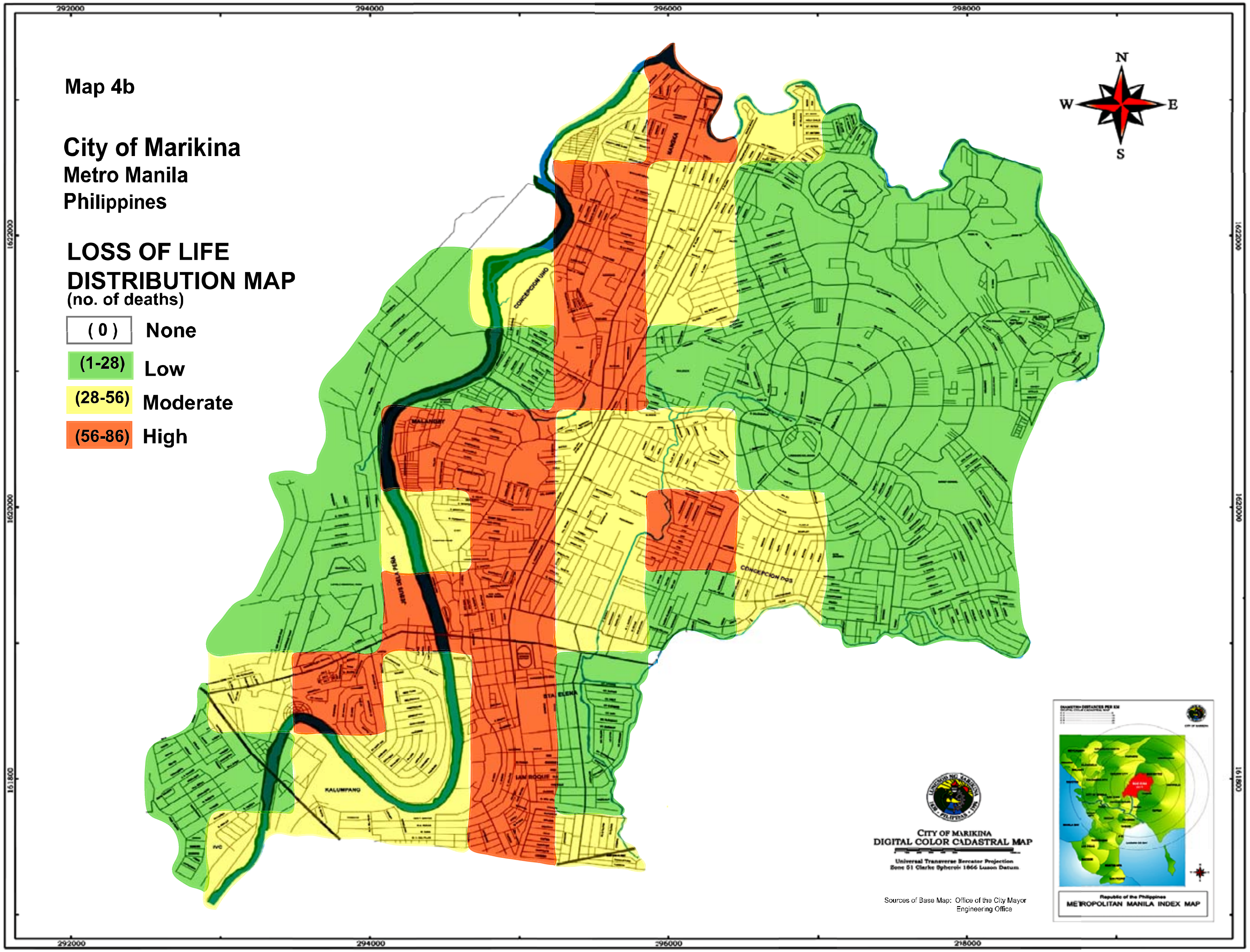
The spatial distribution of casualty estimates is shown on Map 4b (Loss of Life Distribution Map) and Map 4c (Injuries Distribution Map). The raw results of RADIUS are appended as Appendix 12 (RADIUS Casualties-Deaths Distribution) and Appendix 13 (RADIUS Casualties-Injuries Distribution). The spatial pattern of the potential pattern of loss of life and injuries shown on the two maps are similar in that the Area with High Number of Casualties both in terms of deaths and injuries mostly lies within the area of highest ground shaking intensity or MMI=9-9.2. The Area with Moderate Number of Casualties also in terms of deaths and injuries is found in the shaking region of MMI=8-9 while the Area with Low Number of Casualties is situated in the area of lowest intensity or MMI=7-8.

The concentration of casualties, both deaths and injuries, in the Area with High Number of Casualties may be explained by the presence of old RC buildings and mixed masonry and wood structures, particularly along Rizal Avenue and downtown Marikina. Engineered RC structures are generally safer and less likely to collapse, but substandard RC buildings are also vulnerable to ground shaking. And when they do collapse, they are more lethal and kill a higher percentage of occupants than masonry buildings (Noji, 2003).

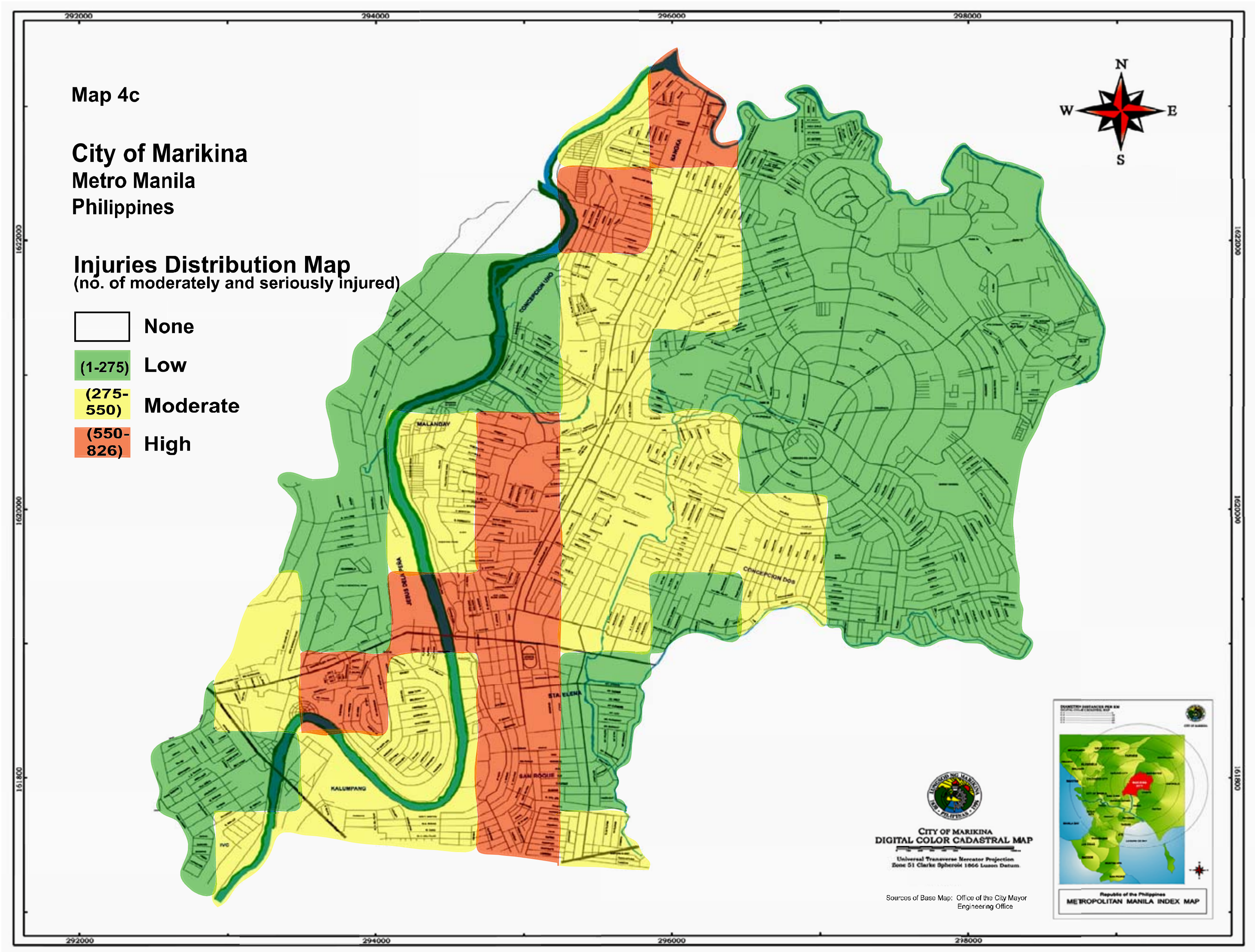
The statistical figures produced by RADIUS Table 6: Population and Casualty Distribution (Appendix 14) are summarized based on shaking region in Table 4x below. As discussed above, the area with the highest casualties in terms of loss of life and injuries is the region with the highest MMI. This agrees with the results of the building damage estimation where the most extensive building damage is likely to occur in the region of strongest ground shaking.

Table 4x. Number and Ratio of Deaths and Injuries per Shaking Region

MMI Intensity	Day Population Count	Number of Deaths	Death Ratio (using day population)	Number of Moderately and Severely Injured	Injury Ratio (using day population)
MMI 7.9-8.0	93,511	499	0.5	6276	6.7
MMI 8.0-9.0	59,451	795	1.3	7318	12.3
MMI 9.0-9.2	68,305	992	1.4	8894	13.0
Total	221,267	2286	1.0	22,488	10.2



Map 4b
City of Marikina
Metro Manila
Philippines
LOSS OF LIFE
DISTRIBUTION MAP
(no. of deaths)
(0) None
(1-28) Low
(28-56) Moderate
(56-86) High
N
W
E
S
CITY OF MARIKINA
DIGITAL COLOR CADASTRAL MAP
Universal Transverse Mercator Projection
Zone 51 Clarke Spheroid 1866 Luzon Datum
Sources of Base Map: Office of the City Mayor
Engineering Office
METROPOLITAN MANILA INDEX MAP
KALUMPANG
CONCEPCION DOS
CONCEPCION UNO
MALANDAY
STA. ELENA
SAN ROQUE
JESUS DELA PEÑA



Map 4c
City of Marikina
Metro Manila
Philippines
Injuries Distribution Map
(no. of moderately and seriously injured)
None
(1-275) Low
(275-550) Moderate
(550-826) High
N
W
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MALANDAY
CONCEPCION UNO
CONCEPCION DOS
JESUS DELA PEÑA
STA ELENA
SAN ROQUE
KALUMPANG
IVC
NANGKA
CITY OF MARIKINA
DIGITAL COLOR CADASTRAL MAP
Universal Transverse Mercator Projection
Zone 51 Clarke Spheroid 1866 Luzon Datum
Sources of Base Map: Office of the City Mayor
Engineering Office
Republic of the Philippines
METROPOLITAN MANILA INDEX MAP
292000
294000
296000
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1622000
1620000
161800

Looking at the statistics, the death ratio implies that 14 people for every thousand population will probably perish in the MMI=9 to 9.2 region, while 130 individuals for every thousand will be moderately or seriously injured, requiring hospitalization. In the shaking region with MMI=8 to 9, the expected loss of life is 795 persons, making a death ratio of 13 persons for every thousand population. Another 7318 individuals will require medical services due to injuries, or an injury ratio of 123 for every thousand population.

The area with the lowest intensity would lose 499 persons to the earthquake or a death ratio of 5 individual for every thousand population. More than 6000 will likely get seriously injured as well or a rate of 67 injured persons for every thousand population.

On average, about 10 people will be killed and 1020 will be moderately to seriously injured for every thousand population. In earthquakes, being crushed under collapsed walls and ceilings usually causes instantaneous death. Severe crushing injuries to the head or chest and internal and external hemorrhage can cause instantaneous death, while asphyxia from dust inhalation or chest compression and hypoyolemic shock can lead to rapid death (Noji, 2003). As for injuries, past earthquakes show that about 40 percent of seriously injured victims required hospitalization due to combination injuries that may include skull fractures, lower and upper extremity trauma, cervical spine injuries, ruptured spleen, and liver lacerations (Noji, 2003).

Numerous victims sustaining minor injuries such as lacerations and contusions would likewise tax emergency health services. Responding to this scenario would pose a gargantuan task to medical institutions and personnel of Marikina City during the disaster, as the neighboring towns and cities would likewise in all probability summon their respective hospitals for their own constituents.

4.4.3 Spatial Vulnerability

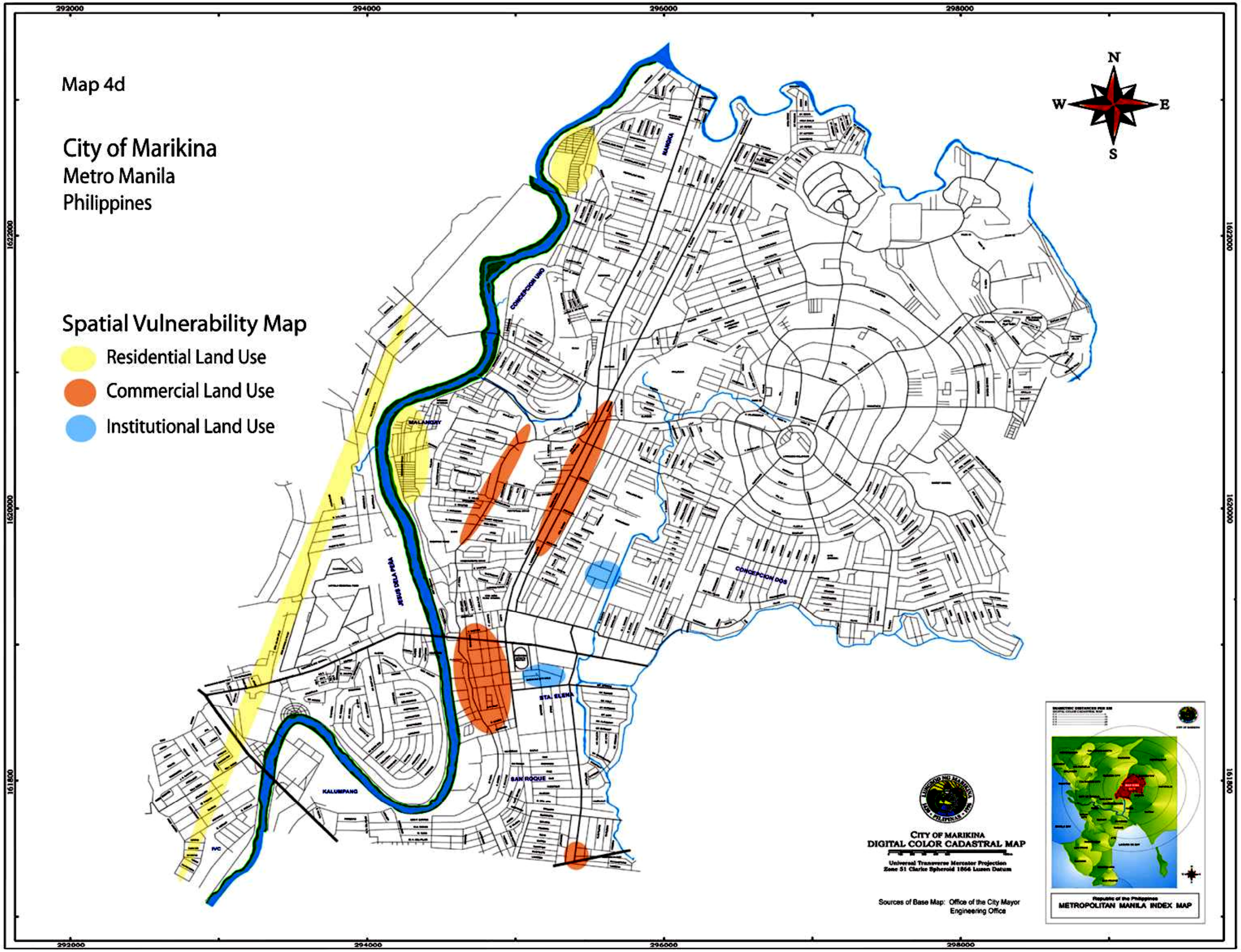
The concept of spatial vulnerability has been introduced earlier in Chapter 1. Unfortunately, this concept is not often mentioned in the disaster literature and is generally termed as vulnerability. Liverman (1990), for example, defines vulnerability as a biophysical condition and as a result of political, social, and economic conditions of society while arguing for vulnerability in geographic place, where vulnerable people and places are located. A more similar meaning to this study is given by Gilard and Gilvone (1997), who assert in their study of flood risk management that vulnerability represents the sensitivity of various land uses to a hazard phenomenon. This further means that the potential impact (damage or losses) of a natural hazard such as an earthquake differ from place to place within a city, depending on the land use pattern vis-à-vis location of hazards. The sensitivity of land use to seismic hazards depends on how intensively land is used, how densely populated these different localities are, and if these land uses perform important urban functions and essential services. Spatial vulnerability therefore varies from place to place.

This study therefore gives this concept a specific name and further aims to operationalize it by constructing a Spatial Vulnerability Map (Map 4d). The Spatial Vulnerability Map is produced by overlaying the MMI Distribution Map (Map 3i) that shows the geographic distribution of the varying levels of ground shaking intensity and the Existing Land Use Map of Marikina City (Map 2d) that reflects the spatial pattern of land uses. Hence, the focus of analysis here is on land uses that are sensitive to intense ground shaking and, due to the presence of the West Valley Fault on the western edge of the city, to surface faulting.

The Spatial Vulnerability Map depicts that the downtown area where the major thoroughfares of Bonifacio Avenue, Shoe Avenue and Rizal Avenue converge, will experience the strongest ground shaking of at least MMI=9. As discussed in Chapter 2, the traditional commercial district of Marikina is characterized by an amorphous mixture of commercial, residential, and institutional land uses. Land uses include wholesale and retail merchants selling higher order goods that require a large market, principal commercial and office shops offering personal, social, and business services, cafes and restaurants, and the wet and dry public market, and other consumption-oriented activities. The seat of government of Marikina City as well as several public and private schools are also found in this area.

As such, the traditional commercial district demands an intensive and high-density utilization of space. It is where most of the socio-economic activities and business transactions of the city take place and where high concentrations of people are found during the day. At the same time, the district provides highly important urban functions to the populace. Being located in the high intensity shaking region, this district is thus highly vulnerable to ground shaking and potentially extensive structural damage.

Moreover, as this area is underlain by liquefiable Quaternary alluvial soils, ground failures may occur which may result to tilting of buildings, buckling of major thoroughfares and secondary roads and pavements, collapse of Marikina Bridge, and damage to water pipelines. This may then hinder accessibility to damaged areas and multiply problems during the emergency response and relief operations.


Map 4d
City of Marikina
Metro Manila
Philippines
Spatial Vulnerability Map
Residential Land Use
Commercial Land Use
Institutional Land Use
N
W
E
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292000
294000
296000
298000
1622000
1620000
161800
MARIKINA
CONCEPCION UNO
CONCEPCION DOS
MALANDAY
JESUS DELA PEÑA
STA. ELENA
SAN ROQUE
KALUMPANG
IVC
CITY OF MARIKINA
DIGITAL COLOR CADASTRAL MAP
Universal Transverse Mercator Projection
Zone 51 Clarke Spheroid 1866 Luzon Datum
Sources of Base Map: Office of the City Mayor
Engineering Office
Republic of the Philippines
METROPOLITAN MANILA INDEX MAP

Also found within the high intensity shaking region is the commercial strip along Rizal Avenue and Rodriquez Avenue and their convergence point with Bayan-Bayanan Avenue, which is considered as a minor another commercial node in the city. These commercial strips also provide urban functions and services and are composed of high-density and high-intensity land uses.

The intensive residential land use situated within the same high intensity shaking region, namely the resettlement and socialized housing sites in Barangay Malanday and Nangka, is also relatively spatially vulnerable compared to other residential land uses. Although the site does not contain high-rise residential buildings, land is still used intensively due to tightly packed substandard housing that create large pockets of densely populated neighborhood in a high intensity shaking region. Moreover, given the right geologic conditions and intensity of ground shaking, these settlements on the Marikina flood plain may experience ground failures due to its liquefiable foundation, which may cause extensive property damage.

The presence of the pre-existing fault trace of the West Valley Fault, cutting south-southwest, is overlain by low- to medium-density residential land uses exemplified by planned residential subdivisions for the upper and middle strata of the society, which makes this area highly vulnerable. Although this area will likely experience the lowest shaking intensity in the city and contains land use that is not highly sensitive to the hazard of ground shaking because of its building characteristics, the linear strip of land overlying the pre-existing fault trace will likely incur severe property damage due to the hazard of surface faulting.

Although surface faulting hazard is not as widespread as that of ground shaking, any well-built structure lying on a fault will not be able to withstand lateral and vertical movements of the ground during an earthquake. In this scenario earthquake, it is expected that surface rupture will likely occur. Based on geologic information from past earthquakes, surface ruptures occurred without any definite exceptions on pre-existing faults (Ikeda, 2002). This means that the exact location of surface faulting can be predicted. Hence, potential damage to structures due to surface faulting in Marikina City will be restricted to the zone of pre-existing fault of West Valley splay of the Valley Fault System.

4.4.3.1 Spatial Vulnerability of Critical Facilities

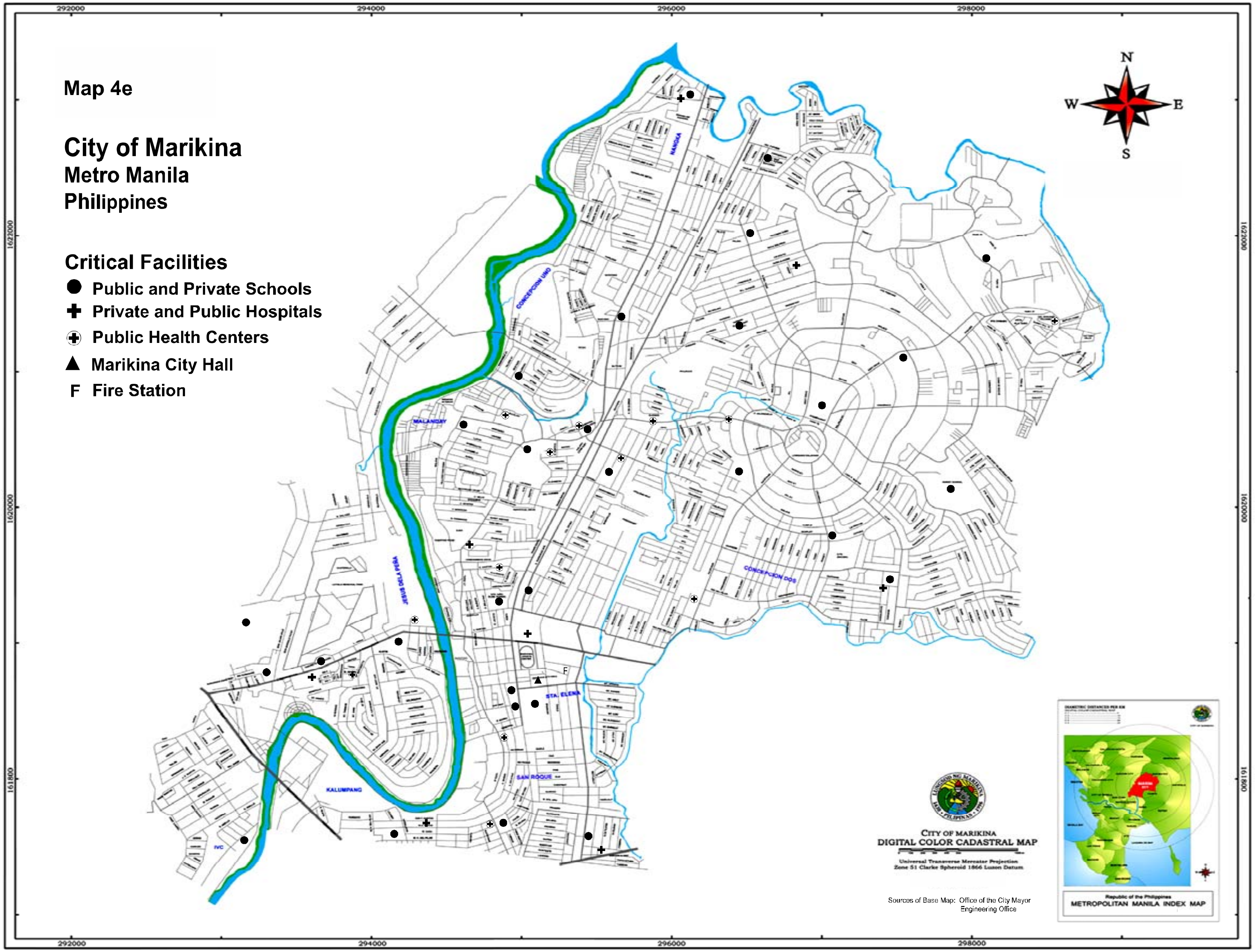
Critical facilities are defined to be buildings of high occupancy buildings, whose structural failure will result in unacceptably high losses to society (King *et al*., 1997). Losses refer to major loss of life or serious casualties, loss of urban functions or disruption of essential services, and high replacement cost (structural and non-structural). Examples of critical facilities are schools, hospitals, commercial shopping centers, electric and water supply substations, and fire stations.

While critical facilities are important, they typically represent only a very small fraction of the building stock of a city. In this study, only the spatial vulnerability of public and private schools, private and public hospitals, and public health centers were scrutinized along with the City Hall, Engineering Department Building, and the fire station (Map 4e – Critical Facilities Map).

In this scenario, the earthquake will occur in daytime on a normal working day during which pupils and students are supposed to be in school and workers are in their offices or factories. Looking at the Intensity Distribution Map and the spatial distribution of critical facilities in the city (Map 4e), only five facilities (16.7 percent) are located in the low intensity shaking region, which leaves 25 school buildings/campuses (83.3 percent) in the areas of moderate (12 or 40 percent) to high (13 or 43.3 percent) shaking level. This makes for a very high level of exposure for school buildings. There is thus a great chance that many of these facilities will suffer physical damage and contribute to total casualty losses. In addition to exposure, there are also other building factors that may add to the vulnerability of school buildings in Marikina City. These are the shape and age of the buildings. One will notice that most of public elementary and high school buildings are of assymetrical shape, e.g. U, T, and L shape, to maximize the lot area and provide for the necessary open space for school activities. Irregularly shaped buildings, as previously discussed, are more vulnerable to ground shaking due to torsion.

Hospital facilities within the city are also highly exposed as five of them (62.5 percent) are located in the high intensity shaking area, including the tertiary public hospital, Eulogio Amang Rodriquez Memorial Hospital. Another two medical facilities (25 percent) are in the moderate shaking area. Only one hospital is located in the low intensity shaking area in *Barangay* Nangka.

Other critical facilities considered in this analysis, namely, the Marikina City Hall, Marikina Fire Station, and the Engineering Department compound, where most of the heavy equipment and emergency response tools are kept, are also highly exposed to ground shaking.



Map 4e
City of Marikina
Metro Manila
Philippines
Critical Facilities
Public and Private Schools
Private and Public Hospitals
Public Health Centers
Marikina City Hall
F Fire Station
N
W
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296000
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1622000
1620000
161800
NANGKA
CONCEPCION UNO
MALANDAY
JESUS DELA PEÑA
CONCEPCION DOS
STA. ELENA
SAN ROQUE
KALUMPANG
IVC
CITY OF MARIKINA
DIGITAL COLOR CADASTRAL MAP
Universal Transverse Mercator Projection
Zone 51 Clarke Spheroid 1866 Luzon Datum
Sources of Base Map: Office of the City Mayor
Engineering Office
Republic of the Philippines
METROPOLITAN MANILA INDEX MAP

4.4.4 Composite Vulnerability of Marikina City

By overlaying the distribution maps of building damage, deaths, and injuries, the composite vulnerability or overall risk of the city can then be mapped and visualized. An overall risk index composed of the available factors of building damage, deaths, and injuries was formulated as follows:

$$R = 0.33BD + 0.33D + 0.33INJ$$

where BD = building damage, measured as none (=0), slight (=1), moderate (=2), and extensive (=3) (refer to Map 4a); and

D = number of deaths, quantified as none (=0), low (=1), moderate (=2), and high (=3) (refer to Map 4b);

INJ = number of the injured, scaled into none (=0), low (=1), moderate (=2), and high (=3) (refer to Map 4c).

This formula means that the higher the summation of the vulnerability factors are, the higher the risk or probability that the area will suffer damage or losses due to a future earthquake.

The resulting distribution of overall risk is shown on Map 4f – Risk Map. The map pinpoints areas within the city that require more risk-sensitive land use measures. The map indicates that the High Risk Areas of Marikina City are concentrated around the downtown district, including the major commercial strips of the city. This is due to a combination of different factors that contribute to seismic risk. Geologically, this area is highly susceptible to ground shaking and further amplification because of its soft soils. The possibility of liquefaction within this area also cannot be ruled out due to the area's hydrologic regime, i.e. shallow water table. The building stock found in the High Risk Areas is also vulnerable to ground shaking due to the presence of old houses constructed of mixed wood and concrete, non-engineered reinforced concrete structures, and self-built substandard dwellings. Moreover, these area are also loci of population concentration. The traditional commercial district of is the highest-order central place within the city, which provide high-order goods and services to the wider regional market outside of Marikina. As it is situated at the corner of the major thoroughfares of the city, it generates and receive a high volume of vehicular traffic. The commercial strips Bonifacio, Rizal, Shoe, and Rodriquez Avenues likewise generate a big volume of vehicular and foot traffic. It also attracts its fair share of the market, although more at the local level.

Also because of the high concentrations of people and vulnerability of the structures found in such places, the high-intensity and high-density residential areas including the resettlement and socialized housing sites will probably experience more seismic damage and losses compared to other areas of the city. These residential areas are found in the flood plains as well as along Rizal Avenue, the site of the old town of Marikina and where the organic growth of the town began.

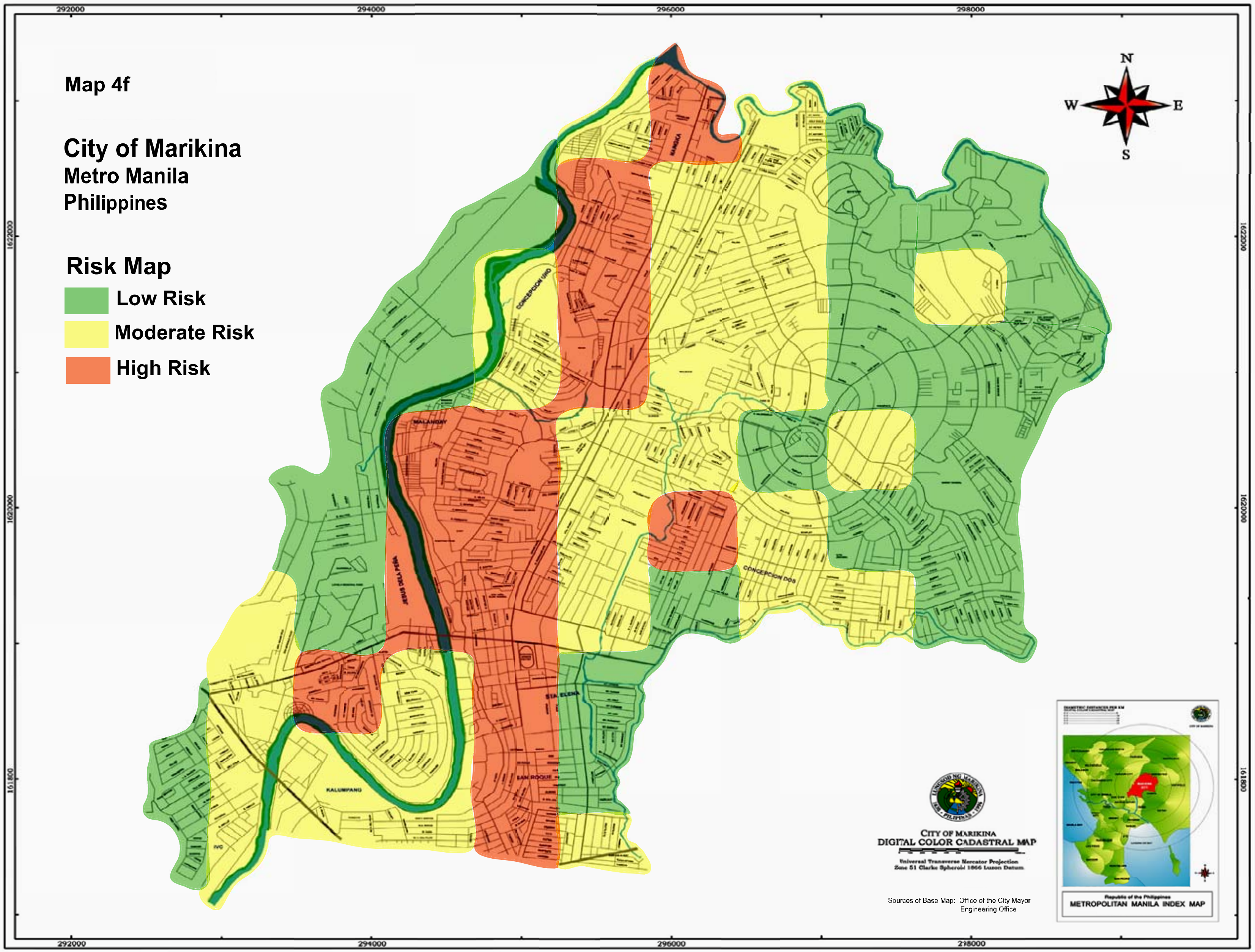
Areas of Moderate Risk are characterized mainly by underlying medium soil and soft rock foundations and land uses typified by medium-density, single-family residential subdivisions. The building stock is made up mostly of engineered reinforced concrete constructions that were built after the introduction of the modern building code. The modern commercial area of Riverbanks Center is also situated within the moderate risk areas.

The Low Risk Areas of the city is expected to suffer relatively less earthquake damage. These areas expect a lower ground shaking intensity than the rest due to underlying hard rock foundation. In terms of land use and building stock, the eastern shoulder of the city is where industrial land uses are concentrated. Many of the manufacturing firms located in Barangay Parang are multinational corporations (e.g., Fortune Tobacco, BF Goodrich, Firestone Pilipinas, Asia Brewery) who build factories and other buildings to company-wide building standards, which where they exist are often very high, reducing potential physical damage as a consequence of seismic hazards, especially if the location is a high-risk one (Benson and Clay, 2003). Although pockets of informal settlements exist in the Low Risk Areas, the physical vulnerability is not as high due to lower shaking intensity.

Other Low Risk Areas include the low-density residential subdivisions and the remaining open spaces or unbuilt land (e.g., cemetery) in the city, which points out the importance of the role of open spaces in reducing the vulnerability of an urban settlement. However, due to the presence of the West Valley Fault which cuts through the eastern shoulder of the city where the low- to medium density residential developments are found, namely in *Barangays* Barangka and IVC, a linear zone above the pre-existing fault trace is assessed as part of the High Risk Areas.

4.4.5 Limitations of Loss Estimation

Predicting when an earthquake will occur is still not possible. It is also not possible to exactly quantify how many buildings will be structurally damaged and collapse and how many people will die or be injured. Only approximate estimates of earthquake losses that a vulnerable city experience can be made. And even with the most current method, computer technology, and expert opinion, damage caused by scenario earthquakes can only be approximated at best.


Map 4f
City of Marikina
Metro Manila
Philippines
Risk Map
Low Risk
Moderate Risk
High Risk
N
W
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CITY OF MARIKINA
DIGITAL COLOR CADASTRAL MAP
Universal Transverse Mercator Projection
Zone 51 Clarke Spheroid 1866 Luzon Datum
Sources of Base Map: Office of the City Mayor
Engineering Office
METROPOLITAN MANILA INDEX MAP
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Uncertainties are innate in damage estimate studies, as there are already uncertainties concerning the parameters of the scenario earthquake such as the levels of ground shaking as well as in the way the ground and buildings on top will respond to earthquakes, inventory database error, and motion-damage relationships (Rojahn *et al.*, 1997; Whitman *et al.*, 1997). In this study, for instance, there are assumptions in the inventory information, both in the number of structures per grid and in terms of classification, i.e. structures may be classified into more than one class on a probabilistic basis. Such uncertainties will be difficult to avoid, especially for places like Marikina City where there is no data on past seismic damage that can be utilized to calibrate damage and loss estimates. As is true for any computational technology, it must be used with judgment and understanding of its underlying parameters. New knowledge and data obtained by new research and continued studies of past and future earthquakes can be used to reduce uncertainty in estimated losses.

Nevertheless, earthquake loss estimation is a necessary means to indicate the nature and magnitude of the seismic problem faced by a city. It should not be taken as the final goal of damage estimation process, but rather as a beginning of seismic disaster reduction planning.

4.5 Implications on Future Land Use Planning and Urban Development

The results of the vulnerability assessment, which can be considered as an outcome of a Do-Nothing Scenario, call attention to several major points. First, Marikina City would suffer unacceptably high losses, both in terms of human life and property as. Damage to buildings and infrastructure would translate to millions in monetary losses, not to mention the costs of replacement and the time needed to reconstruct the city to bring back urban functions and essential services to normal. Economic losses due to damage to private property may not be recoverable as earthquake insurance is not common in the Philippines or even offered by the local insurance industry.

Human life, on the other hand, can neither be recovered nor replaced. Complications of major injuries such as crush syndrome (i.e. disintegration of muscle tissue due to prolonged pressure on limbs) which may further lead to kidney failure requiring dialysis for many victims, or gangrene requiring amputation which may result to a throng of paraplegics are irreversible disaster consequences. More than property damage, such losses can deeply scar the social and psychological aspects of the city in many years to come.

Another significant point is that the risk of seismic disaster is high due to the high vulnerability of its buildings to earthquake hazards. The large number of potential building damage and collapse is highly related to human and spatial vulnerability. Lastly, the present land use configuration and the path of urban development that the city has embarked on are not sustainable. A city that suffers massive physical damage from an earthquake disaster will be hard pressed to return to its previous level of urban development and to restore to pre-disaster condition the essential urban functions and services (i.e. transportation, water supply, electric supply, roads and other public infrastructures, hospitals, schools) that make a city work.

Marikina City's high level of vulnerability and hence unsustainability is a product of the pattern of land uses and the kind of urban development that have occurred and still occurring in the city. Looking at the present layout of the city as described in Chapter II and the results of the damage estimation as discussed in this chapter, several negative trends in urban development process and land use practices emerge as contributory to the city's high level of seismic vulnerability.

The following section will discuss these interrelated causal factors that have heightened the seismic vulnerability of Marikina City as well as their implications on future land use planning and urban development.

4.5.1 Uncontrolled Urban Development and Loss of Public Open Spaces

Contained within its land area of merely 21.5 square kilometers (2,150 hectares) are about 400,000 residents and more than 56,000 buildings. According to the Marikina City Planning and Development Office or CPDO (2000a), only about 0.62 sq. kms. (62 hectares) of land remain to be devoted to pubic parks and open spaces (not including the water-covered surface of Marikina River). The amount of space exploited for houses, buildings, and roads has increased at the expense of green open spaces that shrunk as years went by, which has also adversely affected the quality of urban environment and hence the quality of life of residents. Building over every inch of space means greater physical exposure to damage from a future earthquake and hence incurring more earthquake losses.

A special problem arises from the utilization of sensitive natural environments for urban use. The Marikina River flood plains, for instance, have been turned into residential land, where today many of the existing gated medium-density residential subdivisions as well as socialized housing and resettlement sites lie. Unfortunately, these areas are not only flood-prone. These geologic environments are also susceptible to liquefaction hazards due to the shallow water table and presence of loose, alluvial sediments. Given the right geologic conditions and ground shaking intensity, this part of the city may experience ground failures due to liquefaction. Although ground failures account for a small fraction of the amount of property damage than ground shaking, they cause total damage to buildings by tilting and differential settling, which render the whole building uninhabitable afterwards. If liquefaction does not occur, amplification of ground shaking will also likely lead to more building damage in these areas, as they are underlain by soft soils. These areas, as can be seen from the Building Damage Distribution Map (Map 4a), will most likely suffer the greatest number of severely damaged buildings.

There are also signs of more intense land use to come, especially in the downtown area and along the commercial strip on Rizal Avenue in the form of medium to high-rise buildings. As mentioned in Chapter 2, the city of Marikina is trying to woo potential investors to locate in the city through financial incentives such as by canceling building permit fees and having no building height limit regulation. Hence, the downtown area and Rizal Avenue is characterized by buildings of varying heights standing close to each other with insufficient setbacks. As past earthquakes demonstrated, pounding occurs between two adjacent buildings of varying height, which may result to more structural damage. There is also the danger of a taller building collapsing and damaging the lower structures around it.

In short, people have been allowed to build in areas that are very precarious for human habitation, to ignore environmental considerations, and to make little provision for open space. This has greatly increased the total physical and human exposure of the city to seismic hazards as well.

On the other hand, a few years ago, the banks of Marikina River were crowded with shacks and shanties of the landless and the water was teeming with human and domestic wastes. With the political will of the city leaders, the riverbanks have been cleared of settlements and are now appropriated as community and recreational space. Open spaces may always be used in a variety of ways by the general public. The river and its banks, for instance, provide the stage for a multiplicity of uses at different times of the year: the water is used by young people for boating and commuters opting to take the public motorboat and travel by water instead of by land while the banks witness couples strolling, families picnicking, people jogging and biking, bargain hunters shopping at the flea market set up along the river. This multi-purpose function of open spaces emphasizes their importance as community spaces where social interaction transpires (Munarin and Tosi, 2002).

In highly built up areas such as Marikina City, maintaining green open spaces offer the opportunity to combine objectives of protecting the natural environment, enhancing the amenity values of natural open spaces, facilitating outdoor social interactions, and facilitating emergency response and relief activities after a disaster. Open spaces are necessary not only for creating a healthy city but also for emergency operations immediately after an earthquake, particularly in the middle of the city where most of the damage and losses are expected.

4.5.2 Urban Sprawl and Dispersion of the City

Together with the rapid population growth in Manila from the 1950s and thereafter, an urban explosion occurred in the suburban towns and rural areas ringing the core city. The process of urban sprawl must therefore be seen from a regional perspective, as Marikina is part of the larger metropolitan region of Manila. Urban sprawl is the pervasive process of filling up the landscape with man-made structures leaving in its wake a fragmented natural environment that deserve to be protected (de Böck, 2002).

Before the suburban out-migration of residents from the city of Manila, Marikina was then a small agricultural town on the bend of Marikina River. During these decades, the population in Marikina grew almost 10 fold, from 40,455 in 1965 to almost 400,000 today. Aided by the national government's policy in the 1970s to decongest the capital, infrastructure and road building, and with the convenience of the automobile as well as public transportation, major strains were placed on the formerly rural and undeveloped metropolitan fringes, which is still happening today.

Sprawl has eventually reached the hilly areas transected by the West Valley Fault on the boundary of Marikina and Quezon City and the East Valley Fault in Antipolo City, now exclusive residential suburbs with panoramic views. Here, the challenge is how to keep people from harm due to surface faulting.

The sprawling and dispersed layout of the city has also been aided and abetted by commercial strip development. Strip development is contrary to the basics of good land use planning: it impedes pedestrian and non-motorized traffic, consumes open space, invades the natural environment, and ruins any sense of place (Moldoff, 2004). Furthermore, in the downtown area and along commercial strips in Marikina City, signs and billboards can be seen everywhere. Huge store signs and billboards are non-structural elements that in many cases fail during an earthquake and may cause human harm.

4.5.3 Lax Enforcement of Building Codes

The existing pattern of land use and urban fabric in Marikina City is shaped not only by urban policies and programs of both the local and national government, but also by the counter response and initiatives of the private sector and civil society, e.g., business, individual property owners or households, and real estate developers and builders, who are the principal players in the zoning game (Babcock, 1966).

One problem that beset urban development in Marikina City is the rather lax implementation of building and/or structural codes. This has become a root cause of the high seismic vulnerability of Marikina City. Majority of the building stock is made up of traditional composite wood-masonry dwellings, non-engineered reinforced concrete structures, and substandard self-built houses that were constructed with little consideration for earthquakes.

Moreover, some local urban policies such as those embodied in the adopted Zoning Map of Marikina City (Map 2e), the no-height-limit regulation, and the scrapping of building permit fees promotes more building construction in a city, which is already highly built up and where open spaces are seen as vacant lots waiting to be constructed upon. Having no building height limit encourages builders to build vertically, which may maximize the economic returns for the use of precious commercial land but may not be safe for the occupants.

The land use planning process should contribute to protecting and saving life, property, and the environment for the benefit of all (Johannson, 2003). As an agent of the State, the local government should exercise its inherent power to act as regulator in the land use planning and urban development process in order to safeguard the people's well being. It should properly enforce building and structural codes not only during the design phase of a project but more vigilantly during the construction stage itself, when "cutting corners" is likely to happen. Substandard construction practice will then be lessened and buildings may stand better chances of surviving a large earthquake, which may result to lower risk for human life and limb.

CHAPTER 5

RISK-SENSITIVE LAND USE PLANNING: TOWARDS REDUCED SEISMIC DISASTER VULNERABILITY
The Case of Marikina City, Metro Manila, Philippines

Effective means to mitigating disasters have been found wanting. As catastrophic losses due to natural disasters continue to mount, a one-sided structural approach was deemed insufficient to reduce disasters (Pearce, 2003). What seems more effective would be to modify the impacts of such hazards on people and places by reducing their vulnerability. Together with this realization, disaster management has shifted its focal point from post-disaster relief towards sustainable disaster risk prevention culture (Bieri, undated), or in short, from disaster response management to disaster risk management.

Many authors suggest that land use planning can address the challenge imposed by natural hazards on the built environment (Godschalk *et al*., 1998). This study has been undertaken to demonstrate the possibilities of utilizing land use planning to reduce the vulnerability and therefore the disaster risk of seismically challenged towns, cities, and conurbations. The premise is that land use planning offers strategies that can decrease the potential damage and losses of urban communities from future earthquakes. Land use planning techniques can also be potentially less costly than traditional mitigation measures (Bolton *et al*., 1986). In view of this, seismic risk-sensitive land use planning is proposed as a planning strategy for seismically challenged cities and urban communities.

This chapter will discuss what risk-sensitive land use planning means and how land use planning techniques based on risk analysis can be applied to reduce seismic vulnerability using the case of Marikina City in Metro Manila, Philippines.

5.1 The Strategy of Risk-Sensitive Land Use Planning

Planning is a systematic process with which a problem is identified, data are analyzed, and a program of action is prepared to initiate desired changes and, in a dynamic urban world, guide inevitable changes to occur in a preferred manner. By anticipating changes, land use planning is proactive and looks forward into the future. As a future-oriented process, it seeks to steer or at least bring some degree of order to rapid land use changes and urban development, which necessitates the formulation of long-term goals and strategies. Planning is also a classic example of an eclectic discipline that draws upon many traditional fields such as the physical and social sciences, economics, engineering, and ecology.

Not surprisingly, disaster mitigation shares the same attributes of planning. As a result of the paradigm shift in disaster management, disaster reduction strategies search for long-range solutions. It is focused on reducing vulnerabilities instead of controlling the hazards and on long-term pre-disaster mitigation than on post-disaster relief and recovery (Pearce, 2003; Godschalk, 1998).

Hence, land use planning, by virtue of its multi-disciplinary, anticipative, forward-looking, and decision-oriented nature, logically lends itself as a strategy to attain the objective of reduced disaster vulnerability and the loftier vision of sustainable urban development for seismically challenged towns and cities.

5.1.1 Definition, Goals and Objectives

Simply put, risk-sensitive land use planning is a strategic planning approach that considers the threats of seismic hazards and the susceptibility of cities and urban areas to adverse impacts of future earthquakes in the basic process and authority of local land use planning. It integrates risk analysis into the problem identification and analytical phases in order to formulate management techniques and measures that will reduce disaster vulnerability.

As a decision-making tool, risk-sensitive land use planning combines the technical analysis of seismic hazards and vulnerability with standard planning. This should enable local officials and stakeholders to make informed choices on the use of land. Godschalk *et al*. (1998) emphasize the utmost need to complete disaster risk analysis before integrating land use planning and disaster mitigation. Sustainable land use and development cannot be achieved in earthquake prone areas when decision-making is not sufficiently informed about the risk (Deyle *et al*., 1998). Risk analysis provides the necessary information on what types of hazards exist and their characteristics, how many structures can be damaged, how many people are in harm's way, and where the vulnerable structures and populations are located, which form the factual basis for alternative land use scenarios. A risk-sensitive land use planning approach can therefore help to provide a stronger rationale for decisions made on land uses, siting of critical facilities, creation of open community spaces, and location of infrastructures, among others.

Risk-sensitive land use planning may be applied not only to less urbanized areas where urbanization is still in the earlier stages but also in highly built up urban habitats where redevelopment planning and regulation of existing land uses are of utmost significance, such as in the case of Marikina City. In this regard, risk-sensitive land use planning is a systematic process that is based on a factual assessment of seismic risk and seeks to initiate as well as manage urban changes that consciously lowers the disaster vulnerability of seismically exposed settlements and at the same time increase the chances of their sustainability.

5.1.2 Principles

The strategy of risk-sensitive land use planning is grounded on the realities of how cities work, that are located in seismically hazardous areas. It builds on the land use planning process that local governments undertake within its political power and administrative boundaries. Although risk-sensitive land use planning is applied and rooted at the local level, it acknowledges that planning takes place within an intergovernmental milieu; there are linkages between local, provincial, regional, and national planning authorities and among the different sectoral agencies of government.

In the tradition of comprehensive land use planning widely performed by local governments in the Philippines, risk-sensitive land use planning considers that there are many players in the local land use and urban development arena and that these stakeholders have their respective vested interests to protect. This planning approach is also aware that comprehensive plans address sectoral issues and concerns, e.g. economic, social, environment, infrastructure, of the community and thus seeks not to supplant affirmed community goals but rather support them by providing a pragmatic basis for the spatial arrangement of land uses to increase the likelihood of attainment of such goals. It likewise uses standard planning techniques and methods already familiar to all.

Risk-sensitive land use planning is also a strategy that fortifies the aims of urban sustainability by respecting the interdependence of the urban ecosystem and the natural system, by putting a premium on unbuilt spaces and undeveloped natural ecosystems in an urban area, by setting a limit to urban growth, and by believing that urban habitats are indeed sustainable in a country crisscrossed by active faults and plate boundaries.

Based on this premise, the strategy of risk-sensitive land use planning abides by a number of widely accepted planning principles. First, as it is a way of planning the built environment in more harmony with the natural environment, it contributes to the enhancement of a city's environmental viability and long-term sustainability. The concept of sustainability has been originally introduced to combine concern for the well being of the environment with continual growth and human development. In the context of risk-sensitive land use planning, sustainability refers to the capacity of urban settlements to be resilient in the face of natural hazards and maintain their habitability through time. Resilience can be achieved by minimizing, before an earthquake strikes, the potential earthquake damage and losses of the city and by making it possible for the city to recover from a disaster in the shortest possible time. It does not propose to transform entire cities, even if they sit on fault zones, into bucolic woodlands.

The second, the precautionary principle, is closely related to sustainability. According to the Earth Charter, the best method of environmental protection is to prevent harm, even when knowledge is limited. In the context of risk-sensitive land use planning, the precautionary principle applies in keeping people and their valuable possessions out of harm's way as much as possible, even when there is uncertainty (and there will always be) regarding the natural hazard and people's vulnerability. In short, it is better to err on the conservative side, than to gamble with human life.

Third, risk-sensitive land use planning upholds the principle of intergenerational equity. It recognizes the need to create cities that provide a safe and secure environment to its inhabitants where one can realize one's full potential in the long term. It emphasizes that the freedom of each generation is qualified by the well being of future generations and that short-term objectives have to be made while keeping an eye on the long-range goals.

The children of future generations will inherit existing conditions of present-day cities and urban settlements, just like how the present generation inherited the urban environment created by the previous. It is therefore in the best interest of both, the present and future generations, to create healthy and livable cities.

Fourth and last, risk-sensitive land use planning further strengthens the raison d'être of land use planning as a government function. In an urbanizing world where laissez faire economy and profit motives incessantly drive the forces of competition, the process of urbanization has been dominated by private sector interests and individual rights. The cumulative and long-term effects of individual and private sector land use decisions in many cases do not redound to the common good and may even unwittingly worsen the vulnerable conditions of an urban settlement exposed to natural hazards. Individual land use decisions may be made by people who are either unaware of the hazards or who ignore the writing on the wall, which may endanger not only themselves but the public at large, especially in places where people congregate such as commercial centers and in high-occupancy buildings such as schools and office buildings.

The local government, as an agent of the State, has the inherent responsibility to balance the protection of public welfare and individual rights. The Philippine Constitution indeed espouses the fundamental, inalienable right to property, but it likewise restricts this right by saying that this is not an absolute right. It is subject to reasonable restraints and regulations by the State. The bottom line is the greatest good for the greatest number of people. Hence, risk-sensitive land use planning provides a platform where the local government can take the reins in the urbanization process, particularly of seismically challenged urban communities, to fulfill its duty "to serve and protect the people" and provide an urban environment for them to enjoy the "blessings of democracy through the maintenance of peace and order, protection of life, liberty, and the promotion of the general welfare…." With greater land use planning, urban Philippines will then indeed face a sustainable future.

5.2 Risk-Sensitive Land Use Planning for Seismic Disaster Mitigation: The Case of Marikina City, Metro Manila, Philippines

5.2.1 Tools and Techniques

There are existing tools and techniques that a local land use planner can creatively apply to reduce seismic vulnerability and thereby disaster risk. Based on the results of seismic risk analysis, some land use and development techniques are deemed appropriate in the case of Marikina City. These planning measures have been a standard staple in the tool kit of land use planners in the Philippines. Furthermore, it is wiser to adopt familiar techniques because there will be less chances of encountering resistance from decision makers and stakeholders; ergo, there will be greater political and social acceptance of risk-sensitive land use planning.

Planning tools and techniques such as zoning and retrofitting, combine locational and structural schemes to reduce the potential damage from a future earthquake event (Bolton *et al.*, 1986). The locational approach pinpoint particularly vulnerable areas or land uses within the city, where specific regulations may apply. The structural approach involves certain buildings and infrastructures regardless of their location in the city.

In the pre-disaster period, tools and techniques applied in a risk-sensitive context aim to mitigate harm to people and damage to buildings by keeping them out of harm's way and therefore reduce the seismic vulnerability of the city by lowering population exposure in the direct path of seismic hazards. This includes the complete prohibition of new constructions in highly hazardous zones such as deformation zones of surface rupture. These techniques also seek to reduce vulnerability of the city, or put in another way, increase the resilience of the city to seismic disasters even before an earthquake strikes. Reducing the physical vulnerability of the city entails, for instance, the retrofitting of critical facilities located in high intensity shaking regions and structures found to be substandard in high-risk areas as well as the relocation of sensitive land uses out of highly hazardous areas. By reducing vulnerability, the city's disaster resilience is enhanced. This means, the city's ability to bounce back fast from negative impacts of a devastating earthquake is leveraged because potential damage and losses are minimized compared to a non-mitigation scenario where maximum damage occurs. This will help speed up the reconstruction and rehabilitation process and greatly reduce the reconstruction costs. Furthermore, the

During the disaster period, risk-sensitive planning tools and techniques seek to facilitate emergency response and disaster relief activities such as provision of open spaces as temporary shelter sites and medical field stations, facilitation of search and rescue operations, and other disaster management activities.

In the post-disaster period, risk-sensitive land use planning provides a "window of opportunity" to reconstruct the city in a more sustainable manner, for example, by rebuilding damaged homes and upgrading intact public infrastructures in a seismically resistant method.

5.2.1.1 Zoning

Zoning has been applied in the Philippines ever since the then Ministry of Human Settlements published its model zoning ordinance in the early 1980s. Zoning districts in many cities in the Philippines are established to promote compatible patterns of urban land uses. Zoning is also used to solve conflicts from competing demands for private urban land (Babcock, 1966). In countries where zoning is further evolved like in the US where it was invented, it is used not only to establish site development regulations but also performance standards appropriate to the land use and purposes in each zone. In the Philippines, most of the time, zoning includes only the identification of appropriate land uses for the zoning districts (e.g., allowable, non-allowable, and conditional land uses). In Marikina City, general zoning districts exist for residential, commercial, institutional, and industrial uses. Other criteria such as intensity, height of a proposed project, surrounding land uses, traffic impacts, and environmental concerns are sparingly used.

Risk-sensitive land use planning identifies zones where development should be restricted. It then grafts overlay districts onto the existing base zoning districts. Overlay districts modifies and restricts the use and site development regulations authorized in base districts in the particularly high-risk localities within the city. Where land is already highly developed as in the case of Marikina City, it may be used to justify the imposition of more controls on existing developments in more hazardous areas (Deyle *et al.*, 1998).

Imposing stricter land use regulations through zoning may at first seem to drive away economic development towards more lenient towns and cities in Metro Manila. However, high quality urban growth and development has been proven to be a magnet for long-term private investments, whether it is residential, commercial, or industrial, as investors perceive such actions by the local administration as positive signs of stability and planned urban environment that are conducive to business (McMahon, 1998).

5.2.1.2 Open Space and Parkland Development

Rapid and uncontrolled urban growth in Marikina City and other urban areas in the Philippines has put a premium on unbuilt and open spaces. Concurrently, the dwindling of this resource in urban Philippines has also made it a key urban planning issue. The multiple functions of green open spaces, e.g. aesthetic, functional, ecological, technical, and symbolic have been widely discussed in the literature for more than a century (e.g., Sandström, 2002; Thompson, 2002; Abu-Ghazzeh, 1996; Jacobs, 1961; Howard, 1898). Urban parks and green open spaces act as lungs of a cement jungle and as common spaces that provide social, recreational, and environmental amenities for urban communities.

From the standpoint of risk-sensitive land use planning, open spaces are a must for seismically challenged cities as they can act as readily available places necessary for emergency operations during a disaster. Public parklands and open spaces are ready sites for evacuation centers where temporary shelter can be erected for those rendered homeless by the earthquake and for temporary medical stations where the injured can be given first aid. In Marikina City, many of its pre-identified evacuation centers, i.e. public schools and community multi-purpose halls that have been used by the city government during past flooding disasters in Marikina City, are likely to be damaged by a future earthquake event. Most secondary and tertiary hospitals within the city will probably also be heavily damaged by the earthquake and thereby lose their function as they are located in the high shaking region of at least MMI=9, unless these buildings were seismically designed or will be retrofitted to withstand lateral loads. If they were retrofitted, slight damage may still occur. Hence, there will be a need for open spaces as evacuation sites, particularly in high-density residential and commercial areas where many people are concentrated.

Interconnected urban open spaces—natural unbuilt spaces such as the Marikina River, public parks, greenbelts, green corridors, and pathways—will likewise facilitate mobility and accessibility to different parts of the city during disaster relief and response operations, as roads and streets are expected to be blocked by vehicles or become non-functional due to buckling and cracking. Open paths can facilitate emergency response and will reduce loss of life, lessen complications from injuries, and expedite relief to victims.

A network of open spaces will likewise give Marikina City a much needed urban element that will help provide a distinct urban form in view of its dispersed growth and development. Open spaces should thus be viewed not as secondary spaces, always next in importance to buildings and physical infrastructure, but an intrinsic part and unifying framework of the urban fabric.

5.2.1.3 Urban Renewal Schemes

Urban renewal has been used in many contexts such as when slums are cleared and redeveloped into swanky residential apartments in soaring towers, or when an old harbour with rundown warehouses and condemned piers are transformed into a waterfront district with high-rise hotels and office buildings.

Urban renewal schemes have been viewed differently by different stakeholders in the planning arena. For instance, central city business interests perceive it as a means to boost sagging property values, while local authorities see it as a tool to increase tax revenues. In the sense of risk-sensitive land use planning, urban renewal is a planning tool to reduce the seismic vulnerability of localities within the city which have high seismic risk or high exposure to seismic hazards. Aside from the locational approach based on risk assessment, structural regulations are also necessary to reduce the potential damage to buildings and therefore lower losses in terms of life and injuries. Urban renewal schemes are applicable to certain areas in Marikina, particularly along the old retail strip development along Rizal and Bonifacio Avenue and Marcos Highway, to the traditional downtown area, and to the highly crowded and blighted resettlement and socialized housing sites in the city.

5.2.1.4 Land Acquisition

A land acquisition program is a means to provide the necessary open spaces and unbuilt land for parkland use in the high-risk areas of the city such as within the linear zone of the West Valley Fault and in the downtown area where open spaces are lacking. The local government may negotiate with affected landowners before resorting to expropriation or power of eminent domain. This is the power of government to confiscate private property for public use for which just compensation will be paid, especially when a property owner refuses to negotiate a price for its sale.

5.2.1.5 Regulation of Building Design and Construction

In the Philippines, the general building and subdivision regulations are embodied in the Subdivision Code (PD 957), Low-Income Subdivision Development (BP 220) and the Building Code (PD 1096). Seismic design code is governed by the National Structural Code of the Philippines (NSCP). The Association of Structural Engineers of the Philippines also published a guide to seismic design in 1991 based on the 1991 edition of the Uniform Building Code (UBC) of the US. The NSCP itself was largely based on the UBC and uses a Zone 4 seismic risk for the whole Philippines, a seismic risk equivalent to the most seismic zone in the US. The NSCP, like other seismic codes, present only the minimum criteria and standards to which a new building must be designed to provide prudent life safety for building occupants. Design standards do not aim to design for "zero risk" as economic considerations would prevent any such attempt (FEMA, 1995). This means, seismic codes are aimed at reducing the possibility of life-threatening collapse but some building damage may still occur even in a seismically designed structure.

Although a seismic code exists, seismic design and construction is still up to now not widely practiced in the Philippines for several reasons, namely: many engineers and architects are not well versed with the code; there is a lack of licensed structural engineers; and staff of the city or town engineer's office are not fully aware of their power to enforce the code; enforcement of the code requirements by local building officials is lax (Booth and Martinez-Rueda, 1995).

Although responsibility for quality during the design stage lies primarily with the professionals or firm executing the design, the regulatory powers of the government make local authorities in charge of quality control during the construction process. Buildings, which are structurally sound from design to construction stand to have better chances of surviving a future high-magnitude earthquake no matter where they are located within the city. It is then of crucial importance that local authorities exercise its power to regulate in the construction of new structures prior to an earthquake and to oversee as well the design and reconstruction process of damaged buildings in the post-earthquake disaster period.

For the existing building stock in Marikina City, which can be safely assumed to have been built below seismic standards, retrofitting is the key to increase their chances to withstand earthquake forces. Primarily a structural approach to urban vulnerability reduction, retrofitting entails some cost on the part of the property owner, which can make this measure difficult to implement. Earthquake protection can involve a variety of changes to a property that can vary in complexity and cost. Still, an ounce of prevention is well worth the effort to safeguard one's life, family, and home in the future.

5.2.1.6 Planning Power

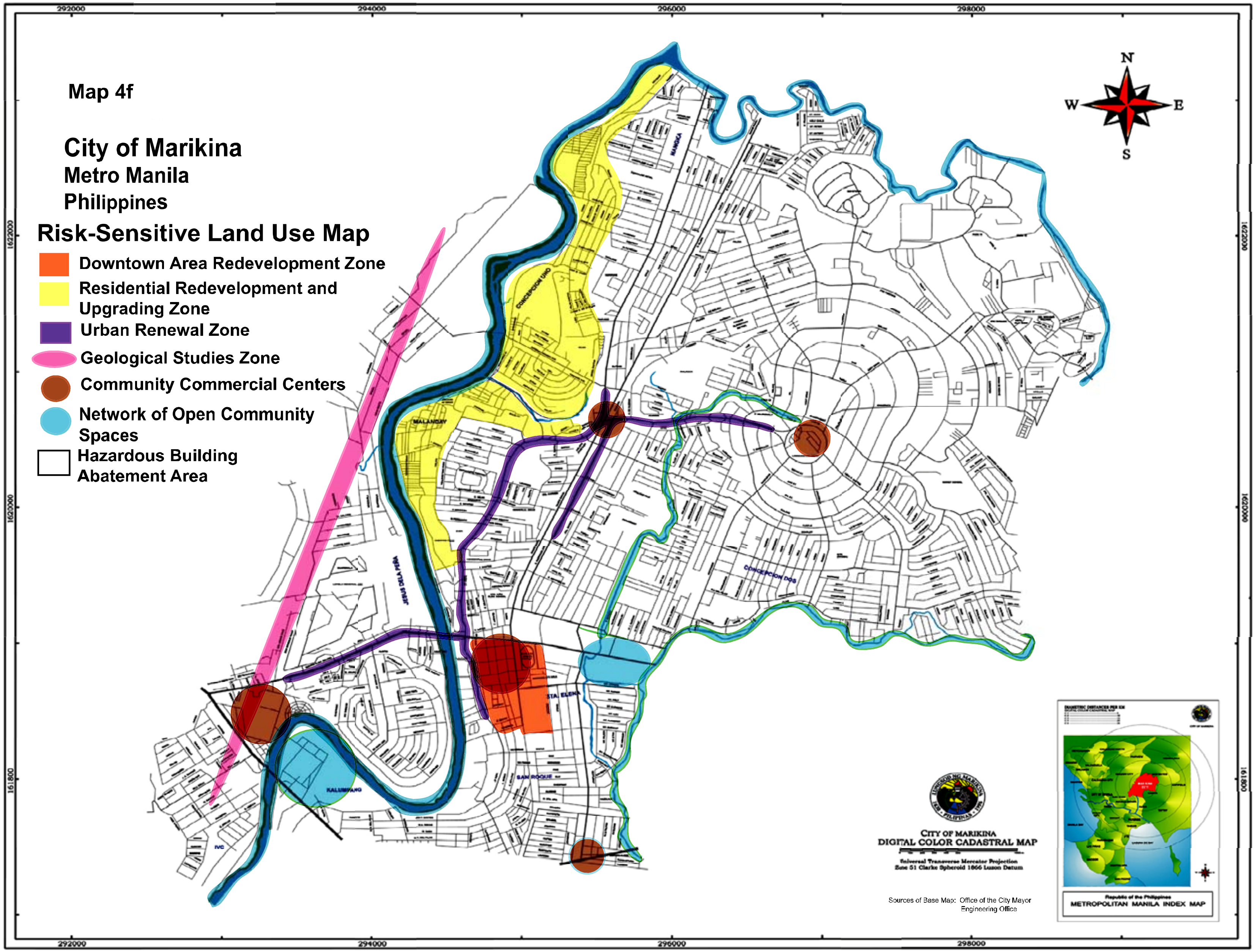
The local government can also institute public participation strategies to build consensus among the different stakeholders and also increase the chances of the plan being socially acceptable. Communication and education campaigns can bolster the awareness of real estate developers, property owners, residents, and the general public about seismic hazards, pique their interest in adopting vulnerability reduction measures on their own accord, or to increase the compliance to risk-sensitive planning measures. This can be performed during the different phases of the planning process: from problem characterization and intelligence gathering to setting of goals, objectives, and strategies, plan adoption and implementation, and monitoring and evaluation stage.

5.2.2 A Risk-Sensitive Land Use Plan for Marikina City

A risk-sensitive land use plan seeks to assist a seismically challenged city with problem solving before, during, and after earthquake disasters. Applying a combination of planning tools and techniques to reduce disaster vulnerability of Marikina City, the following elements of a risk-sensitive land use plan for the city emerge (Map 5a – Risk Sensitive Land Use Map). The following list of potential land use management tools and techniques provide the city government a wide array of choices for seismic risk reduction. The risk-sensitive land use plan maybe implemented by phase based on consultations with the stakeholders.

5.2.2.1 Urban Renewal Zones

The Urban Renewal Zones would be areas defined by the Extensively and Moderately Damaged Areas on the Building Damage Distribution Map. Specifically, these are the localities strung along Rizal Avenue, from Barangay Concepcion in the north down to Barangay San Roque in the south and along Bonifacio Avenue in *Barangays* Tanong and Jesus dela Pena. The Urban Renewal Zone will thus be anchored on the commercial strip on Rizal and Bonifacio Avenues and will include the traditional neighborhoods lining it.


Map 4f
City of Marikina
Metro Manila
Philippines
Risk-Sensitive Land Use Map
Downtown Area Redevelopment Zone
Residential Redevelopment and Upgrading Zone
Urban Renewal Zone
Geological Studies Zone
Community Commercial Centers
Network of Open Community Spaces
Hazardous Building Abatement Area
N
W
E
S
292000
294000
296000
298000
1622000
1620000
161800
CITY OF MARIKINA
DIGITAL COLOR CADASTRAL MAP
Universal Transverse Mercator Projection
Zone 51 Clarke Spheroid 1866 Luzon Datum
Sources of Base Map: Office of the City Mayor
Engineering Office
Republic of the Philippines
METROPOLITAN MANILA INDEX MAP

The strip development along the oldest commercial streets in Marikina can be perceived as a spillover effect of the Traditional Commercial District or the downtown area. Strip development has been criticized by many planning movements of today, such as the New Urbanism and Smart Growth/Smart Development, whose existence came about as a response to urban and suburban sprawl. The evils of strip development have been documented by many researchers (e.g., McMahon, 1997).

The existing commercial and retail trade strips in Marikina City are characterized by poor quality and poorly maintained buildings, mixed wood-concrete constructions, insufficient setbacks, buildings of varying height standing side by side, and in a few places, blight. Sidewalks, if they exist, are either insufficient in width or usurped by other uses, e.g. as parking lots, extension of the shop, display area, and storage space. Business signs proliferate and clutter the streetscape. These characteristics of the commercial strips make the area highly vulnerable to seismic hazards. Poor quality and poorly maintained buildings and wood-concrete constructions are expected to easily give in to the swaying forces of an earthquake. Insufficient setbacks between buildings of varying height may result to pounding during an earthquake. Non-structural elements of commercial buildings such a business signs made of glass and metal, huge wooden billboards mounted on rooftops, and building appendages such as parapets and awnings are all sources of danger during an earthquake, especially if they were badly constructed and weakly attached, and may result to serious physical injuries and perhaps even death. Sidewalks, which act as escape routes during earthquakes, must be kept free from impediments that may hinder the fast movement and evacuation of those inside.

In spite of these conditions, the commercial strip is here to stay. Zoning can be applied in order to prevent commercial strips from happening in other parts of the city or expanding (Moldoff, 2004). What can then be realistically done is to revitalize the existing commercial strips on Rizal and Bonifacio Avenues and Marcos Highway into a more pedestrian-friendly and disaster-resilient shopping area that serves the needs of the surrounding communities and adds economic vibrancy to the city, while prohibiting the growth of new retail trade strips elsewhere in the city.

In a risk-sensitive land use planning context, the Urban Renewal Zone, as an overlay zone to the existing minor and high intensity commercial zones of the city, will have the following elements:

1. Inventory of the building stock within the zone and identification of seismically hazardous dwellings and buildings such as unreinforced masonry (URM), composite wood and concrete, non-engineered reinforced concrete (RC) buildings, and substandard/poorly maintained buildings, e.g., buildings constructed prior to 1971.
2. Mandatory retrofitting of dwellings and buildings evaluated to be seismically vulnerable.
3. A mixture of land uses will be allowed, as normally allowed in minor and major commercial zones, e.g. offices and selected commercial uses predominantly serving community or city-wide needs such as medical or professional offices, shopping facilities that provide limited business service, retail shops, convenience stores, consumer repair services, food sales, pet services, service stations, and restaurants.
4. Requirement of a three-meter front yard setback from the road right-of-way for new developments and clearing of existing sidewalks of impediments. Clean, open sidewalks encourage people to walk and facilitate foot traffic. Unimpeded sidewalks are necessary as they function as escape routes during an earthquake.
5. Imposition of maximum building height, which is non-existent in Marikina City. Maximum permitted stories will be three stories (15 meters) for commercial buildings and two stories (10 meters) for residential dwellings, which may be changed pending the results of a geologic study by an expert for each new project site. This is primarily due to the presence of soft soils, which have a long period, and may thus amplify ground shaking. Tall buildings on soft soils are susceptible to ground shaking as they also have long periods, depending on the number of stories. Normally, the number of stories indicate the period of a building: a one-story building has a period of 0.1 second, a 10-20 story building has a period of 1.0-2.0 seconds. If a tall building stands on soft ground, the building may resonate with the ground due to their similar periods, and may thus experience higher intensity shaking. Property owners whose buildings exceed the maximum building height and owners of nearby buildings that could be affected should be made aware of the possibility of pounding during an earthquake. Non-conforming uses shall be fined.
6. Prohibition of on-street parking along the commercial strip as Rizal and Bonifacio Avenues and Marcos Highway are major thoroughfares. These major roads are also the primary transport connections that will be used for disaster response and search and rescue operations. It is therefore necessary to keep these thoroughfares open and free of congestion that will impede the flow of traffic.

7. Requirement for the provision of parking facilities. As commercial strips generate vehicular traffic and the commercial and retail shops along Rizal and Bonifacio Avenue lack space for off-street parking, the local authorities will, in cooperation with the merchants and business proprietors, look for an idle or vacant lot in the vicinity that can be leased by the business proprietors for use as common parking facility or where a parking structure can be erected, cooperatively established and operated by the business proprietors. The total number of require parking spaces may be reduced for establishments requiring only frequent transit service and also on the basis of common patrons, overlapping peak needs, and existing public parking facilities.
8. Prohibition of huge billboard signs mounted on rooftops of building and houses. Signage controls will be instituted by local authorities to prohibit the use of hazardous materials for business shop signs, for example, glass. Signs and billboards can easily fail in an earthquake and fall on people on the streets.
9. Non-structural elements of a commercial building such as parapets, awnings, and other appendages will be inspected by local authorities and property owners will be required to reinforce the attachment of such appendages following higher standards.
10. Geologic site investigation will be required from future individual developments due to the seismically hazardous location.

5.2.2.2 Downtown Area Redevelopment Zone

The Downtown Area Redevelopment Zone, another overlay zone, provides for the renewal of the Traditional Commercial District and surrounding transitionary areas. The Traditional Commercial District is the retail, business, and governmental center of the city. Accordingly, there is a concentration of pedestrian and vehicular activity in the district. As such, this area has been marked as a High Risk Area, where there is a high probability of losses in human life and injuries, although building damage is expected to be moderate due to the presence of modern RC buildings built to higher quality standards. Hence, the regulations in this Zone pertain more to facilitating foot traffic, retaining such intensity of use and density of pedestrians as is compatible with the function of a traditional downtown.

1. The main road cutting through the Zone, Shoe Avenue, will be closed to vehicular traffic and will be converted into a pedestrian zone. This pedestrian zone will be connected to and become a part of the network of open community spaces. The freeing up of this main thoroughfare will not only add to open community spaces (in

spite of it being gray space), but will also revitalize the downtown area through the improvement of the streetscape, prevention of blight, and promotion of the downtown as a thriving multi-functional core of the city.

2. On-street or surface parking will be permitted in the inner secondary streets. On-street loading and unloading bays for public transportation will be provided in nearby corners to facilitate pedestrian commuting.
3. As a moderate number of buildings within the Zone will likely suffer serious damage, in spite of the high quality construction standards followed by the modern commercial buildings in the zone, an inventory of the building stock is necessary. There exist as well old residential structures turned commercial in the Zone. Retrofitting of structures found to be vulnerable will be mandatory, as this is an area of high population concentration.
4. As in the Urban Renewal Zone, the maximum permitted height is 3 stories (15 meters) for new developments, due to presence of soft, liquefiable soils. This may be changed pending the result of a geologic study of the proposed development site.
5. Front yard setback will not be required. Establishments are encouraged to face the street (Shoe Avenue) and be pedestrian-oriented.
6. Signage controls will also be applicable in this Zone.
7. Building appendages will also be subject to higher construction standards.

5.2.2.3 Residential Redevelopment and Upgrading Zones

The Residential Redevelopment and Upgrading Zone will be specifically established for the different resettlement and socialized housing sites within the city, regardless of their location. Informal, non-engineered types of masonry dwellings (e.g. untied stone or adobe or hollow block walls with no reinforcement bars), which are common in such sites, have been found to be responsible for the 60 percent of earthquake related deaths this century (Key, 1995). These areas are thus identified as High-Risk Areas on the composite Risk Map, with high physical, human, and spatial vulnerability levels. Therefore, retrofitting the structures in these areas is called for. This may then be a golden opportunity for the city government to initiate a holistic urban redevelopment program In this instance, urban renewal is not commerce-centered but residential centered.

In order the reduce the seismic vulnerability of these high-density residential areas, the following general regulations will apply:

1. *In situ* low-cost housing and mixed-use development spearheaded by the local government of Marikina City. This can be done on the existing resettlement and socialized housing sites that are owned by the local or national government. Socialized housing loan from different agencies of the national government such as PAG-IBIG and National Home Mortgage Finance Corporation with the local government acting as developer has been done before in other Philippine municipalities. By so doing, the local government of Marikina can fulfill its duty as provider to the less privileged members of the society in the highly competitive market of urban development. At present, the resettlement and socialized housing sites are areas of congestion, substandard self-built housing, and inadequate streets. These neighborhood characteristics all add to the high seismic risk level of the area due to high physical and human vulnerability. Self-built houses will be easily damaged or will even collapse due to the expected strong ground shaking in the area. Densely populated and congested residential neighborhoods without adequate accessibility also make it difficult during disaster response operations for medical workers to reach them or vice-versa.
2. The Residential Redevelopment and Upgrading Zone will include different types of residential dwellings integrated with a neighborhood commercial center, well-designed streets, and open community spaces. It will be designed to encourage a variety of community activities, locales, and services to co-exist in close proximity. It is an antidote to the widely separated live and work centers that are conducive to urban sprawl. The Zone will offer a variety of housing choices, e.g., single family housing, and multi-family dwelling types: duplex, quadruples, low-rise apartment buildings, and row housing to provide housing opportunities to different types of people with different types of needs (e.g., singles, small families, and big families of varying economic abilities. The residential mixed-use redevelopment integrates in its design parks, playgrounds, and open spaces and a community center along with a neighborhood commercial center. The purpose of the neighborhood commercial center is to establish an area for small specialty stores, offices, eating places and other compatible land uses which furnish convenience goods and services for the needs of the residents of the neighborhood; do not generate large volumes of traffic; are compatible with the surrounding neighborhood; and which are located in buildings of residential design, scale, architecture and exterior materials in order to preserve the residential character of the area.

3. Maximum height limit will be three stories (15 meters), regardless of the type and occupancy of the building due to the presence of soft soils. This may change pending the results of the required geologic site investigation.
4. Acquisition of land to be used for mixed use residential development, preferably in the less hazardous areas of the city for the less privileged and for those who are still living in informal settlements, i.e. along creeks.

5.2.2.4 Geological Studies Zone

Establishing a geological studies zone is a locational and structural approach to dealing with the hazard of surface fault rupture. Hence, this zone is applied only in areas where pre-existing fault traces are suspected. In the city of Marikina, the West Valley Fault has been generally mapped in the western edge of the city, specifically in the vicinity of the residential enclave of Loyola Grand Villas. Unfortunately, the fault traces have not been physically delineated on the ground. Hence, parallel to the establishment of this zone is the passing of an ordinance by the city council to delineate the fault zone on the ground with the help of the Philippine Institute of Volcanology and Seismology (PHIVOLCS).

The following regulations will be implemented within the Geological Studies Zones:

1. Using the precautionary principle, the Zone will be at least 150-meter wide centered along the line of pre-existing fault trace, as the fault will be in some parts well defined and in others, inferred. In comparison, the Alquist-Priolo Act of the US, which mandates regulations in fault zones, requires about 200-meter wide strips along the length of the fault trace.
2. The Zone will be intended for low-density single-family residential land use. Maximum recommended height is 10 meters (two stories).
3. Requirement of a geologic site investigation for new building projects within the Zone by a licensed geologist to find out if a fault exists on the project site as well as other potential earthquake hazards (e.g., ground shaking, liquefaction and landslide) before a building permit is issued by the city government. The investigation report will then be evaluated by the city government and a copy will be sent to PHIVOLCS for review and recommendation
4. Prohibition of any kind of new development projects for human occupancy on sites where a pre-existing fault exists. Any kind of building, even those built to high seismic standards, will not withstand the abrupt shearing displacement occurring along the fault during an earthquake, as surface faulting-resistant construction is not

feasible (Reithermann, 1992). For properties transected by a well-delineated fault, a setback of at least 5 meters on both sides will be required. Where an inferred fault exists, a setback of at least 10 meters on both sides will be necessary. FEMA (1998) recommends at least 30-meter (15 meters on both sides) no-construction zone on active earthquake faults.

5. Based on experience from the 1990 Luzon earthquake, the zone of deformation along the fault was five meters wide (Besana and Daligdig, 1993). It is expected that a future probable earthquake of M=7.5 on the Marikina Valley Fault will create maximum ground displacements of two to four meters (Punongbayan *et al*, 1993; Daligdig and Besana, 1992).
6. Acquisition of land on the direct path of the fault. It is imperative for the local government to use its power to expropriate to acquire the land directly lying above the fault. The five-meter linear strip of land will be converted into the Marikina Geological Park, the first of its kind in the country. The park will feature an educational trail about geology and earthquakes, stone gardens, and a jogging and biking path along its length.
7. Requirement of public disclosure from real estate developers to inform prospective property buyers of the seismic hazard(s) before a development permit is issued by the city government.

5.2.2.5 System of Community Commercial Centers

A dispersed city will be very difficult to manage during times of emergency and disasters. The already limited resources of the local government will be further taxed by the need to spread these resources in many places at the same time (i.e., personnel, logistic supplies, medical stations). Problems of mobility and accessibility will also exacerbate this problem, as many city roads will in all probability be either full of rubble or non-serviceable due to buckling and cracking.

The city of Marikina has already overstepped the line of physical growth. Urbanization has eaten up about 90 percent of the land area, effectively leaving only interstitial open spaces and Marikina River as open green spaces within the city. To counteract the disintegration of the city into a formless mass of gray spaces, major nodes of commerce, trade, and services at the community level will be established in the lower intensity shaking regions of the city. A system of community commercial centers is an alternative to a strip pattern and still meets the demand for service and retail space. In Marikina City, there are emerging concentration points, which can be encouraged to grow to become nodes and help shape a polynodal urban form. Commercial nodes around major intersections can limit retail uses on the rest of the corridor. This will also provide redundancy in urban functions and services in the event of an earthquake. Recovery from a disaster will be faster.

The following are the possibilities for this system of commercial community centers:

1. The Traditional and Modern Commercial Districts will be maintained, as these symbols of the city and have become an intrinsic part of the urban fabric of Marikina. The traditional downtown area, for instance, provides a focal point for shopping, dining, services and transit, and the civic life of the city.
2. Community commercial centers will serve different quarters of the city. These nodes can be planned to integrate retail, personal and business services, office, and even housing development. Within the commercial center, a mix of shops, services, and civic uses capable of satisfying many of the community's' daily needs will be encouraged. Public open spaces in the form of streets, squares, and parks will be integrated as well.
3. Governmental institutions are also given prominent sites. These centers will not only provide commercial and business services, but also essential services provided by the city government such as fire stations, police stations and emergency response operations which are currently centralized in the downtown area.

5.2.2.6 Network of Open Community Spaces

Intentionally planning a network of urban parks, green corridors, and pathways not only for ecological and functional values but also for technical purposes is necessary in a highly built up area such as Marikina City. In spite of the open space requirements in various development laws such as the subdivision code (Presidential Decrees 957 and 1216) in the Philippines, an open space network will not naturally evolve from piecemeal open space conservation measures and without conscious planning. Even interstitial open lots and pathways can be applied to better use when combined and connected to an open space network.

In Marina City, a network of open community spaces will serve as a means to facilitate emergency operations, particularly immediately after an earthquake. The open space network will consist of the following:

1. Creation of urban parks using the existing idle lands at the corner of Bonifacio Avenue and Tuazon Avenue and development of waterfront parks along the length of Marikina River in Barangay Calumpang. These vacant lands have been earmarked for future commercial land use expansion in the Zoning Map of Marikina City. These vacant lands are the two relatively big tracts of land that remain as open space in the middle of a highly built up area. Urban parklands are very much needed in this part of the city. During pre-disaster period, these open spaces can function as public parks where citizens can enjoy passive (sitting, watching the world go by) and active leisure activities (sports, play, walking, biking). These open spaces can also be places of public assembly immediately after the earthquake. Public meeting points are necessary for separated family members to find each other, as a place to disseminate important public announcements, and to communicate with members of the media. During the emergency response period, a temporary central command post for local government and emergency officials and for international organizations responding to the call for help is needed. Public facilities such as the city hall and public school buildings are most likely damaged and not fit for occupancy, especially during the first few days after the earthquake when buildings are still to be inspected for damage by engineers. International organizations would need space for heavy equipment and personnel for search and rescue operations. A portion of these open spaces can also become temporary shelter sites where tents and sanitary facilities can be set up for those whose houses have been damaged by the earthquake and as medical field stations to provide fast medical services for the injured.
2. The identified urban parks will be linked to the Marikina River through a network of pedestrian corridors and green pathways. The interconnected open spaces, particularly the Marikina River, will serve as transport corridors in case of the non-serviceability of cracked and buckled main roads within the city. The river would serve as the main transport route to reach affected neighborhoods up and down the city. Pedestrian corridors and green pathways that connect the urban parks and the river will be established within the High-Risk area of the city. This will entail the conversion of secondary roads and alleys into pedestrian corridors and green pathways. The creation of interconnected open spaces, parks, and pedestrian corridors shall also encourage non-motorized modes of travel such as bicycling and walking. It will provide the necessary open space infrastructure for pedestrian and bicycle travel. Non-motorized modes of transportation offer mobility, reduce

congestion, improve environmental quality, and promote public health (Balsas, 2002). Bicycling and walking are legitimate transportation options, particularly during the post-disaster period when road rehabilitation and reconstruction are ongoing.

3. The Marikina riverfront need not be converted into a planned park like a waterfront park of a modern city. Natural areas and unstructured green open spaces have inherent ecological qualities as well as provide a natural environment where people can be with nature in a highly urbanized setting. Unstructured natural conditions of the riverbank will not hamper emergency operations and mobility.

5.2.2.7 Hazardous Building Abatement Zone

The Hazardous Building Abatement Zone encompasses all the areas outside the previously defined zones. This Zone requires the voluntary retrofitting of privately owned buildings and mandatory retrofitting of critical facilities, e.g., schools, colleges, and hospitals. Although there has been no quantitative study on the effectiveness of seismic codes (e.g., number of lives saves and injuries prevented), recent earthquakes offer convincing proof that seismically resistant buildings will dramatically reduced the impact of a significant earthquake (FEMA, 1995).

The Zone will have the following regulations:

1. Inventory of the building stock and assignation of each structure to a seismic exposure class depending on its use or occupancy and on the expected level of ground shaking at the site. Class 1 can be ordinary buildings; class 2 is high occupancy buildings such as schools; and class 3 is critical facilities essential for disaster management activities such as hospitals. The use or occupancy criterion should be coupled with a location criterion. Marikina City, based on the simple computer program used by the study, is divided into three shaking regions depending on the expected ground shaking intensity resulting from a 7.5 magnitude earthquake. This can be provisionally used to assign each building to a particular seismic exposure class until a more accurate seismic hazards evaluation is conducted. For example, a single-family detached dwelling located in a low intensity shaking region can be exempted from Zone requirements or the property owner can opt to voluntarily retrofit his residence because the risk is relatively low. Or, a storage warehouse located in moderate shaking region can be exempted because of the very low risk to life.

2. Mandatory requirement of retrofitting for all high occupancy buildings (e.g., schools, theaters, shopping malls) and critical facilities (e.g., hospitals, fire stations, governmental buildings) located in the high intensity shaking region of the city.
3. Strict enforcement of seismic design standards and site inspection during construction of new buildings.

5.2.2.8 Education and Awareness Campaign

Public participation was mentioned in the beginning of the study, specifically during the problem identification and intelligence gathering stage. Implementing participatory strategies fall within the ambit of the basic process and power of planning. Public involvement is necessary in developing the plan, and to support any decision-making that would be based on it.

Public involvement strategies should include education and information awareness activities to inform the different stakeholders on the subject of earthquakes, their effects, and earthquake safety. It is emphasized that in order for earthquake safety to permeate the consciousness of the general public, regular education and information campaign program should be part and parcel of land use planning process of the city government in tandem with the urban development and zoning policies discussed above.

5.2.2.8.1 Mobilizing the Youth for a Healthier City

Foremost of the consciousness-raising program should be the education of the youth about earthquakes and earthquake safety within the context of sustainable urban environment. This can be done in two ways. First is by supporting existing school-based environmental clubs and helping to form them in schools where there is none. The city government may initiate an education campaign in public and private primary and secondary school and colleges within its territory with the help of existing school clubs and organizations.

School-based activities in which school children and students can take part may include the following:

- An environment/natural hazards art exhibit/competition. Art is an important form of communication and expression and is an excellent method to increase environmental awareness in the community. This will likewise enable the city to encourage and acknowledge the talented and budding artists among the youth. A theme can be chosen every year, i.e., “What is a Healthy City?”. Since Marikina City is also a highly flood-prone community, the issue of flooding may likewise be included. The atrium at the city hall may serve as the exhibition for the final entries to enable the public at large to view them and reach the widest target audience.

- An Earth Science Week held every year during which a field trip to the Philippine Institute of Volcanology and Seismology (PHIVOLCS). The cooperation of PHIVOLCS will thus be needed in this activity. The PHIVOLCS can show documentary films on various natural hazards and their effects on people and settlements. In addition, a geologist will be on hand to answer questions and explain the scientific side in layman's terms. An earth science/natural hazards fair can also be held in different schools where posters and photos of the impacts of natural hazards can be exhibited. Lastly, individual schools can launch an environmental science quiz bee, after which, a district-wide competition can be conducted.
- A half-day visit to the proposed Marikina Geological Park as an extra-curricular activity at any time of the year. Scientists from the Philippine Institute of Volcanology and Seismology (PHIVOLCS) may be invited by schoolteachers and club advisers to provide a more thorough discussion of earthquakes and active faults and dispel public misconceptions about faults and earthquake, and at the same time, a land use planner can explain the potential damage of earthquakes to man-made structures. This outdoor activity at the very site of the West Marikina Valley Fault Zone will allow students as well as teachers, parents, and school administrators to come face-to-face with the famous fault.
- Tree-planting. Another activity that can be undertaken with school-based environmental organizations together with non-government organizations and community associations is tree planting (discussed further below). This will allow students to have a hands-on approach to learning about environmental issues in general.

The second means to raise natural hazards awareness is to include earthquake science and safety units in lesson plans. At present, what the public school district are mandated by the public school district to conduct emergency and evacuation drill exercises at least once a year. The program also provides teachers with lesson plans and other educational resources in order to link environmental issues into their curriculum. This exercise, however, is not sufficient to increase the awareness of pupils and students about earthquake hazards and how to behave during an earthquake. Aside from undertaking this drill exercise, the city government of Marikina may start to inject more environmental topics in the curriculum of the public school district by including a topic on earthquakes, specifically about the Marikina Valley Fault, earthquake safety, natural hazards in general (as Marikina City is also flood-prone), and sustainable land use in its curriculum. The approach should be that these topics will be incorporated in existing mandated curricula in the areas of science, social studies, and arts and not will be designed as stand-alone curriculum.

Integrating environmental education into the curriculum should be conducted both within and outside the fours walls of the classroom. Therefore, extra-curricular activities such as those outlined above are necessary to have a more holistic approach to environmental education. In this regard, the whole city of Marikina can be a living laboratory for elementary and high school students, where they can learn first hand where and why earthquakes happen, or what a fault zone looks like, or how can the community work together to build a more sustainable city.

5.2.2.8.2 Earthquake Awareness and Mitigation Month

Probably another first in the Philippines, an Earthquake Awareness and Mitigation Month can be proclaimed by the city government to promote a culture of disaster preparedness among the populace. Instead of burying its head in the sand, the city government will spearhead a yearly earthquake awareness and mitigation month in order to promote earthquake safety and disaster preparedness and mitigation. This will emphasize that althought earthquakes and seismic hazards will not disappear or diminish, residents of Marikina City can reduce their vulnerability, prepare for the event, and manage the risk that can reduce the impacts of seismic hazards.

Many activities can be undertaken in conjunction with the earthquake awareness and mitigation month, which may include the following:

- A seminar on Earthquakes, Marikina Valley Fault System, and Disaster Preparedness. Seismologists, structural engineers, disaster managers, and land use planners will be invited as resource persons to speak on relevant topics, to wit:
    - What could a large earthquake do in Marikina City?
    - How can I protect my home and family from earthquakes?
    - How can I protect my workplace from earthquakes?
    - What should I do if a strong earthquake occurs?
    - How to survive an earthquake in the first 72 hours.

  Visual aids such as maps locating the Marikina Valley Fault System (as well as other active faults in the country), geological maps that help describe earthquake hazards, and photographs of faults, fault breaks, and earthquake damage can help to send the message across a wide variety of audience. The seminar can also be done at the local level, as in each of the 14 *barangays, so* that more people can be reached.

- A disaster preparedness seminar that is tailored-fit for children. An alternative kind of seminar should also be conducted that will relay the same message to children in a fun learning environment. Instead of a seminar format, interactive learning stations can be constructed outside, perhaps in the Marikina Geological Park or in the urban park in the middle of the city. The learning stations will be designed so that adults and children can work together to learn about natural hazards (particularly earthquakes and floods) as well as how to protect themselves. For example, a shake table demonstration can be performed where children can build houses made of different construction materials and subject then to shaking motions. This can be conducted in cooperation with non-government organizations involved in disaster management.
- First aid training. A short-term training program on first aid techniques should also be offered during the earthquake awareness month with the help of experts and doctors. The aim should be that at least one member of the family will be trained in first aid techniques. The local Red Cross chapter can be tapped for this activity.
- Information dissemination on earthquake awareness. Leaflets or brochures that outline in simple terms a concise checklist and survival tips should be freely disseminated to the public. Another method would be publishing it a widely circulated local newspaper. The Marikina City information office and Disaster Coordinating Council can work together on this project. A family earthquake awareness checklist/survival tips may include the following information:
    - Family members 10 years old and older know how to turn off all utilities, e.g. water, gas, electricity.
    - An earthquake survival kit including a flashlight with extra batteries, a portable radio with extra batteries, blankets, a first aid kit and first aid manual, and small plastic bags with ties for human waste disposal, small amount of cash, etc. has been packed, accessibly placed in the house, and ready for instant use following an earthquake.
    - Store a 72-hour supply of water in plastic containers.
    - Prepare a 72-hour supply of dried and canned food at home.
    - Keep a flashlight for each family member near one's bed.
    - At least one all-purpose fire extinguisher is available in the house.
    - Each family has developed an earthquake emergency plan, e.g. a meeting place has been pinpointed where everybody can reunite after the quake. This can be the proposed urban park within the city.

- Seminar on retrofitting. This seminar aims to disseminate information on the ways and means of retrofitting residential buildings and making houses safer from ground shaking. Many would automatically think that retrofitting would cost a lot. Simple methods such as bracing walls and anchoring the house to the foundation through bolts, however, can be easily done by building contractors at a modest cost. The seminar will also inform the public about home repair and strengthening tips for vulnerable non-structural features of the house that usually cause injuries such as porches, sliding glass doors, canopies, carports, and garage doors. Moreover, making the interior of the house more secure, for instance, by bracing or anchoring book cases, shelves, hanging lamps, etc. to the wall or flooring and by simply storing heavy objects and fragile items in lower shelves or in closed cabinets with latches are also important topics that will help reduce human losses or injuries. The seminar can be spearheaded by the city government and professional organizations such as the Association of Structural Engineers of the Philippines and local builders' association.

5.2.2.8.3 Greening the City

As a corollary to the open space development that will be undertaken as part of the zoning outlined above, the city will start a greening movement that aims to the identified open community space network in and around the city, specifically the Marikina River banks, open space corridors, and urban parks. Tree planting will be undertaken on a yearly basis until the open space network is complete with foliage.

Tree planting will also be a necessary adjunct activity to the establishment of the Marikina Geological Park. The aim is to create a five-meter wide linear park along the trace of the West Valley Fault Zone to physically delineate the trace of the active fault. This will not only demarcate the necessary setback from the active fault trace but also increase the awareness of the neighborhoods in the surrounding areas as well as the general public of the existence of the active fault and the constant probability of an earthquake.

The city government can enlist the assistance of the public school district and the different colleges and universities within the city in this greening activity. Residential associations and environmental non-government organizations may be requested to provide human and logistical resources as well.

5.2.2.8.4 Building Partnerships with Builders and Artisans

The city government should initiate a multi-partite partnership with the different actors in the urban development scene such as civil and structural engineers, architects, project managers, contractors, and artisans (i.e. masons, carpenters, plumbers). The partnership aims to provide a platform for further cooperation in promoting sustainable building practices. Activities may include education and training on topics such as seismic building code, seismic resistant construction, and retrofitting existing structures.

5.2.2.9 Marikina City Urban Regeneration Committee

An Urban Regeneration Committee (which can be called by other name) will be institutionalized in order to oversee the implementation of the plan. This will be chaired by the City Mayor and co-chaired by the Vice-Mayor. Members of the committee may include the city councilor(s) involved in land use planning and urban development, the president of the *barangay* captain association, city engineer, city planning and development officer, city park administrator, fire station commander, Rescue 161 chief, settlements office chief, and budget officer.

A licensed geologist, preferably with an earthquake engineering background, will be hired by the city government to assume the functions of City Geologist. A City/Town Geologist position is not in the plantilla of personnel of local governments. However, due to necessity, the city of Marikina will institute a City/Town Geologist as a regular staff function in local government administration, perhaps the first in the country. He will be one of the members of the Committee.

5.2.3 Planning with Nature: Some Examples of Conceptual Plans

Many variables contribute to seismic vulnerability of an urban area. The nature of the seismic hazard likewise varies throughout the Philippines. This makes risk and vulnerability of the different towns and cities variable as well. It is therefore important that hazard evaluation and vulnerability assessment be performed for all seismically challenged urban settlements. What works in a large, highly built up urban area in Metro Manila cannot be simply adopted by a small town in Cebu Province, for example. In this regard, risk sensitive land use planning offers a unifying strategy in approaching the various problems of seismically challenged towns and cities.

In view of local realities, some conceptual plans are prepared for certain zones that have been described above to help visualize what a risk-sensitive planning may achieve.

5.2.3.1 Geological Park in the Geological Studies Zone

A 5- to 10-meter no-construction zone along the pre-existing fault trace of the West Marikina Valley Fault will be established. This linear path will be turned into a geological park that terminates into a multi-purpose open space.

5.2.3.2 Open Community Space Network - interconnected open space corridors, pathways and parks

✓facilitates emergency operations

✓rivers act as transport corridors after an earthquake

✓open space infrastructure offers mobility to pedestrians and bikers, reduces congestion, improves environmental quality and promotes public health

✓walking and bicycling are legitimate transportation options during the post-disaster period

5.2.3.3. Multifunctional Urban Park as Part of the Open Community Space Network

✓ available open space to function as temporary command center and evacuation site

✓ functions as public assembly point for information dissemination and meeting point for affected residents

✓ ready site for medical and sanitary facilities

The presence of earthquake hazards in their territory should be used as an opportunity by local governments to plan and implement long-term interventions in land use planning and urban development. Risk-sensitive land use planning offers a unifying approach for seismically challenged towns and cities to reduce their risk to earthquake disasters. By combining risk analysis with the standard planning process, risk-sensitive land use planning is a systematic and logical method to achieve the objective of reducing seismic vulnerability and risk while producing long-lasting urban improvements towards healthier and sustainable urban settlements.

5.2.4 Areas for Further Research

In the field of hazard evaluation, more detailed geological studies should be done along the lines of probabilistic seismic hazards assessment. Since funds are meager, seismic hazard maps and ground shaking intensity maps should be produced for metropolitan areas and major cities around the country that have high exposure to earthquakes.

As for vulnerability assessment, actual post-disaster building damage data will help in pinpointing local building types that are more prone to earthquakes. This will be useful in earthquake engineering studies that are applicable to local conditions, which are sadly lacking. Actual damage data are also necessary to develop vulnerability curves for local building classes for more precise potential damage estimates.

An action research on how to make risk-sensitive land use planning truly participatory will be very challenging.

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Appendix 1

ADAPTED ROSSI FORREL INTENSITY SCALE

Intensity Scale	Description
I	Hardly perceptible shock - felt only by an experienced observer under favorable conditions.
II	Extremely feeble shock - felt by a small number of persons at rest.
III	Very feeble shock - felt by several persons at rest. Duration and direction may be perceptible. Sometimes dizziness or nausea experienced.
IV	Feeble shock - felt generally indoors, outdoors by a few. Hanging objects swing slightly. Creaking of frames of houses.
V	Shock of moderate intensity - felt generally by everyone. Hanging objects swing freely. Overturning of tall vases and unstable objects.
VI	Fairly strong shock - general awakening of those asleep. Some frightened persons leave their houses. Stopping of pendulum clocks. Oscillation of hanging lamps. Slight damage to very old or poorly built structures.
VII	Strong shock - overturning of movable objects. General alarm, all run outdoors. Damage slight in well-built houses, considerable in old or poorly built structures, old walls, etc. Some landslides from hills and steep banks. Cracks in road surfaces.
VIII	Very strong shock - people panicky. Trees shaken strongly. Changes in the flow of springs and wells. Sand and mud ejected from fissures in soft ground. Small landslides.
IX	Extremely strong shock - panic general. Partial or total destruction of some buildings. Fissures in ground. Landslides and

Appendix 2

RICHTER MAGNITUDE SCALE

Magnitude Scale	Description
1	Earthquake with M below 1 are only detectable when an ultra sensitive seismometer is operated under favorable conditions.
2	Most earthquakes with M below 3 are the "hardly perceptible shocks" and are not felt. They are only recorded by seismographs of nearby stations.
3	Earthquake with M 3 to 4 are the "very feeble shocks" and only felt near the epicenter.
4	Earthquakes with M 4 to 5 are the "feeble shocks" where damages are not usually reported.
5	Earthquakes with M 5 to 6 are the "earthquakes with moderate strength" and are felt over the wide areas; some of them cause small local damages near the epicenter.
6	Earthquake with M 6 to 7 are the "strong earthquakes" and are accompanied by local damages near the epicenters. First class seismological stations can observe them wherever they occur within the earth.
7	Earthquake with M 7 to 8 are the "major earthquakes" and can cause considerable damages near the epicenters. Shallow-seated or near-surface major earthquakes when they occur under the sea, may generate tsunamis. First class seismological stations can observe them wherever they occur within the earth.
8	Earthquake with M 8 to 9 are the "great earthquakes" occurring once or twice a year. When they occur in land areas, damages affect wide areas. When they occur under the sea, considerable tsunamis are produced. Many aftershocks occur in areas approximately 100 to 1,000 kilometers in diameter.
9	Earthquakes with M over 9 have never occurred since the data based on the seismographic observations became available.

Appendix 3

RADIUS Soil Type Distribution Map

Region (City) Name : Marikina City
Total Population Count : 389765
Total Building Count : 56089
Total Mesh : 77

Spacing of Mesh(km) : 0,62

Color	Value Range for mesh	Description
	0	Unknown
	1	Hard Rock
	2	Soft Rock
	3	Medium Soil
	4	Soft Soil

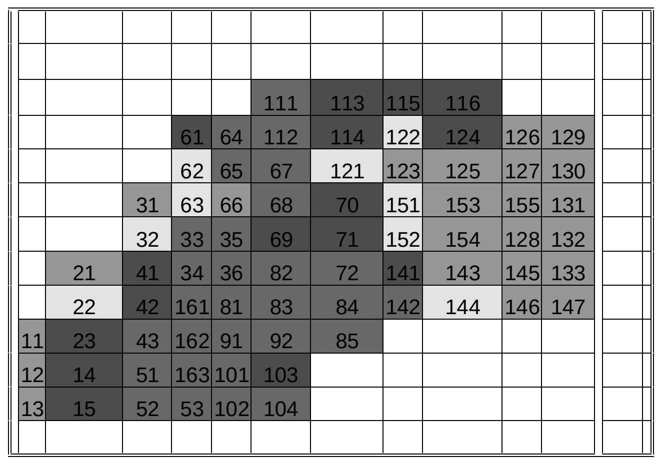
Return

##

Mesh Soil Type Summary

MeshID	AreaID	Area Name	Soil Type	Description	Amplication Factor
1	11	IVC	1	Hard Rock	0,6
2	12	IVC	1	Hard Rock	0,6
3	13	IVC	1	Hard Rock	0,6
4	21	Barangka	1	Hard Rock	0,6
5	22	Barangka	2	Soft Rock	0,7
6	23	Barangka	3	Medium Soil	1,0
7	14	IVC	3	Medium Soil	1,0
8	15	IVC	3	Medium Soil	1,0
9	31	Malanday	1	Hard Rock	0,6
10	32	Malanday	2	Soft Rock	0,7
11	41	Tanong	3	Medium Soil	1,0
12	42	Tanong	3	Medium Soil	1,0
13	43	Tanong	4	Soft Soil	1,3
14	51	Kalumpang	4	Soft Soil	1,3
15	52	Kalumpang	4	Soft Soil	1,3
16	61	Concepcion 1	3	Medium Soil	1

Soil Type Distribution Map (Colors show Value Range of mesh data and characters show AreaID)



17	62	Concepcion 1	2	Soft Rock	0,7
18	63	Concepcion 1	2	Soft Rock	0,7
19	33	Malanday	4	Soft Soil	1,3
20	34	Malanday	4	Soft Soil	1,3
21	161	J. Dela Pena	4	Soft Soil	1,3
22	162	J. Dela Pena	4	Soft Soil	1,3
23	163	J. Dela Pena	4	Soft Soil	1,3
24	53	Kalumpang	4	Soft Soil	1,3
25	64	Concepcion 1	4	Soft Soil	1,3
26	65	Concepcion 1	4	Soft Soil	1,3
27	66	Concepcion 1	1	Hard Rock	0,6
28	35	Malanday	4	Soft Soil	1,3
29	36	Malanday	4	Soft Soil	1,3
30	81	Sto.Nino	4	Soft Soil	1,3
31	91	Sta.Elena	4	Soft Soil	1,3
32	101	San Roque	4	Soft Soil	1,3
33	102	San Roque	4	Soft Soil	1,3
34	111	Nangka	4	Soft Soil	1,3
35	112	Nangka	4	Soft Soil	1,3
36	67	Concepcion 1	4	Soft Soil	1,3
37	68	Concepcion 1	4	Soft Soil	1,3
38	69	Concepcion 1	3	Medium Soil	1,0
39	82	Sto.Nino	4	Soft Soil	1,3
40	83	Sto.Nino	4	Soft Soil	1,3
41	92	Sta.Elena	4	Soft Soil	1,3
42	103	San Roque	3	Medium Soil	1,0
43	104	San Roque	4	Soft Soil	1,3
44	113	Nangka	3	Medium Soil	1,0
45	114	Nangka	3	Medium Soil	1,0
46	121	Parang	2	Soft Rock	0,7
47	70	Concepcion 1	3	Medium Soil	1,0
48	71	Concepcion 1	3	Medium Soil	1,0
49	72	Concepcion 1	4	Soft Soil	1,3
50	84	Sto.Nino	4	Soft Soil	1,3
51	85	Sto.Nino	4	Soft Soil	1,3
52	115	Nangka	3	Medium Soil	1,0
53	122	Parang	2	Soft Rock	0,7

54	123	Parang	1	Hard Rock	0,6
55	151	Marikina Heights	2	Soft Rock	0,7
56	152	Marikina Heights	2	Soft Rock	0,7
57	141	Concepcion 2	3	Medium Soil	1,0
58	142	Concepcion 2	4	Soft Soil	1,3
59	116	Nangka	3	Medium Soil	1,0
60	124	Parang	3	Medium Soil	1,0
61	125	Parang	1	Hard Rock	0,6
62	153	Marikina Heights	1	Hard Rock	0,6
63	154	Marikina Heights	1	Hard Rock	0,6
64	143	Concepcion 2	1	Hard Rock	0,6
65	144	Concepcion 2	2	Soft Rock	0,7
66	126	Parang	1	Hard Rock	0,6
67	127	Parang	1	Hard Rock	0,6
68	155	Marikina Heights	1	Hard Rock	0,6
69	128	Parang	1	Hard Rock	0,6
70	145	Concepcion 2	1	Hard Rock	0,6
71	146	Concepcion 2	1	Hard Rock	0,6
72	129	Parang	1	Hard Rock	0,6
73	130	Parang	1	Hard Rock	0,6
74	131	Parang	1	Hard Rock	0,6
75	132	Parang	1	Hard Rock	0,6
76	133	Parang	1	Hard Rock	0,6
77	147	Concepcion 2	1	Hard Rock	0,6

Appendix 4

MODIFIED MERCALLI INTENSITY SCALE (1956 version)

Intensity Scale	Description
I	Not felt. Marginal and long period effects of large earthquakes.
II	Felt by persons at rest, on upper floors, or favourably placed.
III	Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.
IV	Hanging objects swing. Vibration like a passing heavy trucks; or sensation of a jolt like a heavy ball striking the walls. Standing cars rock. Window, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV, wooden walls and frames creak.
V	Felt outdoors; direction estimated. Sleepers awakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.
VI	Felt by all. Many frightened and run outdoors.. persons walk unsteadily. Windows, dishes, glassware broken. Knick-knacks, books, etc. fall off shelves. Pictures fall off walls. Furniture moved or overturned. Weak plaster and masonry D cracked. Small bells ring (church and school). Trees, bushes shaken visibly, or heard to rustle.
VII	Difficult to stand. Noticed by drivers. Hanging object quiver. Furniture broken. Damage to masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices, also unbraced parapets and architectural ornaments. Some cracks in masonry C. waves on ponds, water turbid with mud. Small slides and caving-in along sand or gravel banks. Large bell ring. Concrete irrigation ditches damaged.
VIII	Steering of cars affected. Damage to masonry C; partial collapse. Some damage to masonry B.; none to masonry A. fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken off trees. Changes inflow or temperature of springs and wells. Cracks in wet ground and on steep slopes.
IX	General panic. Masonry D destroyed; masonry C heavily damaged, sometimes with complete collapse; masonry B seriously damaged. General damage to foundations. Frame structures, if not bolted, shifted off foundations. Frames racked. Conspicuous cracks in ground. In alluvial areas, sand and mud ejected, earthquake fountains, sand craters.

Intensity Scale	Description
X	Most masonry and frame structures destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serious damage to dams, dykes, embankments. Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.
XI	Rails bent greatly. Underground pipelines completely out of service.
XII	Damage nearly total. Large masses displaced. Lines of sight and level distorted. Objects thrown into the air.

The quality of masonry, brick or otherwise is described as follows:

Masonry A	Good workmanship, mortar and design; reinforced, specially laterally, and bound together by using steel, concrete etc.; designed to resist lateral forces.
Masonry B	Good workmanship and mortar; reinforced but not designed in detail to resist lateral forces.
Masonry C	Ordinary workmanship and mortar; no extreme weaknesses like failing to tie-in at corners, but neither reinforced nor designed against horizontal forces.
Masonry D	Weak materials, such as adobe; poor mortar; low standards of workmanship; weak horizontally.

Appendix 5. Other Intensity Scales

PHIVOLCS EARTHQUAKE INTENSITY SCALE (PEIS)

Intensity Scale	Description
I	Scarcely Perceptible - Perceptible to people under favorable circumstances. Delicately balanced objects are disturbed slightly. Still Water in containers oscillates slowly.
II	Slightly Felt - Felt by few individuals at rest indoors. Hanging objects swing slightly. Still Water in containers oscillates noticeably.
III	Weak - Felt by many people indoors especially in upper floors of buildings. Vibration is felt like one passing of a light truck. Dizziness and nausea are experienced by some people. Hanging objects swing moderately. Still water in containers oscillates moderately.
IV	Moderately Strong - Felt generally by people indoors and by some people outdoors. Light sleepers are awakened. Vibration is felt like a passing of heavy truck. Hanging objectsswing considerably. Dinner, plates, glasses, windows and doors rattle. Floors and walls of wood framed buildings creak. Standing motor cars may rock slightly. Liquids in containers are slightly disturbed. Water in containers oscillate strongly. Rumbling sound may sometimes be heard.
V	Strong - Generally felt by most people indoors and outdoors. Many sleeping people are awakened. Some are frightened, some run outdoors. Strong shaking and rocking felt throughout building. Hanging objects swing violently. Dining utensils clatter and clink; some are broken. Small, light and unstable objects may fall or overturn. Liquids spill from filled open containers. Standing vehicles rock noticeably. Shaking of leaves and twigs of trees are noticeable.
VI	Very Strong - Many people are frightened; many run outdoors. Some people lose their balance. motorists feel like driving in flat tires. Heavy objects or furniture move or may be shifted. Small church bells may ring. Wall plaster may crack. Very old or poorly built houses and man-made structures are slightly damaged though well-built structures are not affected. Limited rockfalls and rolling boulders occur in hilly to mountainous areas and escarpments. Trees are noticeably shaken.
VII	Destructive - Most people are frightened and run outdoors. People find it difficult to stand in upper floors. Heavy objects and furniture overturn or topple. Big church bells may ring. Old or poorly-built structures suffer considerably damage. Some well-built structures are slightly damaged. Some cracks may appear on dikes, fish ponds, road surface, or concrete hollow block walls. Limited liquefaction, lateral spreading and landslides are observed. Trees are shaken strongly. (Liquefaction is a process by which loose saturated sand lose strength during an earthquake and behave like liquid).

Intensity Scale	Description
IX	Devastating - People are forcibly thrown to ground. Many cry and shake with fear. Most buildings are totally damaged. bridges and elevated concrete structures are toppled or destroyed. Numerous utility posts, towers and monument are tilted, toppled or broken. Water sewer pipes are bent, twisted or broken. Landslides and liquefaction with lateral spreadings and sandboils are widespread. the ground is distorted into undulations. Trees are shaken very violently with some toppled or broken. Boulders are commonly thrown out. River water splashes violently on slops over dikes and banks.
X	Completely Devastating - Practically all man-made structures are destroyed. Massive landslides and liquefaction, large scale subsidence and uplifting of land forms and many ground fissures are observed. Changes in river courses and destructive seiches in large lakes occur. Many trees are toppled, broken and uprooted.

ROSSI-FORREL INTENSITY SCALE (ORIGINAL)

Intensity Scale	Description
I	Microseismic shock. Recorded by a single seismograph of by seismographs of the same model, but not by several seismographs of different kinds: the shock felt by an experienced observer.
II	Extremely feeble shock. Recorded by several seismographs of different kinds; felt by a small number of persons at rest.
III	Very feeble shock. Felt by several persons at rest; strong enough for the duration to be appreciable.
IV	Feeble shock. Felt by person in motion; disturbance of movable objects, doors windows, cracking of ceilings.
V	Shock of moderate intensity. Felt generally by everyone; disturbance of furniture, beds, etc., ringing of some bells.
VI	Fairly strong shock. General awakening of those asleep; general ringing of bells; oscillation of chandeliers; stopping of clocks; visible agitation of trees and shrubs; some startled persons leaving their dwellings.
VII	Strong shock. Overthrow of movable objects; fall of plaster; ringing of church bells; general panic, without damage to buildings.
VIII	Very strong shock. Fall of chimney; crack in the walls of buildings.
IX	Extremely strong shock. Partial of total destruction of some buildings.
X	Shock of extreme intensity. Great disaster; ruins; disturbance of the strata, fissures in the ground, rock falls from mountains.

Appendix 6. **RADIUS MMI Distribution Results**

Region (City) Name : Marikina City	Earthquake Name : Marikina Earthquake
Total Population Counts : 389765	Occurrence Date :
Total Building Count : 56089	Occurrence Time : 1005
Total Mesh : 77	EQ Magnitude : 7.5
Spacing of Mesh(km) : 0,62	EQ Direction relative from Ref.Mesh : South West
Reference Mesh : 12	EQ Distance(km) to Ref.Mesh : 5
Used Attenuation Equation : Fukushima & Tanaka - 1990	

Color ID	Automatic Range		Manual Range	
	From	To	From	To
a	7,9	8,2	0,0	0,0
b	8,2	8,5	7,8	8,0
c	8,5	8,8	8,0	9,0
d	8,8	9,1	9,0	9,2

Return | Use Automatic | Use Manual

13 15 77

MMI Summary

Average MMI is 8,57

Sr.No	AreaID	Area Name	Average Distance	Average PGA (g)	Average MMI
1	11	IVC	9,4	0,2	7,9
2	12	IVC	9,4	0,2	7,9
3	13	IVC	9,4	0,2	7,9
4	14	IVC	9,4	0,4	8,7
5	15	IVC	9,4	0,4	8,7
6	21	Barangka	9,4	0,2	7,9
7	22	Barangka	9,4	0,3	8,2
8	23	Barangka	9,4	0,4	8,7
9	31	Malanday	9,4	0,2	7,9
10	32	Malanday	9,4	0,3	8,2
11	33	Malanday	9,4	0,6	9,1
12	34	Malanday	9,4	0,6	9,1
13	35	Malanday	9,4	0,6	9,1
14	36	Malanday	9,4	0,6	9,1
15	41	Tanong	9,4	0,4	8,7
16	42	Tanong	9,4	0,4	8,7

Map Using Manual Range (Cell characters show AreaID)

						111	113	115	116					
				61	64	112	114	122	124	126	129			
				62	65	67	121	123	125	127	130			
			31	63	66	68	70	151	153	155	131			
			32	33	35	69	71	152	154	128	132			
		21	41	34	36	82	72	141	143	145	133			
		22	42	161	81	83	84	142	144	146	147			
	11	23	43	162	91	92	85							
	12	14	51	163	101	103								
	13	15	52	53	102	104								

17	43	Tanong	9,4	0,6	9,1
18	51	Kalumpang	9,4	0,6	9,1
19	52	Kalumpang	9,4	0,6	9,1
20	53	Kalumpang	9,4	0,6	9,1
21	61	Concepcion 1	9,4	0,4	8,7
22	62	Concepcion 1	9,4	0,3	8,2
23	63	Concepcion 1	9,4	0,3	8,2
24	64	Concepcion 1	9,4	0,6	9,1
25	65	Concepcion 1	9,4	0,6	9,1
26	66	Concepcion 1	9,4	0,2	7,9
27	67	Concepcion 1	9,4	0,6	9,1
28	68	Concepcion 1	9,4	0,6	9,1
29	69	Concepcion 1	9,4	0,4	8,7
30	70	Concepcion 1	9,4	0,4	8,7
31	71	Concepcion 1	9,4	0,4	8,7
32	72	Concepcion 1	9,4	0,6	9,1
33	81	Sto.Nino	9,4	0,6	9,1
34	82	Sto.Nino	9,4	0,6	9,1
35	83	Sto.Nino	9,4	0,6	9,1
36	84	Sto.Nino	9,4	0,6	9,1
37	85	Sto.Nino	9,4	0,6	9,1
38	91	Sta.Elena	9,4	0,6	9,1
39	92	Sta.Elena	9,4	0,6	9,1
40	101	San Roque	9,4	0,6	9,1
41	102	San Roque	9,4	0,6	9,1
42	103	San Roque	9,4	0,4	8,7
43	104	San Roque	9,4	0,6	9,1
44	111	Nangka	9,4	0,6	9,1
45	112	Nangka	9,4	0,6	9,1
46	113	Nangka	9,4	0,4	8,7
47	114	Nangka	9,4	0,4	8,7
48	115	Nangka	9,4	0,4	8,7
49	116	Nangka	9,4	0,4	8,7
50	121	Parang	9,4	0,3	8,2

51	122	Parang	9,4	0,3	8,2
52	123	Parang	9,4	0,2	7,9
53	124	Parang	9,4	0,4	8,7
54	125	Parang	9,4	0,2	7,9
55	126	Parang	9,4	0,2	7,9
56	127	Parang	9,4	0,2	7,9
57	128	Parang	9,4	0,2	7,9
58	129	Parang	9,4	0,2	7,9
59	130	Parang	9,4	0,2	7,9
60	131	Parang	9,4	0,2	7,9
61	132	Parang	9,4	0,2	7,9
62	133	Parang	9,4	0,2	7,9
63	141	Concepcion 2	9,4	0,4	8,7
64	142	Concepcion 2	9,4	0,6	9,1
65	143	Concepcion 2	9,4	0,2	7,9
66	144	Concepcion 2	9,4	0,3	8,2
67	145	Concepcion 2	9,4	0,2	7,9
68	146	Concepcion 2	9,4	0,2	7,9
69	147	Concepcion 2	9,4	0,2	7,9
70	151	Marikina Heights	9,4	0,3	8,2
71	152	Marikina Heights	9,4	0,3	8,2
72	153	Marikina Heights	9,4	0,2	7,9
73	154	Marikina Heights	9,4	0,2	7,9
74	155	Marikina Heights	9,4	0,2	7,9
75	161	J. Dela Pena	9,4	0,6	9,1
76	162	J. Dela Pena	9,4	0,6	9,1
77	163	J. Dela Pena	9,4	0,6	9,1
Average Information			9,4	0,4	8,6

Appendix 7

Constant Data Used for Analysis in the RADIUS Program

Attenuation Equations		
AttnID	**Source**	**Attenuation Equation**
1	Joyner & Boore - 1981	PGA=10^(0.249*M-Log(D)-0.00255*D-1.02, D=(E^2+7.3^2)^0.5
2	Campbell - 1981	PGA=0.0185*EXP(1.28*M)*D^(-1.75), D=E+0.147*EXP(0.732*M)
3	Fukushima & Tanaka - 1990	PGA=(10^(0.41*M - LOG10 (R + 0.032 * 10^(0.41*M)) - 0.0034*R + 1.30))/980
	Note:	E-----Epicentral distance R----Hypocentral distance

The MMI will be calculated by the formula:

log(PGA*980)=0.30*MMI+0.014

or MMI=1/0.3*(log10(PGA*980)-0.014)

by Trifunac & Brady (1975). PGA unit is G.

Appendix 8

RAPID BUILDING SURVEY QUESTIONNAIRE

I. Building/Structure Identification and Description

1. Type of Structure

___ Single House
___ Duplex
___ Rowhouse/Townhouse
___ Condominium/High Rise Building
___ Factory
___ Warehouse/Storage
___ Others ____________________________

2. Predominant Use of Buildings

___ Residential
___ Commercial
___ Industrial/Manufacturing
___ Transport/Warehouse/Utilities/Communications
___ Other uses/under construction
____
___ Residential/Commercial
___ Residential/Industrial
___ Residential/Transport
___ Residential/Other uses
___ Vacant

3. Facility Name ____

4. Address ____ Barangay _________________

5. Name of Owner/Household Head ____

6. Nature of Ownership

___ personal private property
___ rented
___ public property of ____________________________
___ others _____________________________________

7. Month and Year Built _________________________

8. ____ Engineered Structure
____ Non-Engineered Structure (self-built)

9. Roofing Materials

___ Galvanized Iron/Aluminum
___ Tile/Concrete/Clay Tile
___ Part galvanized iron/part concrete
___ Makeshift/salvaged/improvised
___ Cogon/nipa/anahaw
___ Wood
___ Others _____________________________

10. Walling Materials

___ Reinforced concrete
___ Concrete hollow blocks/Brick/Stone
___ Wood/Timber
___ Part concrete/brick/stone
___ Galvanized iron/aluminum
___ Bamboo/sawali/cogon/nipa
___ Makeshift/salvaged/improvised
___ No walls
___ Others _____________________________

11. Number of Floors

___ 1-2
___ 3-4
___ 5-8
___ 9 or more

12. Height of the structure (m) ________________

13. Floor Area (ground floor) _________________ second floor ________________
Total floor area (multi-storey) ______________

14. Building Irregularity

Design (H, L and U-shaped, roof appendages such as tanks, parapets, penthouses, presence of soft or weak storeys):____

____

Height/Elevation: ____

____

Other observations____

15. Interaction Between Buildings May Occur Due To:

___ Separation among buildings is insufficient
___ Differences in height
___ Remotely possible

II. General Demographic Description of Occupants/Household

1. Number of occupants during daytime __________ nightime ___________

2. Sex

___ Male
___ Female

3. Age

___ 1 – 15 years old
___ 16 – 40 years old
___ 40 – 64 year old
___ 65 and over

4. Monthly Household Income

___ Less than 10,000 pesos
___ 10,001-20,000 pesos
___ 20,001-30,000 pesos
___ 30,001-50,000 pesos
___ over 50,000 pesos

III. General Economic Description of Commercial/Industrial Establishments

1. Name of Principal products ____

Services ____

____

2. Employment

Total working force _________
Male _________
Female _________

3. Number of working days last year __________

4. Number of shifts __________

4. Capacity and Production

Annual Production in quantity _____________________
Annual Production in Value (Php) _____________________

5. Building Content

Item	Approximate Value	Item	Approximate Value

Filled up by:__________________

Date: ______________________

Appendix 9. **RADIUS Building Inventory Partitioned to Meshes**

City is Marikina City **Total MeshID is 77** **Total Building Count is 56089**

Mesh ID	Mesh Weight	Area ID	Area Name	RES1	RES2	RES3	RES4	EDU1	EDU2	MED1	MED2	COM	IND	Total Bldg Count
1	1	11	IVC	0	0	0	313	0	16	0	0	0	0	330
2	2	12	IVC	79	231	0	350	0	0	0	0	0	0	660
3	1	13	IVC	0	0	0	330	0	0	0	0	0	0	330
4	1	21	Barangka	0	0	0	330	0	0	0	0	0	0	330
5	2	22	Barangka	0	0	0	653	7	0	0	0	0	0	660
6	2	23	Barangka	34	143	0	476	0	0	0	0	7	0	660
7	2	14	IVC	79	231	0	271	0	66	0	0	0	13	660
8	3	15	IVC	140	550	0	300	0	0	0	0	0	0	990
9	1	31	Malanday	0	0	0	330	0	0	0	0	0	0	330
10	1	32	Malanday	0	0	0	330	0	0	0	0	0	0	330
11	1	41	Tanong	0	0	0	330	0	0	0	0	0	0	330
12	1	42	Tanong	17	71	0	229	0	0	0	10	0	3	330
13	3	43	Tanong	50	210	0	680	0	0	0	0	0	50	990
14	2	51	Kalumpang	75	224	0	265	0	61	0	0	0	34	660
15	2	52	Kalumpang	79	224	0	264	0	66	0	0	0	26	660
16	0	61	Concepcion 1	0	0	0	0	0	0	0	0	0	0	0
17	1	62	Concepcion 1	0	0	0	330	0	0	0	0	0	0	330
18	2	63	Concepcion 1	93	367	0	200	0	0	0	0	0	0	660
19	4	33	Malanday	189	727	0	404	0	0	0	0	0	0	1320
20	3	34	Malanday	140	540	0	300	0	0	0	0	0	10	990
21	3	161	J. Dela Pena	51	222	0	717	0	0	0	0	0	0	990
22	2	162	J. Dela Pena	33	133	0	440	0	20	0	0	0	33	660
23	2	163	J. Dela Pena	33	139	0	462	0	0	0	0	0	26	660
24	2	53	Kalumpang	34	143	0	476	7	0	0	0	0	0	660

25	0	64	Concepcion 1	0	0	0	0	0	0	0	0	0	0	0
26	2	65	Concepcion 1	93	367	0	200	0	0	0	0	0	0	660
27	4	66	Concepcion 1	187	733	0	400	0	0	0	0	0	0	1320
28	4	35	Malanday	67	269	0	889	27	0	0	0	0	67	1320
29	4	36	Malanday	67	267	0	880	40	0	0	0	0	67	1320
30	4	81	Sto.Nino	69	289	0	962	0	0	0	0	0	0	1320
31	3	91	Sta.Elena	50	200	0	660	20	10	0	0	0	50	990
32	4	101	San Roque	67	280	0	920	0	40	0	0	0	13	1320
33	3	102	San Roque	50	210	0	680	0	0	0	0	0	50	990
34	2	111	Nangka	93	260	0	307	0	0	0	0	0	0	660
35	4	112	Nangka	160	467	0	560	0	133	0	0	0	0	1320
36	4	67	Concepcion 1	187	720	0	400	0	0	0	0	0	13	1320
37	4	68	Concepcion 1	187	733	0	400	0	0	0	0	0	0	1320
38	2	69	Concepcion 1	33	133	0	427	27	7	0	0	0	33	660
39	2	82	Sto.Nino	88	256	0	303	0	0	0	0	0	13	660
40	2	83	Sto.Nino	54	0	0	606	0	0	0	0	0	0	660
41	1	92	Sta.Elena	0	0	0	330	0	0	0	0	0	0	330
42	1	103	San Roque	0	0	0	330	0	0	0	0	0	0	330
43	2	104	San Roque	0	0	0	660	0	0	0	0	0	0	660
44	4	113	Nangka	0	0	0	1320	0	0	0	0	0	0	1320
45	3	114	Nangka	140	390	0	460	0	0	0	0	0	0	990
46	4	121	Parang	175	525	0	619	0	0	0	0	0	0	1320
47	2	70	Concepcion 1	80	233	0	273	0	67	0	0	0	7	660
48	3	71	Concepcion 1	51	212	0	717	10	0	0	0	0	0	990
49	3	72	Concepcion 1	140	390	0	460	0	0	0	0	0	0	990
50	1	84	Sto.Nino	0	0	0	330	0	0	0	0	0	0	330
51	0	85	Sto.Nino	0	0	0	0	0	0	0	0	0	0	0
52	2	115	Nangka	88	259	0	306	0	0	0	0	0	7	660
53	3	122	Parang	130	370	0	430	40	0	0	0	0	20	990
54	4	123	Parang	177	531	0	612	0	0	0	0	0	0	1320

55	3	151	Marikina Heights	140	390	0	460	0	0	0	0	0	0	990
56	2	152	Marikina Heights	88	259	0	306	7	0	0	0	0	0	660
57	3	141	Concepcion 2	140	390	0	460	0	0	0	0	0	0	990
58	2	142	Concepcion 2	0	0	0	660	0	0	0	0	0	0	660
59	1	116	Nangka	0	0	0	330	0	0	0	0	0	0	330
60	1	124	Parang	37	147	0	80	33	0	0	0	0	33	330
61	2	125	Parang	87	347	0	187	0	0	0	0	0	40	660
62	2	153	Marikina Heights	73	67	0	493	20	0	0	0	0	7	660
63	3	154	Marikina Heights	120	340	0	410	0	100	0	0	0	20	990
64	2	143	Concepcion 2	88	249	0	296	7	20	0	0	0	0	660
65	3	144	Concepcion 2	140	390	0	460	0	0	0	0	0	0	990
66	2	126	Parang	80	313	0	173	0	0	0	0	0	93	660
67	3	127	Parang	121	485	0	263	0	0	0	0	0	121	990
68	2	155	Marikina Heights	81	323	0	175	0	0	0	0	0	81	660
69	2	128	Parang	67	267	0	147	87	7	0	0	0	87	660
70	2	145	Concepcion 2	0	0	0	660	0	0	0	0	0	0	660
71	2	146	Concepcion 2	0	0	0	660	0	0	0	0	0	0	660
72	1	129	Parang	40	157	0	87	0	0	0	0	0	47	330
73	2	130	Parang	88	343	0	189	0	0	0	0	0	40	660
74	2	131	Parang	93	367	0	200	0	0	0	0	0	0	660
75	1	132	Parang	0	0	0	330	0	0	0	0	0	0	330
76	1	133	Parang	47	183	0	100	0	0	0	0	0	0	330
77	1	147	Concepcion 2	0	0	0	330	0	0	0	0	0	0	330
	Summary Information			Res1	Res2	Res3	Res4	EDU1	EDU2	MED1	MED2	COM	IND	Total
				5086	17262	0	31673	331	613	0	10	7	1107	56089

Appendix 10. **RADIUS Number of Buildings Damaged by Earthquake**

Earthquake Name is Marikina Earthquake **Total Bldg is 56089** **Total Damaged Bldg is 13755**

Mesh ID	Area ID	Area Name	MMI	RES1	RES2	RES3	RES4	EDU1	EDU2	MED1	MED2	COM	IND	Total
1	11	IVC	7,9	0	0	0	29	0	4	0	0	0	0	32
2	12	IVC	7,9	26	52	0	32	0	0	0	0	0	0	110
3	13	IVC	7,9	0	0	0	30	0	0	0	0	0	0	30
4	21	Barangka	7,9	0	0	0	30	0	0	0	0	0	0	30
5	22	Barangka	8,2	0	0	0	77	1	0	0	0	0	0	78
6	23	Barangka	8,7	18	52	0	74	0	0	0	0	2	0	146
7	14	IVC	8,7	43	84	0	42	0	26	0	0	0	4	199
8	15	IVC	8,7	75	199	0	47	0	0	0	0	0	0	321
9	31	Malanday	7,9	0	0	0	30	0	0	0	0	0	0	30
10	32	Malanday	8,2	0	0	0	39	0	0	0	0	0	0	39
11	41	Tanong	8,7	0	0	0	52	0	0	0	0	0	0	52
12	42	Tanong	8,7	9	26	0	36	0	0	0	4	0	1	76
13	43	Tanong	9,1	31	89	0	125	0	0	0	0	0	18	264
14	51	Kalumpang	9,1	47	95	0	49	0	29	0	0	0	12	232
15	52	Kalumpang	9,1	50	95	0	49	0	31	0	0	0	9	234
16	61	Concepcion 1	8,7	0	0	0	0	0	0	0	0	0	0	0
17	62	Concepcion 1	8,2	0	0	0	39	0	0	0	0	0	0	39
18	63	Concepcion 1	8,2	38	104	0	23	0	0	0	0	0	0	166
19	33	Malanday	9,1	118	308	0	75	0	0	0	0	0	0	501
20	34	Malanday	9,1	88	229	0	55	0	0	0	0	0	4	375
21	161	J. Dela Pena	9,1	32	94	0	132	0	0	0	0	0	0	258
22	162	J. Dela Pena	9,1	21	56	0	81	0	9	0	0	0	12	180
23	163	J. Dela Pena	9,1	21	59	0	85	0	0	0	0	0	9	174
24	53	Kalumpang	9,1	21	60	0	88	2	0	0	0	0	0	172
25	64	Concepcion 1	9,1	0	0	0	0	0	0	0	0	0	0	0

26	65	Concepcion 1	9,1	59	155	0	37	0	0	0	0	0	0	251
27	66	Concepcion 1	7,9	61	166	0	36	0	0	0	0	0	0	263
28	35	Malanday	9,1	42	114	0	164	10	0	0	0	0	24	354
29	36	Malanday	9,1	42	113	0	162	15	0	0	0	0	24	356
30	81	Sto.Nino	9,1	43	122	0	178	0	0	0	0	0	0	343
31	91	Sta.Elena	9,1	31	85	0	122	7	5	0	0	0	18	268
32	101	San Roque	9,1	42	119	0	170	0	19	0	0	0	5	354
33	102	San Roque	9,1	31	89	0	125	0	0	0	0	0	18	264
34	111	Nangka	9,1	59	110	0	57	0	0	0	0	0	0	225
35	112	Nangka	9,1	100	198	0	103	0	63	0	0	0	0	464
36	67	Concepcion 1	9,1	117	305	0	74	0	0	0	0	0	5	501
37	68	Concepcion 1	9,1	117	310	0	74	0	0	0	0	0	0	501
38	69	Concepcion 1	8,7	18	48	0	67	8	3	0	0	0	11	154
39	82	Sto.Nino	9,1	55	108	0	56	0	0	0	0	0	5	224
40	83	Sto.Nino	9,1	34	0	0	112	0	0	0	0	0	0	146
41	92	Sta.Elena	9,1	0	0	0	61	0	0	0	0	0	0	61
42	103	San Roque	8,7	0	0	0	52	0	0	0	0	0	0	52
43	104	San Roque	9,1	0	0	0	122	0	0	0	0	0	0	122
44	113	Nangka	8,7	0	0	0	206	0	0	0	0	0	0	206
45	114	Nangka	8,7	75	141	0	72	0	0	0	0	0	0	288
46	121	Parang	8,2	71	150	0	73	0	0	0	0	0	0	294
47	70	Concepcion 1	8,7	43	84	0	43	0	27	0	0	0	2	199
48	71	Concepcion 1	8,7	27	77	0	112	3	0	0	0	0	0	219
49	72	Concepcion 1	9,1	88	165	0	85	0	0	0	0	0	0	338
50	84	Sto.Nino	9,1	0	0	0	61	0	0	0	0	0	0	61
51	85	Sto.Nino	9,1	0	0	0	0	0	0	0	0	0	0	0
52	115	Nangka	8,7	47	94	0	48	0	0	0	0	0	2	191
53	122	Parang	8,2	53	105	0	50	8	0	0	0	0	5	222
54	123	Parang	7,9	58	120	0	56	0	0	0	0	0	0	234
55	151	Marikina Heights	8,2	57	111	0	54	0	0	0	0	0	0	222

56	152	Marikina Heights	8,2	36	74	0	36	1	0	0	0	0	0	147
57	141	Concepcion 2	8,7	75	141	0	72	0	0	0	0	0	0	288
58	142	Concepcion 2	9,1	0	0	0	122	0	0	0	0	0	0	122
59	116	Nangka	8,7	0	0	0	52	0	0	0	0	0	0	52
60	124	Parang	8,7	20	53	0	12	10	0	0	0	0	11	106
61	125	Parang	7,9	28	79	0	17	0	0	0	0	0	10	134
62	153	Marikina Heights	7,9	24	15	0	45	3	0	0	0	0	2	88
63	154	Marikina Heights	7,9	39	77	0	37	0	23	0	0	0	5	182
64	143	Concepcion 2	7,9	29	56	0	27	1	5	0	0	0	0	118
65	144	Concepcion 2	8,2	57	111	0	54	0	0	0	0	0	0	222
66	126	Parang	7,9	26	71	0	16	0	0	0	0	0	23	136
67	127	Parang	7,9	40	110	0	24	0	0	0	0	0	30	203
68	155	Marikina Heights	7,9	26	73	0	16	0	0	0	0	0	20	135
69	128	Parang	7,9	22	60	0	13	12	2	0	0	0	21	130
70	145	Concepcion 2	7,9	0	0	0	60	0	0	0	0	0	0	60
71	146	Concepcion 2	7,9	0	0	0	60	0	0	0	0	0	0	60
72	129	Parang	7,9	13	35	0	8	0	0	0	0	0	11	68
73	130	Parang	7,9	29	78	0	17	0	0	0	0	0	10	133
74	131	Parang	7,9	30	83	0	18	0	0	0	0	0	0	132
75	132	Parang	7,9	0	0	0	30	0	0	0	0	0	0	30
76	133	Parang	7,9	15	42	0	9	0	0	0	0	0	0	66
77	147	Concepcion 2	7,9	0	0	0	30	0	0	0	0	0	0	30
Summary of Dmg Bldg			MMI(Ave)	Res1	Res2	Res3	Res4	EDU1	EDU2	MED1	MED2	COM	IND	Bldg
			8,6	2518	5850	0	4725	82	245	0	4	2	330	13756

Appendix 11. **RADIUS Damaged Building Distribution**

Region (City) Name : Marikina City	Earthquake Name : Marikina Earthquake
Total Population Counts : 389765	Occurrence Date :
Total Building Count : 56089	Occurrence Time : 1005
Total Mesh : 77	EQ Magnitude : 7.5
Spacing of Mesh(km) : 0,62	EQ Direction relative from Ref.Mesh : South West
Reference Mesh : 12	EQ Distance(km) to Ref.Mesh : 5
Used Attenuation Equation : Fukushima & Tanaka - 1990	

Color ID	Automatic Range		Manual Range	
	From	To	From	To
a	0	125	0	0
b	125	251	1	167
c	251	376	167	334
d	376	501	334	502

Return | Use Automatic | Use Manual

13 15 77

Building Damage Summary

The total building count are 56089 and 24% damaged

Sr.No	AreaID	Area Name	Bldg Counts	Damaged Counts	MDR (%)
1	11	IVC	330	32	9,8
2	12	IVC	660	110	16,7
3	13	IVC	330	30	9,1
4	14	IVC	660	199	30,2
5	15	IVC	990	321	32,4
6	21	Barangka	330	30	9,1
7	22	Barangka	660	78	11,8
8	23	Barangka	660	146	22,2
9	31	Malanday	330	30	9,1
10	32	Malanday	330	39	11,7
11	33	Malanday	1320	501	38,0
12	34	Malanday	990	375	37,9
13	35	Malanday	1320	354	26,9
14	36	Malanday	1320	356	27,0
15	41	Tanong	330	52	15,6
16	42	Tanong	330	76	22,9
17	43	Tanong	990	264	26,6
18	51	Kalumpang	660	232	35,2

Map Using Manual Range (Cell characters show AreaID)

					111	113	115	116					
			61	64	112	114	122	124	126	129			
			62	65	67	121	123	125	127	130			
		31	63	66	68	70	151	153	155	131			
		32	33	35	69	71	152	154	128	132			
	21	41	34	36	82	72	141	143	145	133			
	22	42	161	81	83	84	142	144	146	147			
11	23	43	162	91	92	85							
12	14	51	163	101	103								
13	15	52	53	102	104								

19	52	Kalumpang	660	234	35,5
20	53	Kalumpang	660	172	26,1
21	61	Concepcion 1	0	0	26,1
22	62	Concepcion 1	330	39	11,7
23	63	Concepcion 1	660	166	25,1
24	64	Concepcion 1	0	0	25,1
25	65	Concepcion 1	660	251	38,0
26	66	Concepcion 1	1320	263	20,0
27	67	Concepcion 1	1320	501	37,9
28	68	Concepcion 1	1320	501	38,0
29	69	Concepcion 1	660	154	23,4
30	70	Concepcion 1	660	199	30,1
31	71	Concepcion 1	990	219	22,1
32	72	Concepcion 1	990	338	34,1
33	81	Sto.Nino	1320	343	26,0
34	82	Sto.Nino	660	224	34,0
35	83	Sto.Nino	660	146	22,1
36	84	Sto.Nino	330	61	18,5
37	85	Sto.Nino	0	0	18,5
38	91	Sta.Elena	990	268	27,1
39	92	Sta.Elena	330	61	18,5
40	101	San Roque	1320	354	26,8
41	102	San Roque	990	264	26,6
42	103	San Roque	330	52	15,6
43	104	San Roque	660	122	18,5
44	111	Nangka	660	225	34,1
45	112	Nangka	1320	464	35,2
46	113	Nangka	1320	206	15,6
47	114	Nangka	990	288	29,1
48	115	Nangka	660	191	29,0
49	116	Nangka	330	52	15,6
50	121	Parang	1320	294	22,3
51	122	Parang	990	222	22,4
52	123	Parang	1320	234	17,7
53	124	Parang	330	106	32,2

54	125	Parang	660	134	20,2
55	126	Parang	660	136	20,6
56	127	Parang	990	203	20,5
57	128	Parang	660	130	19,7
58	129	Parang	330	68	20,6
59	130	Parang	660	133	20,2
60	131	Parang	660	132	20,0
61	132	Parang	330	30	9,1
62	133	Parang	330	66	20,0
63	141	Concepcion 2	990	288	29,1
64	142	Concepcion 2	660	122	18,5
65	143	Concepcion 2	660	118	17,8
66	144	Concepcion 2	990	222	22,4
67	145	Concepcion 2	660	60	9,1
68	146	Concepcion 2	660	60	9,1
69	147	Concepcion 2	330	30	9,1
70	151	Marikina Heights	990	222	22,4
71	152	Marikina Heights	660	147	22,3
72	153	Marikina Heights	660	88	13,4
73	154	Marikina Heights	990	182	18,4
74	155	Marikina Heights	660	135	20,5
75	161	J. Dela Pena	990	258	26,1
76	162	J. Dela Pena	660	180	27,3
77	163	J. Dela Pena	660	174	26,4
Summary Information			56089	13756	24,5

Appendix 12. **RADIUS Casualties (Deaths) Distribution**

Region (City) Name : Marikina City	Earthquake Name : Marikina Earthquake
Total Population Counts : 389765	Occurrence Date :
Total Building Count : 56089	Occurrence Time : 1005
Total Mesh : 77	EQ Magnitude : 7.5
Spacing of Mesh(km) : 0,62	EQ Direction relative from Ref.Mesh : South West
Reference Mesh : 12	EQ Distance(km) to Ref.Mesh : 5
Used Attenuation Equation : Fukushima & Tanaka - 1990	

Color ID	Automatic Range		Manual Range	
	From	To	From	To
a	0	21	0	0
b	21	43	1	28
c	43	64	28	56
d	64	85	56	86

Return

Use Automatic

Use Manual

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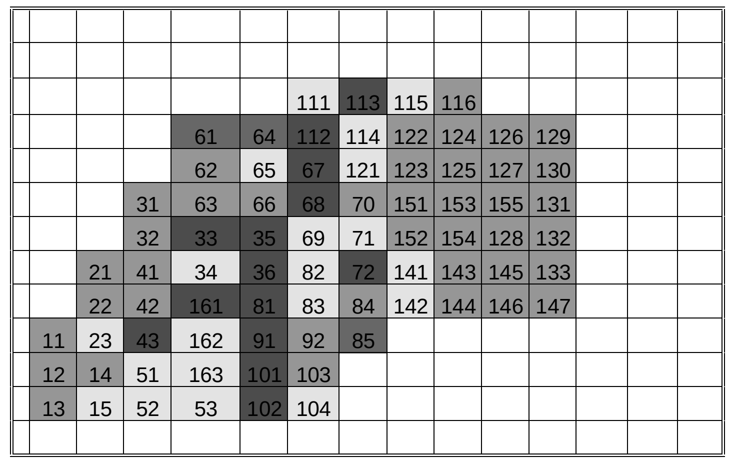
Population & Casualty Summary

The total population counts are 389765 and 0% death

AreaID	Area Name	Day Pop Counts	Night Pop Counts	Death	Injury
11	IVC	2272	3602	5	95
12	IVC	2185	4371	9	133
13	IVC	1894	3787	5	99
14	IVC	3685	3480	26	229
15	IVC	2118	4235	40	313
21	Barangka	1894	3787	5	99
22	Barangka	3826	7500	18	277
23	Barangka	2866	5671	31	330
31	Malanday	1894	3787	5	99
32	Malanday	1894	3787	9	140
33	Malanday	2844	5689	74	516
34	Malanday	2158	4226	55	384
35	Malanday	5913	10611	80	762
36	Malanday	6006	10507	79	755
41	Tanong	1894	3787	17	206
42	Tanong	1519	2776	15	166
43	Tanong	4281	8114	61	582
51	Kalumpang	3608	3411	34	276

Map Using Manual Range (Cell characters show AreaID)



52	Kalumpang	3704	3400	35	277
53	Kalumpang	2913	5671	42	406
61	Concepcion 1	0	0	0	0
62	Concepcion 1	1894	3787	9	140
63	Concepcion 1	1412	2823	14	142
64	Concepcion 1	0	0	0	0
65	Concepcion 1	1412	2823	37	257
66	Concepcion 1	2823	5647	17	202
67	Concepcion 1	2877	5635	73	512
68	Concepcion 1	2823	5647	73	514
69	Concepcion 1	3194	5103	28	299
70	Concepcion 1	3692	3514	26	232
71	Concepcion 1	4383	8536	46	496
72	Concepcion 1	2944	5888	60	476
81	Sto.Nino	5729	11457	85	820
82	Sto.Nino	1998	3876	39	313
83	Sto.Nino	3509	7018	48	483
84	Sto.Nino	1894	3787	23	254
85	Sto.Nino	0	0	0	0
91	Sta.Elena	4677	7880	59	566
92	Sta.Elena	1894	3787	23	254
101	San Roque	6687	10969	82	787
102	San Roque	4281	8114	61	582
103	San Roque	1894	3787	17	206
104	San Roque	3787	7575	46	507
111	Nangka	1963	3925	40	318
112	Nangka	7399	7177	72	580
113	Nangka	7575	15150	68	826
114	Nangka	2944	5888	44	387
115	Nangka	1987	3914	29	256
116	Nangka	1894	3787	17	206
121	Parang	3958	7915	31	351
122	Parang	3305	5523	22	247
123	Parang	3920	7840	18	248
124	Parang	1100	1144	11	85

125	Parang	1504	2649	8	95
126	Parang	1649	2462	7	89
127	Parang	2412	3738	11	135
128	Parang	2617	2107	6	76
129	Parang	824	1231	4	44
130	Parang	1515	2668	8	96
131	Parang	1412	2823	8	101
132	Parang	1894	3787	5	99
133	Parang	706	1412	4	50
141	Concepcion 2	2944	5888	44	387
142	Concepcion 2	3787	7575	46	507
143	Concepcion 2	2551	3794	9	120
144	Concepcion 2	2944	5888	24	262
145	Concepcion 2	3787	7575	10	199
146	Concepcion 2	3787	7575	10	199
147	Concepcion 2	1894	3787	5	99
151	Marikina Heights	2944	5888	24	262
152	Marikina Heights	2034	3914	16	174
153	Marikina Heights	3172	5829	10	163
154	Marikina Heights	5578	5261	12	167
155	Marikina Heights	1608	2492	7	90
161	J. Dela Pena	4272	8545	64	612
162	J. Dela Pena	3347	5253	39	377
163	J. Dela Pena	2871	5505	41	394
Summary Information		221267	389765	2286	22488

Appendix 13. **RADIUS Casualties (Injury) Distribution**

Color ID	Automatic Range		Manual Range	
	From	To	From	To
a	0	206	0	0
b	206	413	1	275
c	413	619	275	550
d	619	826	550	826

Return | Use Automatic | Use Manual

13 15 77

Region (City) Name : Marikina City	Earthquake Name : Marikina Earthquake
Total Population Counts : 389765	Occurrence Date :
Total Building Count : 56089	Occurrence Time : 1005
Total Mesh : 77	EQ Magnitude : 7.5
Spacing of Mesh(km) : 0,62	EQ Direction relative from Ref.Mesh : South West
Reference Mesh : 12	EQ Distance(km) to Ref.Mesh : 5
Used Attenuation Equation : Fukushima & Tanaka - 1990	

Population & Casualty Summary

The total population counts are 389765 and 5% injuried

AreaID	Area Name	Day Pop Counts	Night Pop Counts	Death	Injury
11	IVC	2272	3602	5	95
12	IVC	2185	4371	9	133
13	IVC	1894	3787	5	99
14	IVC	3685	3480	26	229
15	IVC	2118	4235	40	313
21	Barangka	1894	3787	5	99
22	Barangka	3826	7500	18	277
23	Barangka	2866	5671	31	330
31	Malanday	1894	3787	5	99
32	Malanday	1894	3787	9	140
33	Malanday	2844	5689	74	516
34	Malanday	2158	4226	55	384
35	Malanday	5913	10611	80	762
36	Malanday	6006	10507	79	755
41	Tanong	1894	3787	17	206
42	Tanong	1519	2776	15	166
43	Tanong	4281	8114	61	582
51	Kalumpang	3608	3411	34	276

Map Using Manual Range (Cell characters show AreaID)

						111	113	115	116					
				61	64	112	114	122	124	126	129			
				62	65	67	121	123	125	127	130			
			31	63	66	68	70	151	153	155	131			
			32	33	35	69	71	152	154	128	132			
		21	41	34	36	82	72	141	143	145	133			
		22	42	##	81	83	84	142	144	146	147			
	11	23	43	##	91	92	85							
	12	14	51	##	101	103								
	13	15	52	53	102	104								

52	Kalumpang	3704	3400	35	277
53	Kalumpang	2913	5671	42	406
61	Concepcion 1	0	0	0	0
62	Concepcion 1	1894	3787	9	140
63	Concepcion 1	1412	2823	14	142
64	Concepcion 1	0	0	0	0
65	Concepcion 1	1412	2823	37	257
66	Concepcion 1	2823	5647	17	202
67	Concepcion 1	2877	5635	73	512
68	Concepcion 1	2823	5647	73	514
69	Concepcion 1	3194	5103	28	299
70	Concepcion 1	3692	3514	26	232
71	Concepcion 1	4383	8536	46	496
72	Concepcion 1	2944	5888	60	476
81	Sto.Nino	5729	11457	85	820
82	Sto.Nino	1998	3876	39	313
83	Sto.Nino	3509	7018	48	483
84	Sto.Nino	1894	3787	23	254
85	Sto.Nino	0	0	0	0
91	Sta.Elena	4677	7880	59	566
92	Sta.Elena	1894	3787	23	254
101	San Roque	6687	10969	82	787
102	San Roque	4281	8114	61	582
103	San Roque	1894	3787	17	206
104	San Roque	3787	7575	46	507
111	Nangka	1963	3925	40	318
112	Nangka	7399	7177	72	580
113	Nangka	7575	15150	68	826
114	Nangka	2944	5888	44	387
115	Nangka	1987	3914	29	256
116	Nangka	1894	3787	17	206
121	Parang	3958	7915	31	351
122	Parang	3305	5523	22	247
123	Parang	3920	7840	18	248
124	Parang	1100	1144	11	85

125	Parang	1504	2649	8	95
126	Parang	1649	2462	7	89
127	Parang	2412	3738	11	135
128	Parang	2617	2107	6	76
129	Parang	824	1231	4	44
130	Parang	1515	2668	8	96
131	Parang	1412	2823	8	101
132	Parang	1894	3787	5	99
133	Parang	706	1412	4	50
141	Concepcion 2	2944	5888	44	387
142	Concepcion 2	3787	7575	46	507
143	Concepcion 2	2551	3794	9	120
144	Concepcion 2	2944	5888	24	262
145	Concepcion 2	3787	7575	10	199
146	Concepcion 2	3787	7575	10	199
147	Concepcion 2	1894	3787	5	99
151	Marikina Heights	2944	5888	24	262
152	Marikina Heights	2034	3914	16	174
153	Marikina Heights	3172	5829	10	163
154	Marikina Heights	5578	5261	12	167
155	Marikina Heights	1608	2492	7	90
161	J. Dela Pena	4272	8545	64	612
162	J. Dela Pena	3347	5253	39	377
163	J. Dela Pena	2871	5505	41	394
Summary Information		221267	389765	2286	22488

Appendix 14. **RADIUS Population And Casualty Distribution**

Total population is 389765 | Total deaths are 2286 | Total Severe Injuries are 6887 | Total Moderate Injuries are 15600

Mesh ID	Area ID	Mesh Weight	AreaName	Population (Day)	Population (Night)	Death Ratio (%)	Deaths Count	Injury Ratio (%)	Severe Injury Count	Moderate Injury Count	Injury (Moderate+Severe) Count
1	11	1	IVC	2272	3602	0,1	5	2,6	18	77	95
2	12	2	IVC	2185	4371	0,2	9	3,1	26	107	133
3	13	1	IVC	1894	3787	0,1	5	2,6	19	80	99
4	21	1	Barangka	1894	3787	0,1	5	2,6	19	80	99
5	22	2	Barangka	3826	7500	0,2	18	3,7	66	211	277
6	23	2	Barangka	2866	5671	0,5	31	5,8	101	229	330
7	14	2	IVC	3685	3480	0,7	26	6,6	71	158	229
8	15	3	IVC	2118	4235	0,9	40	7,4	98	215	313
9	31	1	Malanday	1894	3787	0,1	5	2,6	19	80	99
10	32	1	Malanday	1894	3787	0,2	9	3,7	33	107	140
11	41	1	Tanong	1894	3787	0,4	17	5,5	63	144	206
12	42	1	Tanong	1519	2776	0,6	15	6,0	51	115	166
13	43	3	Tanong	4281	8114	0,7	61	7,2	196	386	582
14	51	2	Kalumpang	3608	3411	1,0	34	8,1	94	182	276
15	52	2	Kalumpang	3704	3400	1,0	35	8,1	95	182	277
16	61	0	Concepcion 1	0	0		0		0	0	0
17	62	1	Concepcion 1	1894	3787	0,2	9	3,7	33	107	140
18	63	2	Concepcion 1	1412	2823	0,5	14	5,0	35	107	142
19	33	4	Malanday	2844	5689	1,3	74	9,1	178	338	516
20	34	3	Malanday	2158	4226	1,3	55	9,1	133	251	384
21	161	3	J. Dela Pena	4272	8545	0,7	64	7,2	206	406	612
22	162	2	J. Dela Pena	3347	5253	0,7	39	7,2	127	250	377
23	163	2	J. Dela Pena	2871	5505	0,7	41	7,2	133	261	394
24	53	2	Kalumpang	2913	5671	0,7	42	7,2	137	269	406

25	64	0	Concepcion 1	0	0		0		0	0	0
26	65	2	Concepcion 1	1412	2823	1,3	37	9,1	89	168	257
27	66	4	Concepcion 1	2823	5647	0,3	17	3,6	40	161	202
28	35	4	Malanday	5913	10611	0,7	80	7,2	257	505	762
29	36	4	Malanday	6006	10507	0,7	79	7,2	255	500	755
30	81	4	Sto.Nino	5729	11457	0,7	85	7,2	276	543	820
31	91	3	Sta.Elena	4677	7880	0,7	59	7,2	191	375	566
32	101	4	San Roque	6687	10969	0,7	82	7,2	265	521	787
33	102	3	San Roque	4281	8114	0,7	61	7,2	196	386	582
34	111	2	Nangka	1963	3925	1,0	40	8,1	109	209	318
35	112	4	Nangka	7399	7177	1,0	72	8,1	198	382	580
36	67	4	Concepcion 1	2877	5635	1,3	73	9,1	177	335	512
37	68	4	Concepcion 1	2823	5647	1,3	73	9,1	178	336	514
38	69	2	Concepcion 1	3194	5103	0,6	28	5,9	92	207	299
39	82	2	Sto.Nino	1998	3876	1,0	39	8,1	107	206	313
40	83	2	Sto.Nino	3509	7018	0,7	48	6,9	162	321	483
41	92	1	Sta.Elena	1894	3787	0,6	23	6,7	85	169	254
42	103	1	San Roque	1894	3787	0,4	17	5,5	63	144	206
43	104	2	San Roque	3787	7575	0,6	46	6,7	170	338	507
44	113	4	Nangka	7575	15150	0,4	68	5,5	251	574	826
45	114	3	Nangka	2944	5888	0,7	44	6,6	120	267	387
46	121	4	Parang	3958	7915	0,4	31	4,4	86	265	351
47	70	2	Concepcion 1	3692	3514	0,7	26	6,6	72	160	232
48	71	3	Concepcion 1	4383	8536	0,5	46	5,8	152	344	496
49	72	3	Concepcion 1	2944	5888	1,0	60	8,1	163	314	476
50	84	1	Sto.Nino	1894	3787	0,6	23	6,7	85	169	254
51	85	0	Sto.Nino	0	0		0		0	0	0
52	115	2	Nangka	1987	3914	0,7	29	6,5	80	177	256
53	122	3	Parang	3305	5523	0,4	22	4,5	60	186	247
54	123	4	Parang	3920	7840	0,2	18	3,2	49	199	248

55	151	3	Marikina Heights	2944	5888	0,4	24	4,5	64	198	262
56	152	2	Marikina Heights	2034	3914	0,4	16	4,4	43	131	174
57	141	3	Concepcion 2	2944	5888	0,7	44	6,6	120	267	387
58	142	2	Concepcion 2	3787	7575	0,6	46	6,7	170	338	507
59	116	1	Nangka	1894	3787	0,4	17	5,5	63	144	206
60	124	1	Parang	1100	1144	1,0	11	7,4	27	58	85
61	125	2	Parang	1504	2649	0,3	8	3,6	19	76	95
62	153	2	Marikina Heights	3172	5829	0,2	10	2,8	31	132	163
63	154	3	Marikina Heights	5578	5261	0,2	12	3,2	33	134	167
64	143	2	Concepcion 2	2551	3794	0,2	9	3,2	24	97	120
65	144	3	Concepcion 2	2944	5888	0,4	24	4,5	64	198	262
66	126	2	Parang	1649	2462	0,3	7	3,6	18	71	89
67	127	3	Parang	2412	3738	0,3	11	3,6	27	108	135
68	155	2	Marikina Heights	1608	2492	0,3	7	3,6	18	72	90
69	128	2	Parang	2617	2107	0,3	6	3,6	15	61	76
70	145	2	Concepcion 2	3787	7575	0,1	10	2,6	38	161	199
71	146	2	Concepcion 2	3787	7575	0,1	10	2,6	38	161	199
72	129	1	Parang	824	1231	0,3	4	3,6	9	35	44
73	130	2	Parang	1515	2668	0,3	8	3,6	19	76	96
74	131	2	Parang	1412	2823	0,3	8	3,6	20	81	101
75	132	1	Parang	1894	3787	0,1	5	2,6	19	80	99
76	133	1	Parang	706	1412	0,3	4	3,6	10	40	50
77	147	1	Concepcion 2	1894	3787	0,1	5	2,6	19	80	99
Summary or Average Information				Total DayPop	Total NightPop	Average DeathRatio	Total DeathPop	Average InjuryRatio	Total SeverInjury	Total ModerateInjury	Total Injury
				221267	389765	0,6	2286	5,8	6887	15601	22488